

Designs change suppositions

Taeke M. de Jong 20260224

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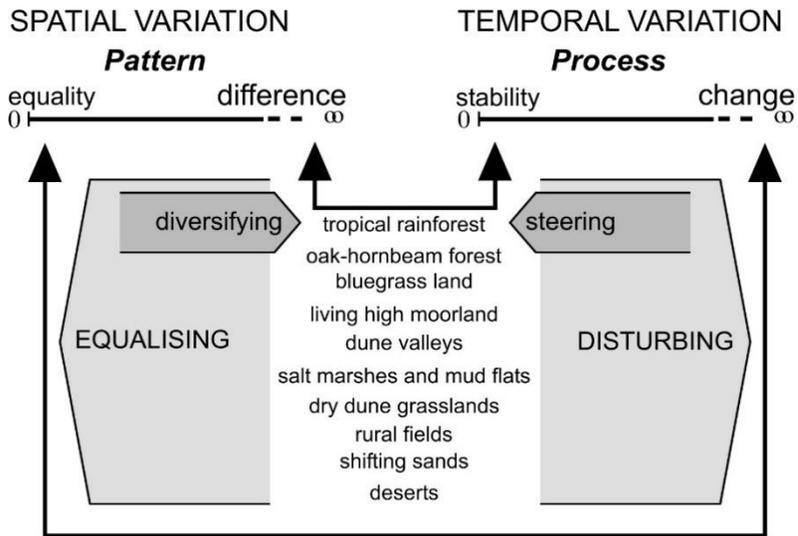
A .pdf version with operational [links](#) (e.g. to full texts of classic literature at the internet), detailed calculations and figures, are downloadable from:

[http://taekemdejong.nl/Images Jong\(2026\)Design changes suppositions\(Zoetermeer\).rar](http://taekemdejong.nl/Images%20Jong(2026)Design%20changes%20suppositions(Zoetermeer).rar).

Images are mainly made and available in [Xara](#), the calculations in the free downloadable math program [Maxima](#) or Excel, the chemical figures in the freely downloadable computer program [ChemAxon's Marvin sketch](#) for own editing.

Remarks are welcome at taekemdejong@outlook.com.

Dedicated to ecologist Chris G. van Leeuwen (1920-2005)



**He changed some common suppositions.
I elaborated one: equality as the zero-point of difference.**

1. IMAGINATION IS BUILT ON SUCCESSIVE SUPPOSITIONS

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This study aims to uncover unnecessary suppositions that hinder design.^a

This chapter raises questions about the *design* of language, logic, science, and the humanities. It relativates the concept of 'object'.

It signals the insufficiency of verbal language and of formal logic for design.

It signals a strict sequence of suppositions enabling our imagination.

Awareness of that order may reveal useless or even blocking suppositions.

It starts with observing or making a difference.

The object of design does not exist before it is designed.

So, it can be studied empirically only *after* the act of design.

Before its creation, however, there is always a context^b to be analysed on its possibility, probability, and desirability.

^a The medieval study of suppositions focuses on language and the meaning of words: https://en.wikipedia.org/wiki/Supposition_theory see [Spade\(2002\)](#). The present study focuses on often tacit or non verbal suppositions that enable or block imagination.

^b 'Context' will be used for 'environment' or 'circumstances' in the widest sense, without a specific reference to 'text'.

§ 1 DESIGNS EXPLORE POSSIBILITIES BEYOND PROBABILITY

Sciences and the humanities search for what is *true* or *probable*.

Design searches for what is not (yet) true or probable, but realisable, *possible*.

What is true or probable must be possible, not the reverse.

Sciences and the humanities are designs, not the reverse.

Design includes, but goes beyond truth and probability.

A designer

1 cannot isolate a singular problem from a field of problems that may be solved together (causing new problems to be solved on their turn);

2 cannot isolate a singular goal from a field of diverging aims from diverging interests;

3 cannot work only in a goal-oriented way, but it requires also a means-oriented way (looking for what is possible by what is available);

4 cannot formulate a research object before it has been designed, before the work is done: that object varies in thought and gradually develops from vague into concrete by looking, sketching, calculating, reading or writing;

5 receives only a **context** with many variables at different levels of scale as its starting point;

6 brings together explicit and unspoken administrative, cultural, economic, technical, ecological and physical problems, aims and means from this context in a concept, a representation or proposal in which more stakeholders may project and weigh their own (sometimes unforeseen and unspoken) aims;

7 produces a concept as a general hypothesis that is hardly worth mentioning: 'This will work';

8 therefore has starting points different from scientific research: a clear definition of object and problem, an aim, a hypothesis, a representation of how facts are collected, arranged and related to each other (method);

9 has many methods to arrive at a concept: starting with substance, form, structure, function or intention, continuing in all conceivable sequences and intensities of this series;

10 has more references than written text: images, forms, types, models and previous concepts;

11 uses notions that cannot be expressed (generalised) in everyday language as words;

12 distinguishes their meanings per level of scale and per unique context.

This does not correspond to the current suppositions of (conditions for) valid and reliable science. For example, how do you start without a clear object of research? It still has to be designed. How to start without a clear cut problem and aim, if both are 'wicked'^a *fields*?

Moreover, each preliminary design concept raises new problems of its own.

Designing is not only a profession, it is a typical human ability applied in anybody's daily life.

This study aims to prune common suppositions that may hamper design.

It aims to reduce them to the strictly necessary suppositions enabling realistic imagination.

Where science and the humanities search for equalities, design searches for difference.

^a Buchanan(1992)

DESIGNING HAS MORE THAN ONE PURPOSE

There have been many attempts to unravel the mystery of design methods *showing* existing designs^a, *analysing*^b and *comparing*^c them, *interviewing* designers, design students and design teachers^d, studying the *phases* of existing design processes^e, making *schemes* of successive steps in a design process^f.

In these studies, the very start of any design process is mainly its aim.

This aim, however, is rarely a single goal.

It is usually a vague and wicked^g *field* of aims^h caused by problems, arising from physical, technical, economic, cultural and organizational contexts, at different levels of scale.ⁱ

Eekels already recognized it in his "Industrial goal development"^j as a painful leak in methodology. A designer often eliminates the most obvious problems directly in a 'design concept', a rough design^k, a hypothesis. A drawn design shows the consequences of a solution. It evokes and clarifies unforeseen opportunities and new problems caused by the concept itself.

Design is not the third field of Cross^l. Science and the humanities are designs *themselves*. Sciences and the humanities are *part* of design in general, as Glanville^m seems to agree. Designing is more than applying science and humanities.

Searching for *truth* is a subset of the wider field of searching for *possibilities*.

Both are built upon successive, often tacit, and not always necessary or useful *suppositions*.

Imagination is enabled by consecutive suppositions. The first supposition is difference.

Without any difference nothing can be observed, chosen, imagined or thought. It is the basis of any next supposition, enabling successively more complex imaginations. You cannot define difference as inequalityⁿ, because that *supposes* a difference. Equality is a *value* of difference.

That may have consequences for next suppositions (defined as conditions of imagination).

a Numerous publications that can be summarized as art historical, showing the product of design, but not its process.

b E.g. Leupen; Grafe; Körnig; Lampe; Zeeuw(1997), or Hoeven;Louwe(2003) and other publications.

c E.g. Jong(1995)

d E.g. Schön(1985), and many following publications, Dorst(2015) and Dalke;Evans;Self(2013)

e E.g. Jong;Voordt eds(2002)

f E.g. Roozenburg;Eekels (1996), Eekhout(1997), in English: Eekhout(2008).

g Buchanan(1992)

h Lawson(1990) discusses the interconnected problems of design, each carrying different weights in each specific context. Their weights depend on many more or less valid *suppositions*. It suggests a dynamic *landscape* (Fig.225p120) or a *vector field* (Fig. 85p63).

i It's not so wicked. In 2005 I developed a computer program 'FutureImpact' (Fig.14 p14) in order to analyse the *possible* impacts of a particular design project *desired* or *feared* by the stakeholders in the *probable* future context they expect. See Jong(2007)

j Eekels(1973)p140

k "every formulation of a wicked problem corresponds to the formulation of a solution": Rittel;Webber(1972), cited by Buchanan(1992)p16.

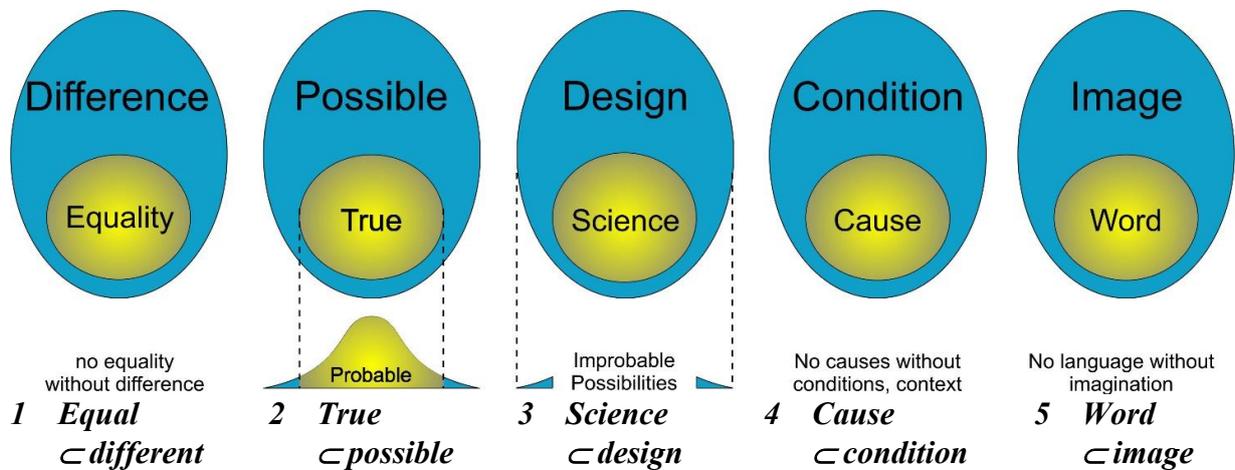
Alexander(1977) saw the problem of many relations simultaneously earlier: Alexander(1968)

l Cross(1982).

m Glanville(1999), and many following publications, cited by Vahidov(2012)

n Russell(1903)*The Principles of Mathematics*(Cambridge)University Pressp179

§ 2 EQUALITY SUPPOSES DIFFERENCE



In order to conclude *equality*, you should observe *different* objects.

If you cannot observe any other difference than a difference of location, then you *call* it equal.

The starting point of this inquiry is: you cannot imagine Equality without Difference.

If you cannot imagine Y without X, and the reverse you can, then X is *supposed* in Y.

If difference is supposed in any *concluded* equality, then questions raise about the tacit suppositions of language, logic, science, the humanities, and design.

Consequences of this starting point are:

1 Equal is the limit or 'zero-point' of different. Equal cannot be more equal than equal, but a given difference always may become more different: equal $0|— - \infty$ different.

A 'category' or 'set' contains objects not *equal*, but *less different* from each other than from the rest. There are different differences e.g. stable $0|— - \infty$ change, united $0|— - \infty$ separated.

2 Truth or probability supposes an equality between observation and conclusion.

Anything true or probable must be possible, but not the reverse.

That requires an extension of the common truth-based logic. You may say 'It is possible to be true', but 'It is true to be possible', resembles saying 'an animal is a dog'. A set is not its subset.

3 Research searches *equalities* enabling prognoses.

Designing, however, makes something *different*; otherwise it is copying. Design searches a possibility that is *not* (yet) true. So, design is not a science. Science is a design. Mathematics is its zero-point, the science of 'exact' equality by equations. Anyhow, it is still a human design.

4 There may be many conditions for something to happen. A 'cause' is one of them.

There are two types of causes: the last added condition for something to happen and the cause-of-failure, a lacking condition for something to happen or a condition preventing it to happen. The zero-point of causal I will call sui-causal.

5 Language supposes imagination. It reduces images to words, supposing sets of '*equal*' objects, *different* from other sets. A sentence contains a verb, a word supposing action, an object of change. 'To be' and 'to have' then suppose zero change.

A verb mainly supposes an active subject and a passive object as cause and effect of action.

'Object', however, is not a self-evident concept.

§ 3 'OBJECT' IS CONSTRUCTED IN CHILDHOOD

'ONE' (A DISTINCT OBJECT) ENABLES A LOGICAL 'NOT', AND REFUSING OR WANTING

As soon as parallax exercises have enabled you to separate a moving part in the field of vision permanently from its background ('object constancy'), then the first image of difference in any direction emerges: object and non-object (background).^a

The sense of direction stems from different senses (eyes, ears, touch, muscular). It enables targeted gripping. If the object is accessible and tangible, then you may get a proper 'grip' on the object. 'Com-prehension' (prehension is 'grip') supposes separating a self-made image from the total impression.



6 Grip

You then may remember, re-present (make present) the object without further input from the senses (imagination). But, this imagination is a strong reduction of the sensory impression. You have demonstrably made aware very little.^b Only a tiny part remains in your memory.

Many elements associated with that impression (smell, sound, touch), may remain connected with the representation of the object (a part of the context is still included in the object). The object still has vague boundaries. With a next impression of a similar object, the image may be redefined, generalised, and the original representation is updated (expanded or further reduced).

In the impression itself, the focus and attention is concentrated on the object, while the rest (non-object) in the outwardly fading periphery remains undetermined (if it is not directly associated with the object for the time being).

Object constancy then enables the development of a concept for that indefinite rest (the denial of the object): your first 'logical' conjunction is 'not' (although that does not yet has got a name). That makes refusing possible and wanting what is *not* there.

If an object disappears behind something else ('in the nothing') and then reappears (the essential game of 'peek-a-boo'), then there is a moment of indeterminacy (loss, hope, expectation?), which is resolved by the reappearance and recognition (surprise, relief?).

After a short disappearance, this recognition is not essentially different from the recognition of appearing and disappearing objects that you pass moving, and re-appear looking back. The first object you notice distinct from the rest is probably your mother.

Primitive memory primarily stores what is useful for survival (food and safety).

That may be sobering for adults.^c Parents mainly think to be seen as 'human' by babies, but that category may be an illusion until our second year.

Even a parent then is still no more than an object^d that may or may not be wanted.

'TWO' ENABLES DECENTRALIZATION OF THE INDIVIDUAL

You must already have that stage of distinction long behind in order to be able to distribute your attention to more than one object simultaneously. If two objects move in different directions, you cannot follow them in one go. In order to distinguish a second object from the first one, requires a further distinction: difference of objects mutually.

^a Piaget(1937) p6

^b According to Silbernagl(1991) p274: less than 0,00001%.

^c The answer of two children at the age of two, able to answer my question "What is a mother?", was: "Big and warm". See also Piaget (1966), p28 in the Dutch version.

^d I observed that the eyes of a one year old child continued to look straight ahead, while my head passed her field of vision.

She even laughed, apparently with pleasure, but not at me. Probably she was only surprised by my passing head looking at the more permanent background (parallax).

For example, to distinguish between mother and father requires a more advanced pattern recognition than what parallax does. If they move in different directions, their movements can no longer be followed by own muscular effort (e.g. turning your head) for object constancy. The two would have to be contained as one image within your own (still solipsistic) unity.

A second focus is no longer part of that unity of object and subject. There is 'something else'. The more so, if their images differ. It is 'no', but not 'nothing'. The unity in which at any moment everything is yours may fall apart ('decentralisation' in space).

This requires room for more 'memory places' than the one immediately recording your own recent moment. The increasing memory space becomes occupied by a primitive 'past': the succession of (reduced) impressions,.

Being able to crawl and walk creates a new revolution in imagination.

The subject 'me' supposes a centre (origin) in which all directions come together.

The primitive past, the *sequence* of represented impressions and objects may disturb that once observed and incorporated 'own' solipsistic subject-object unity.

Your imagined past is no longer the actual centre (decentralization in time).

Different objects, however, may still be only combined in one set if they share the same place in one impression. The experience of own movement through different places enables an awareness of sequence. Objects that do not obey your own movements should get their own place, but then these are not 'yours' anymore.

'THREE' ENABLES TO IMAGINE A SET AND A SET OF SETS

Long after Piaget, Feigenson and Carey(2005)^a discovered that a baby shortly after birth may comprise sets of 2 and 3 elements, but not of 4. So, 3 is an innate limit, and a third object in one image enables to imagine simultaneously a *set* combining the other two.

It also enables to imagine an 'interfunctional' *tool* between the observed and the wanted.

That requires to imagine 3 objects in one image: a useless object, a tool and a useful product.

The tool itself has to be *designed*, imagining an object, an action and its result.

That will finally enable the use of language: a tool at least connecting two nouns by a verb.

Naming objects by nouns requires a reference to images. The first time you saw a tree, somebody pointing it with the finger saying 'tree' has made an arbitrary connection.

Repeating that event reduces the image into a signal evoking a generalised picture. Your wild imagination became literate, linear and limited, as soon as you learned to read and to write.^b

Verbal language expresses an image in a *linear sequence*. An image may be read in *any* direction. Any route within the image then results in a different verbal story.

A text chooses a main road and keeps crossing stories in footnotes, appendices or next chapters.

Verbal language prunes not only sidebranches, it also sharpens objects by words.

Any word is worn down and smoothed by common use, eventually sharpened by 'definitions'.

Widening their *extension* (generalizing) reduces their *intension*. Objects of wild imagination lose their bounding gradients and plasticity by verbal expression. The fruit is peeled and pitted.

A drawing still may be precise; a painting restores the gradients and plasticity of imagination.

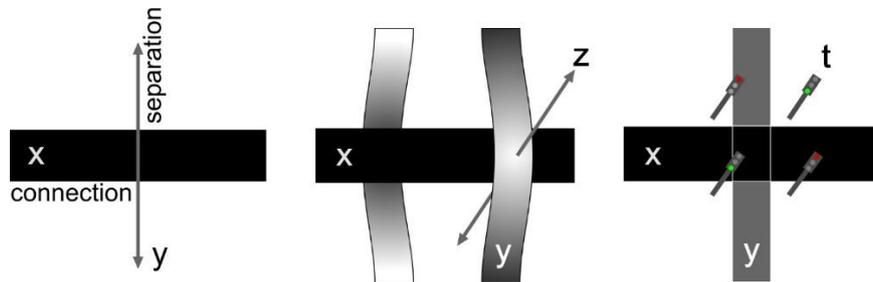
A deformable object (e.g. clay) makes it even sculptable.

^a Feigenson;Carey(2005)

^b Kraak(2006)

§ 4 VERBAL LANGUAGE ENCOUNTERS PARADOXES AND BARRIERS

A PERPENDICULARITY PARADOX



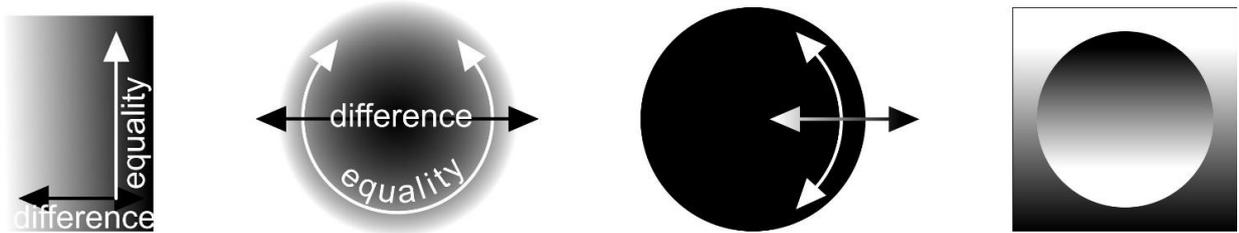
7 Perpendicularity paradox

The also linear *logic* of language, forbids contradictions as 'both true and not true'. A road, however, connects *and* (in a perpendicular direction) separates. The connection may be restored by separating in a third or even fourth dimension.

A bridge may be open to the walker *and* closed to the skipper.

A cylinder is rectangular *and* round. A straight line is a point, seen from the in-line direction. Naming directions and understanding 'perpendicular' requires a reference to physical signs or images, because a linear language is limited to one direction: the time line of speech.

AN INSIDE-OUTSIDE PARADOX



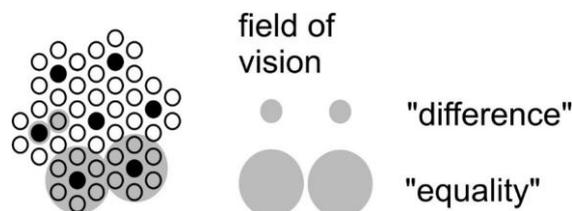
8 Inside-outside paradox

A ball is convex *and* concave. An object or set supposes an inner 'equality' and outer difference. A verbal definition sharpens a vague boundary by generalisation. It is no longer sculptable. The in-between is neglected by such defining. The opportunities of inbetween gradients are lost.

Verbal language may overcome such paradoxes by conditional clauses, specifying the directions of view and zones of transition, but these *must* refer to images once observed.

'Object' supposes difference in all directions. Linear language provides just the one of speech.

A SCALE PARADOX



9 Scale paradox

A pattern may be both homogeneous and heterogeneous at the same time.

If you observe **Fig.9** in detail, then you see difference: every black dot has white neighbours.

But, with a 3 times larger radius of vision (about 10 times larger surface), you see equality. The judgment 'difference' thus may change into 'equality' already at a factor 3 larger radius of vision.

That is a minimum and only a possibility, but there are 10 decimals between the size of sand and of the earth. That is more than 20 factors 3, eventually causing alternating judgements. In order to be explicit about the resolution of words I propose a range of 'nominal radiuses' $R = \dots 1, 3, 10 \dots m$ with wide tolerances as the 'frames' of vision. Take the word 'function'.

What is the function of a brick (nominal radius $R=10\text{cm}$), a window (30cm), a door (1m), a room (3m), a house (10m), a building complex (30m), an 'ensemble' (100m), a neighborhood (300m), a district (1km), a city (3km), a conurbation (10km), a metropolis (30km), a region (100km), a country (300km), a continent (1000km), yes, what is the function of the world?

If you define 'function' as operation or working, then you should also distinguish an inward and an outward function. A house has an inward function for its residents, but also outward for the neighborhood, the city and so on. A car should fulfill many internal functions, but it has also an external function for a family, a business, a city and so on.

Moreover, at any level of scale the meaning of an outward 'function' differs in an external physical, ecological, technical, economic, cultural or governmental context or structure. It has to be specified as 'physical function', 'ecological function', and so on.

In the same way, an inward function meets internal structures in which it can or cannot operate.

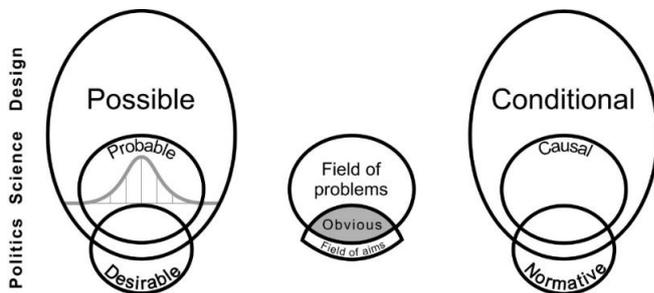
The mathematical concept of function $y=f(x)$, the working of x on y , is limited to quantifiable properties x and y of objects. Direction is represented as one of these 'properties' (vectors). The scale is determined by the units used. The function supposes a structure by which x operates through connections (+), separations (-) and their repetitive combinations $\ast, /, \Sigma, \Delta, \int, d$ etc..

Repetition supposes equality in time. Mathematics is the science of 'exact' equalities, including exact repetitions. Measuring a quantity, however, always has a margin of error, and the number of required decimals for fundamental constants such as the number π may approach infinity. So, *total* 'exactness' cannot be reached. Anything repeating may be *approached* by mathematics.

LIMITS OF VERBAL LANGUAGE

1 selective observation

Our perception is a small selection of what actually 'plays'. It is no more than a sample from a very large set. This selection is expressed in three modalities (possible, probable, desirable). We select what we *can* observe, are *used to* observe, or *want* to see, limited by what we can imagine at all.^a Their combination may contain 'problems' or 'aims' to be communicated.



Problems are probable, but *not* desirable; *aims* are desirable *and* possible, but not probable.

If a desire is also probable (and thus possible), then there is no problem and no aim. It will probably happen anyway (*Obvious*).

10 Modalities

The limit of the 'imaginable' cannot be drawn, because the other side is not imaginable. The imaginable may stretch beyond the possible (fiction). The possible may stretch beyond the imaginable (unimaginable possibilities).

A verb, preceded by the modal verbs 'can' or 'want' changes its primarily *causal* supposition into a *conditional* or *normative* one. These often tacit suppositions of the sender may be filled

^a To be elaborated in the next sections.

in by receiver of the message by its own suppositions about possibility, probability and desirability. ‘What’s the problem?’. ‘What’s the aim?’.

2 tacit causality

The sequence subject-verb-object hides a supposition of the active subject as a cause.

3 selective representation

The remembered re-presentation (‘brought back to present’) of observations is again a small selection, a further reduction of that sample.

4 templating

These selections are fitted into words, old generalizations from a culturally conditioned, traditional, vocabulary with templates, seldom explicit about direction and scale.

5 verbal tolerance

The words in which these templates are expressed as standards for exchange, never fit exactly. They include different images generalised in a heterogeneous set, eventually specified in a sentence with conjunctions, adjectives and adverbs.

These are, however, also generalizations. Even a verbally specified result generalizes.

6 word choice

As soon as the intended meanings are described in words, two more barriers loom.

The speaker should find words fitting (understood) in the supposed culture and context of the *receivers*, and ...

7 interpretation

these words should evoke images in the receiver similar to those of the sender, but probably built on different suppositions. A receiver seldom shares the tacit suppositions of the sender.

8 covering

The proof that 'the message has come over' may be delivered by *action*, e.g. a laboratory test, replaying a crime, following a cooking recipe or showing a fitting reaction.

That proof, however, is inductive, and never conclusive.

Using language tacitly supposes that these barriers will not disable communication.

New ideas, however, just may arise by such failures, deviant interpretations of the message.

Errors in gene transfer also have produced the diversity of life, enabling survival of the fittest.

Diversity enables choice, selection.

The *external* function of language is primarily to coordinate human actions (expressed in verbs). Its *internal* function, however, limits your imagination by words with many hidden suppositions. Wittgenstein once wrote: “Whereof one cannot speak, thereof one must be silent”^a, but that neglects the possibilities of drawing, painting, sculpturing, theatre, music and body language.

The imagination of a designer goes beyond words. (S)he may have other suppositions than those expressible (and hidden!) in verbal language. Design may add, skip some, or replace them.

Even the imagination beyond words, however, is built on *consecutive* suppositions.

They *enable* imagination: ‘If I *can* ..., then I *can* ...’, but they also may *hamper* imagination.

Conditions enable possibilities. Let me define **suppositions** as ‘the conditions of imagination’.

Suppositions are conditions of thought, steps in founding a thought-building.

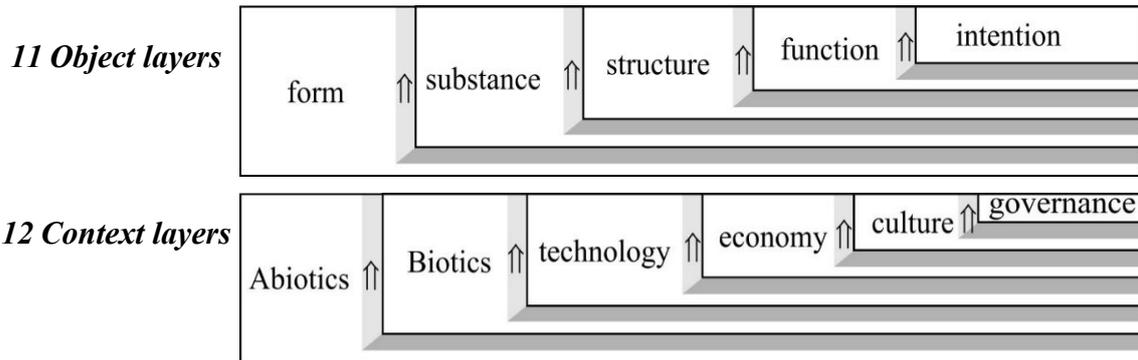
Which suppositions hamper possible imaginations? Which suppositions enable them?

What then are the *minimally necessary* conditions of possibility and realistic imagination?

Any inquiry starts with making a difference. Let me first distinguish object and context.

^a “Wofon man nicht sprechen kan, darüber muss man schweigen”
[Wittgenstein\(1921\)](#).

§ 5 SUPPOSITIONS (TACIT OR NOT) ARE STRICTLY SEQUENTIAL



A great advantage will be, to discover that suppositions show a strict sequence.

Function, used in the sense of an aim, deserves a separate name: 'intention'.

I cannot express an intention without mentioning the functions I have in mind (workings, actions, verbs), the reverse I can. So, intentions *suppose* functions.

If I define 'structure' as a set of connections and separations, then I cannot imagine a function without a fitting structure in which it may function, but a structure without a function I can. So, a function **supposes** (⇓) a structure and the reverse, a structure **enables** (⇑) a function.

I cannot imagine connections and separations (structure) without a substance, the reverse I can.

If I define 'form' as a state of dispersion, then I cannot imagine a substance without a form, but a form without a substance I can (e.g. a boundary). 'Shape' *includes* a content or substance.

These suppositions then appear to have a strict sequence: intention ⇓ function ⇓ structure ⇓ substance ⇓ form, not to be confused with *truth*-based logical if-then conditions (⇒) or subsets being part of (⊂) sets. 'If intention then function' would suggest that the function is already *true*, but 'Intention supposes function' expresses an *possible* function still to be realised.

The reverse sequence of **Fig. 11** is a stepwise enabling (⇑) '*possibilities*'.

A form does not *include* (⊃) a substance, it *enables* (⇑) to imagine a content or substance.

The shadowlines express *possible* layers instead of *true* (sub)sets.

The *context* of an object (**Fig. 12**) shows a similar strict and layered sequence.

Governance, democratic or not, requires a *culture* that accepts compromise or coercion and violence. Subsequently, a culture will not survive without a sufficient *economic* basis.

No contemporary overpopulated economy will survive without *technology*.

Agricultural and industrial technology supposes *Biotic* and *Abiotic* resources.

Governance decides what we should do together and what each may do by itself.

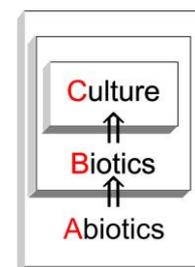
Socialists choose a large scale for 'together' (from international into national, regional, municipal), christian democrats primarily the family, and liberals the individual.

The 'what', however, may deviate from a primary intention of the party (e.g. public defence).

The context layers can be simplified as **A**biotics⇑**B**iotics⇑**C**ulture ('ABC model'). Culture is defined as 'a set of shared suppositions', but **C** includes governance and conceptual conditions. **B** includes already some conditions of technology and economy.

Paragraph § 7p14 subdivides **A**, **B** and **C** in an extended sequence of essential suppositions successively enabling increased imagination.

Chapters 6, 7, and 8 are examples of common **A**-, **B**-, and **C**-sciences where designers once have changed usual suppositions.



13 ABC model

§ 6 CONTEXT ANALYSIS IS THE VERY START OF DESIGN

How do you start designing without a clear object of research? It still has to be designed.

How to start without a clear cut problem and aim, if both are 'wicked' *fields*?

What if each preliminary concept raises new problems of its own? (§ 1, p4).

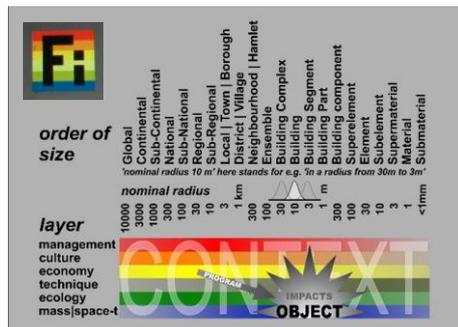
The beginning is *before* all that. The common suppositions deserve doubt and clarification.

What is the wicked *field* of problems^a stemming from a physical, technical, economic, cultural and organizational *context* at different levels of scale?

Well, ask the stakeholders and future users what they want and fear.

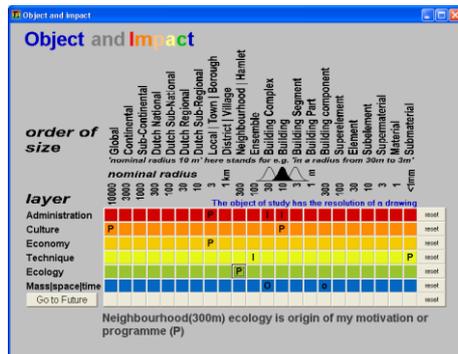
The context of an intended design object contains the *possible* impacts *desired* or *not* by the stakeholders and users in the *probable* future context they expect (three modes).^b

My computer program Future impact (programmed for design students) may suggest a method:

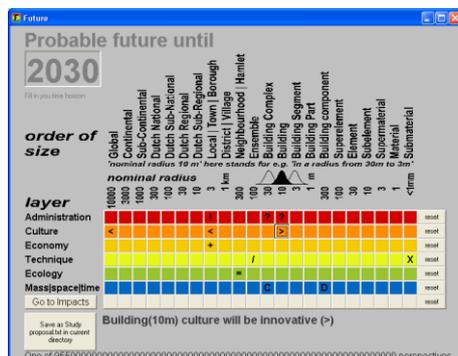


The context should be analysed at different levels of scale and in different layers of context.

The interval of scale levels and their nominal tolerance are both approximately a factor 3 radius.



Choose the intended largest (O) size and smallest (o) elements of your design in the blue row below. Locate the intended (P, program) and probable other impacts (I) in its context. Then go to Future.



Specify the probable future context you expect.

At any level of scale, you may choose Administration will be active '!' or passive '?', Culture will be innovative '>' or traditional '<', Economy will grow '+' or decline '-', Technique will specialise '/' or integrate 'x', Ecology will differentiate '|' or equalise, '= Mass will concentrate 'C' or disperse 'D'.

Save the result as a proposal for design study

14 Context analysis

^a Lawson(1990) specifies the connected problems with different weights to be balanced differently in each specific context. Their weights depend on more or less valid *suppositions*.

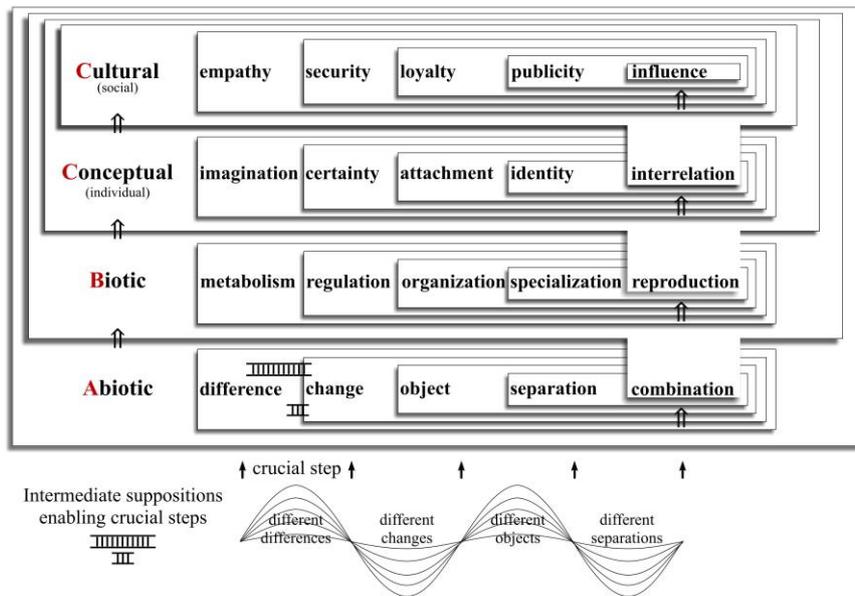
^b Jong(2007) This can be shown with a computer <http://www.taekemdejong.nl/Publications/XLS/FutureImpact04.exe>, individually or by voting in a meeting. It produces a summary of conditions for the design project to be elaborated into a 'program of requirements' for design.

§ 7 SUPPOSITIONS ENABLE IMAGINATION

A context limits the *possibilities* of design at different levels of scale and in different layers. The basic layer concerns the design object itself and its physical context of *probably* concentrating or dispersing masses, enabling a specific ecology \uparrow technique \uparrow economy \uparrow culture \uparrow governance.^a The reverse, a design has *probable* impacts on that context, *desired* or not.

A future context is not ‘true’. It is imagined, built on suppositions about *probabilities*. A design within that context is an image built on suppositions about wider *possibilities*. To find new possibilities, skip or replace lacking, weak, useless or even blocking suppositions. A contiguous order of safe suppositions from foundation to roof may unveil where they appear.

§ 7 SUPPOSITIONS ENABLE IMAGINATION



15 A staircase of suppositions (Ψ) enabling (\uparrow) mental images

I propose a staircase of crucial suppositions in a conditional order enabling imagination. What supposes what? The method is simple: if I cannot imagine Y without X, but the reverse I can, then X \uparrow (enables to imagine) Y and Y \downarrow (supposes) X. It is an introspective method, but anyone can apply that to check, add, insert or to change suppositions and their sequence.

Difference is the first and only a priori supposition. The others are different differences a posteriori. Any next step may be reached by different paths of intermediate suppositions, motivated by observations. The introspective method does not start referring to existing literature, but its result appears afterwards to be in line with, and bridge literature of genetic epistemology, cybernetics and evolutionary biology^b.

The drawn crucial steps will be expressed in **bold** words, intermediate suppositions in **bold italics**. Words, however, do not exist in a neural system called ‘mind’ before mental images have got a name. The words are carefully chosen, but poorly cover the intended **Biotic** structure, a dynamic combination with electric-chemical connections and separations, responsible for the mental image experienced.

^a Concentrating may save space, dispersion may save time. The sequence of layers suggests a materialistic view. Environmental depletion forces the human sciences to recognize physical limits of technology, economy, culture and governance. History is rewritten in this sense, e.g. by Frankopan(2023).
^b According to ChatGPT(2025) it bridges thoughts of [Ashby\(1954\)](#), [Bunge\(2010\)](#), [Campos cs\(2000\)](#), [Cassirer\(1923\)](#), [Cassirer\(1944\)](#), [Davidson\(1980\)](#), [Feigenson cs\(2005\)](#), [Foerster\(1974\)](#), [Gibson\(1979\)](#), [Husserl\(1901\)](#), [Husserl\(1913\)](#), [Jakobson cs\(1956\)](#), [Jacobson\(1960\)](#), [Kant\(1787\)](#), [Kant\(1790\)](#), [Lorenz\(1973\)](#), [Maslow\(1943\)](#), [Maturana cs\(1970\)](#), [Meltzoff\(1977\)](#), [Peirce\(1903\)](#), [Piaget\(1932\)](#), [Piaget\(1937\)](#), [Piaget\(1970\)](#), [Riedl\(1981\)](#), [Riedl\(1994\)](#), [Saussure\(1916\)](#), [Simon\(1962\)](#), [Silbernagl cs\(2001\)](#), [Spelke\(1988\)](#), [Tomasello\(2014\)](#), [Vygotsky\(1934\)](#), [Waddington\(1942\)](#), [West-Eberhard\(2003\)](#), [Wiener\(1948\)](#), and it bridges opposites of Kant versus AI.

WITHOUT A DIFFERENCE NOTHING CAN BE OBSERVED, CHOSEN OR THOUGHT^a

A1 Difference is the first and only a priori supposition required to enable an *observation* and an *image*. It is applicable to every next supposition (different changes, different objects etc.).

Every supposition has a zero-value^b (*equality* is zero difference, *stability* is zero change, etc.).

That enables *less* or *more* difference, change, object (vague or sharply bounded), separation etc..

Difference (e.g. adjacent black and white)^c enables to imagine *direction*, *sequence* and *place*.

The difference and its sides are places. Direction and sequence stretch *from* one side *into* the *other*.

‘Different differences’ enable to imagine different *places*, *directions*, and *sequences*.

That enables to imagine *space* (an a posteriori construction).

A2 An observation ‘from ... into’ enables to imagine a **change** from one place into another.

Different places enable to imagine *movement* (the core of physics) or *action*.

Different changes enable to imagine ‘changing change’ (e.g. acceleration).

Stable movement enables to imagine *time* (an a posteriori construction).

A3 Equal differences in all directions enable to distinguish **object** and *environment* (non-object).

That enables to imagine *in*, *inside*, *not*, *outside*, *out*, and an outline (a closed *boundary*, a *form*).

An object appears *coherent* if the object changes less than its environment (e.g. parallax).

A form enables to imagine a *content*. Different *subjects*^d *within* the content enable *dispersion* in space.

Different (more) subjects enable to imagine *multitude* as object. Its space enables *pattern* or *shape*.

A4 Separating a multitude enables to imagine *parts* and *whole*, *small* and *large*, *magnitude*, *unit*.

A multitude enables to separate its form, content, structure (**A5**), function (**B1**) or intention (**C1**).

Separating a multitude from its space and time enables to imagine a *set*.

A5 Separated parts enable **combinations**. Any addition ‘-ing’ supposes a dispersion in time (*process*).

Structure supposes a combination of separations and connections (connections as ‘zero separations’).

That enables **Biotic** suppositions in five steps parallel to the five **Abiotic** steps.

Artifacts are part of life. Imagining technique requires the same steps as imagining life.

WITHOUT METABOLISM, LIFE OR TECHNIQUE IS NOT IMAGINABLE

B1 Metabolism supposes the *function* of a *system*, a *combination* with *input* and *different output*.

If metabolism fails, then you should check all **A**-suppositions to find the ‘cause(s) of failure’.^e

Failure is the core object of medical science and technology. It unveils lacking *conditions*.

Changing such conditions (imagined as suppositions) enables *evolution* and *selection* of the *fittest*.

Death (a fatal failure) prevents reproduction (anticipating **B5**) and survival of the less fitting systems.

Metabolism supposes selecting parts of the input *required* for (*tending* to) *survival* of the whole.

Input (**flow** from outside to inside) and output (the reverse) suppose a change of place *and* object.

The paradox of a changing *object* (‘remaining equal in a changing environment’) is a scale paradox.

A ‘change of the object’ supposes a multitude of parts, smaller objects ‘remaining equal’ in the move.

The *content* of the whole remains equal, but its distribution, coherence (shape or structure) changes.

Imagining metabolism pictures the whole as an object with different flows of its parts.

A snake catching a bird (input) separates and *produces* (output) its parts for new combinations. These

operations are the core object of physiology and chemistry. *Metamorphosis* (the core of biogenetics and embryology) supposes metabolism *including* the new combinations called organisations (see **B3**).

Metabolism *enables* to imagine a ‘changing change’, adapting input, output and flows inside.

B2 Regulation supposes *adaptation* of flows by *feedback*, *resisting* environmental disturbance.

Regulators (**Abiotic separators** and **Biotic selectors**) limit movement or flow.

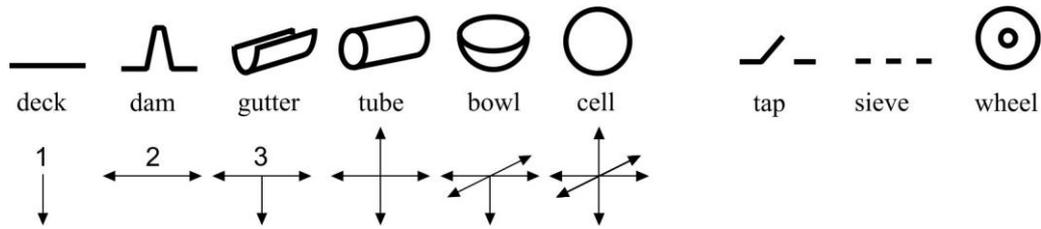
^a **A**, **B**, **C** and **bold** words refer to Fig.15p16. Newly added intermediate suppositions are written *bold italics*.

^b ‘Zero-value’ is a value, not ‘no value’. It supposes a variable, not its negation.

^c Equality may appear as zero-difference at a different direction or scale, see **Fig.8** and **9** p10.

^d Subject will be used as part of an object (of observation or focus). At a lower level of scale (‘closer look’), it becomes an object.

^e For example, the checklist for a failing electric device contains questioning difference:voltage?, change:current?, object:resistance to change?, separation:isolation?, combination:construction?.



16 Separators prohibit movement in 1-6 directions, locally allowed by selectors

Cells and *tubes* with coherent surfaces or *sieves (membranes)* and *taps* enable Organisms (B3). Ecosystems suppose *decks*, *dams*, *gutters* and *bowls* with a weak upward separation by gravity. Their construction and operation suppose regulation by Biotic *messengers* and receiving *actors*. Their chemical and electric suppositions deserve elaboration beyond the scope of this overview.

Regulation enables to imagine an organization.

B3 Organization supposes a regulated system of subsystems resisting environmental change. Organisations suppose a level of scale: *genes*, *organelles*, *cells*, *organs*, *organisms* or *ecosystems*.

Organization enables to imagine specialization.

B4 Specialization supposes an organisation with different functions of its parts.

Specialization enables to imagine reproduction.

B5 Reproduction supposes an organisation with functions, specialized in (partially) *copying* genes, messengers, messages, actors (e.g. proteins), cells, organisms or copying their mental image. Imagining imaginations makes them *conscious* imaginations, now shortly called ‘imaginations’.

IMAGINATION SUPPOSES REPRODUCTION OF SUPPOSED REALITIES

C1 Imagination (conscious) may cover *the* distinctive human factor.

Animals may be simultaneously aware of minimally two images (e.g. ‘flight or fight’).

They may combine some images in order to make decisions, but humans combine more.

It should be little more, otherwise it could not have been added in a short period of evolution.

I suppose that humans combine at least three. A third enables to imagine a *set* of two as a *category*, in turn enabling a *name*, a *number*, a logical *conjunction*, a *causal* sequence, or a *verb* between the two. For example, you may imagine a set 'parents' combining ‘mother *and* father’, but then you also may construct ‘mother *or* father’, ‘*if* mother *then* father’, ‘mother *chose* father’ or ‘mother *calls* father’. That enables *reconstructions*, *models*, *concepts* of the environment separated from observed reality.

Sets enable to imagine sets of sets, proceeding to ever higher levels of *abstraction* (combining sets).

That enables to combine images of more actions in a time sequence (*plans*).

If you have in mind a result to be realised by actions, then that result *precedes* the cause (the action).

Imagination enables to manipulate sequences in time and space.

In a social context, imagination enables **empathy**, the ability to add other’s suppositions next to own.

That enables to change suppositions (compare AI learning to change its suppositions).

Imagination supposes a motivation to imagine, or to change its suppositions, an *intention* or *tendency*.

The origin of intention, *desire* or *will* supposes a Biotic ‘tending’ to extend the possibilities of life (B1).

C2 Certainty or *safety*, or in a social context **security** suppose imagining *danger* (lacking conditions).

Security supposes regulated certainty (e.g. insurance, government, defense, science).

C3 Attachment (e.g. affection, focus, interest) or in a social context **loyalty** supposes certainty or security and empathy reduced to **sympathy** avoiding **antipathy**.

C4 Identity^a or in a social context **publicity** (public identity) supposes attachment or loyalty.

C5 Interrelation, or in a social context **influence**, supposes a recognisable identity or publicity.

^a I define identity as ‘difference from the rest and stability in itself’. Identity in logic and mathematics, however, suppose equality (‘identical’).

PRELIMINARY SUPPOSITIONS ENABLE PRELIMINARY IMAGINATIONS

This staircase suffers a paradox. It pretends to enable imagining **A**biotics and **B**iotics before imagination itself has been enabled as a **C**onceptual ability.

'Enable', however, supposes a possibility, not necessarily realised or 'true'.

Moreover, you may suppose unconcious imagination before it becomes concious (**C**onceptual).

Reading this text, understanding the staircase of suppositions, already supposes imagination.

So the reader must have climbed the stairs before, but (s)he might have skipped steps.

A second climb may be concious. The staircase may point to steps missing or to be changed.

'Know yourself' may be interpreted as 'Know your suppositions'.

Any observation enables *preliminary suppositions* in order to imagine what is observed.

If you see a tree (still without knowing that name) it should be **different** from the rest. If the difference **continues** against the backgroud of moving clouds you may be aware of an **object**.

The object, however, changes if its branches and leafs wave in the wind. It also changes if you are moving yourself. There still should be intermediate suppositions between changes of the object and of its environment (e.g. perspective and stereoscopic view), probably difficult to express in single words. But, let us assume that this problem is solved by added suppositions.

If you have constructed a stable mental image of the tree, then you may **separate** it in a stem, its braches, and their leafs, each with diffent changes (e.g. moving slow and fast in the wind).

What remains is their **combination** by separations and connections. The autumn may disturb that image. Falling leafs may enable to imagine life by connection and death by separation.

Any **combination** then may be imagined as 'living', and destructive **separation** as 'dying'.

That on itself is not a bad supposition. It still enables to **reproduce**, to **imagine imagination** (being 'concious'), to get a preliminary **certainty**, **attachment** and the next **C** suppositions.

The detailed suppositions of **B**iotics then are skipped in one step, until observations force to review your suppositions of **certainty**, to go down the staircase of suppositions in order to check, add, insert or to change earlier suppositions. That may disturb your attachment, your identity. That may undermine the motive to dig deeper into the suppositions you're attached to.

Observing new facts may surprise. 'New' supposes '**different** from previous observations'.

If no suppositions fit the observation, then the staircase should be climbed anew from the beginning as a spiral of increasing knowledge. It may point to questions in a proper sequence.

Which difference, change, coherence, parts, internal structure etc.?

The motive to dig deeper increases as knowledge increases.

Little knowledge motivates 'indifference'.

§ 8 DESIGN REQUIRES MORE AND LESS SUPPOSITIONS THAN TEXT

Science sets abiotic and biotic limits to design possibilities. Chapters 4, 5, and 6 resume common science at high school level, intended to represent what we may concern as valid and reliable suppositions for design. They are written as by a layman to laypeople, including suppositions often tacitly skipped by professionals as being obvious for anybody.

Which ‘discoveries’ are actually inventions, designs of a model? What is their design content? Do they cover a broader field of possibility beyond probability? The portraits of scientists and the literature references in footnotes present some inventors of the described models. The other chapters are more critical, attempting to change common suppositions.

I tried to:

- 1 start a page with a pair of *images* raising questions by their difference;
- 2 use colours relating the explaining text below to the images at the same page;
- 3 be aware of hidden suppositions not shared by the reader;
- 4 show them implicitly in a text about something else, instead of making them a separate item;
- 5 combine items in no more than 4 lines, separated from the next items;
- 6 compress a sentence as much as possible in one line;
- 7 include daunting formulas as small text in the larger context of comforting normal language;
- 8 store explanations disturbing the line of reasoning into footnotes;
- 9 avoid the necessity of often scrolling back;
- 10 repeat in other words, locally useful for the reader, instead;
- 11 use *propositions* as titles of chapters and paragraphs, not poetic phrases hiding the content;
- 12 make *disputable* propositions to be defended in the text following.

My recommendation for using this study is "images first" or ‘titles first’.

Look at the images first, and read the additional text only if the image remains unclear.

Start sections without images by carefully considering their title (always as a proposition).

You can skip reading the additional text if you suspect its content.

2. SCIENCE SUPPOSES A PHILOSOPHIC DESIGN

§ 9	Thales related observations to mathematics	20
§ 10	Plato's dialogues enabled scientific debate	23
§ 11	Aristoteles enabled empirism and logic	25
§ 12	Descartes' doubt enabled certainty	28
§ 13	Science observes differences resisting change	33
§ 14	Science supposes a verbal language	41
§ 15	Questions are not true or false, answers are	43
	Questions raise questions about questions	44

What is the designerly content of science?

Which discoveries are actually inventions, designs of a model?

Does its philosophy cover a broader field than truth and ethics (possibility)?

We call a previously unknown observation a "discovery." An unexplained observation raises questions (p43). These questions are supposed to be answered (explained) by a model that fits the observation (fitting supposes 'true'). If such a *model* was previously unknown, the model itself is often also called a 'discovery', but it is a design, a fitting model devised by humans.^a

Philosophy studies truth or desirability but seldom possibility (**Fig.10**p10).

Science *supposes truth*, but truth only exists as an expression. That supposes a language.

Moreover, science *supposes the possibility* of testing an expression by observations.

Then, there should be a philosophic design of science making a ground of these suppositions.

What then is supposed by the 'existence' of truth and possibility as it is studied by philosophy?

This stresses the more so, if truth is *part of a possibility* (**Fig.2**p6).

A possibility cannot be studied before it is designed.

There is, however, a context with suppositions from the time in which such a design develops.

Context analysis is the very start of design (§ 6p13).

The successive contexts of that development are a subject of this chapter.

Where and when did the common suppositions change by design?

Science requires accurate observation, discernment, reduction, generalisation, logic, and doubt.

Such a scientific attitude started step by step in Greek presocratic philosophy. Why in Greece?

In the Middle Ages it froze in the authority of ancient texts and the condemnation of dissenters.

The rebirth (Renaissance) raised doubts about entrenched suppositions.

This chapter may seem a history of science, but history is used to find the conditional sequence of suppositions (and their rejections) at different levels of scale and viewpoint.

^a Euler would disagree. He is cited saying 'Science only discovers the laws that the Creator has imprinted in nature.'

§ 9 THALES RELATED OBSERVATIONS TO MATHEMATICS



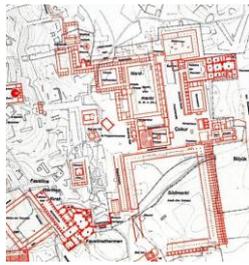
17 Greek colonies^a



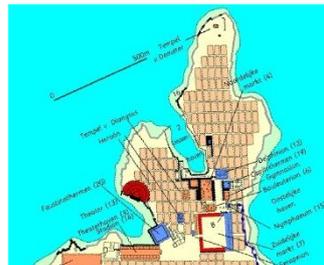
18 Meandermouth silted^b



19 Milete now^c



20 Excavations^d



21 Milete -450 as rebuilt a century or two after Thales^e



Western philosophy (relating observation to imagination) has many roots worldwide. Some concentrated around 600 BC in Milete, a Greek colony with more than 80 own colonies. There, caravan goods from the east were shipped and distributed to the west.

Trade with other cultures puts your own traditions into perspective. Gods turn out to be local. You may *believe* that they make stars and planets move, but for navigation at sea, to *know how* they move is more useful. For pragmatists 'true' is what works.

The more than 600 islands and 160 colonies of Ancient Greece were separated by water, but connected by the Greek language. The Olympic Games turned mutual warfare into a communal competitive game, rather than the practice of useless revenge, known from old Homer's Iliad.

Due to the simplicity of the Greek language and its alphabet, many Greeks could read and write. So, that art was not the monopoly of priests who, based on inaccessible holy writings, could guard the 'true religion' centrally as they did elsewhere.

No island or city-state had sole rights to one truth, although the mother city Athens still had some orthodox pretensions towards her children. Greek Gods operated locally, but they met on Mount Olympus. They could deceive each other and argue.

The Greek language also has been the first with a definite article ('the').^f Greeks could therefore discuss verbs and adjectives as independent objects such as "the being" and "the bravery", sometimes even personalized as a goddess e.g. "Virtue" (Aretè) or "Wisdom" (Athena).

For scientific abstraction, it is a great advantage if you can easily make a noun from an adjective or a verb such as changing 'fast' (ταχυς) into a quantifiable noun such as 'velocity' (το ταχυς) or to transform 'heavy' (βαρυσ) into the more general 'weight' (το βαρος). Therefore, correctly translating Greek texts into Latin (missing a definite article) has been difficult at the time.

^a Creative Commons

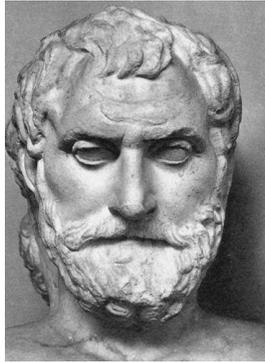
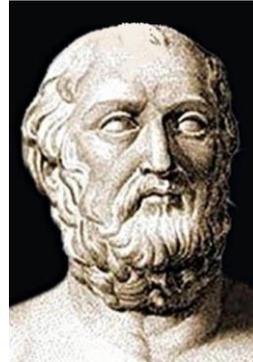
^b <https://en.wikipedia.org/wiki/Miletus>

^c Google Earth

^d <https://www.ruhr-uni-bochum.de/milet/in/topo.htm>

^e <https://www.stilus.nl/oudheid/wdo/GEO/M/MILETE.html> and Pergamom Museum Berlin

^f Krafft(1971) p49

22 *Thales?*^a23 *Anaximandros*^b24 *Aristarchos*^c25 *Eratosthenes*^d

Thales of Miletus (c.-625 to -545) is the first well-known Western philosopher.

There are no writings of him left, but there are quotes attributed to Thales: What is difficult?: "Knowing oneself!". What is easy? "Giving advice!". How should you live a good and just life? "Avoid what you blame others for!" (Kant's 'categorical imperative' 2500 years later).

Thales, the first of the Greek 'Seven sages' is said to predict the solar eclipse of 585BC and buying all the olive presses from Milet while everyone expected a poor harvest. That may indicate stressing empirical alertness and theoretical insight instead of mythical explanation by the capricious actions of gods. He claimed the use of philosophy as a practical instrument.

Beyond such empirical probabilities, he introduced mathematical methods in experience, extended into the Euclidean geometry three centuries later.^e He is said to determine the distance to a ship from the change in angle of view during a beach walk and the height of pyramids from their shadows at equal solar altitude. The 'theorem of Thales'^f is attributed to him.

Thales had reduced the world to water as a primordial cause, because water has all known aggregation states (solid, liquid, gaseous). According to Anaximandros (c.-610 to -546), a pupil of Thales, the primal principle, the 'primal cause' of Being, is an indefinite 'apeiron' from which all opposites such as wet and dry would have been arisen.

Anaximandros supposed: a circle of fire would, spattered apart, revolve and new worlds would emerge and return to it. On such a floating, initially liquid, solidifying globe, organisms arose, first living in the water and only later moving to the land. That is a remarkably modern view. Anaximandros apparently had already rejected the idea of a flat earth.

Three centuries later, Aristarchos of Samos^g (c.-310 to -230) calculated the distances to the moon and the sun (practically infinite) based on observations of the lunar eclipse.

He found that the Earth revolves around the sun ("heliocentric").

Copernicus would confirm this only 1800 years later.

Eratosthenes of Cyrene (c. -240 in modern-day Libya) determined the circumference of the earth fairly accurate, apparently using suppositions such as:

1 the earth assumed to be a free-floating globe by Anaximandros,

2 practically parallel sun rays, based on Aristarchos' *calculations* (-270).

Parallel sunrays are not self-evident, due to perspective distortion (**Fig.26** p22).

^a Thales Roman copy of a 4th century BC Greek original Vatican, Vatican, Galleria Geografica Inv. 2892; [Herda\(2013\)](#)

^b Anaximandros Relief with seated Anaximander from Rome, Via delle Sette Sale, 2nd century BC. Rome, Terme Museum Inv. 506

^c Perhaps an image of the statue of Aristarchus on the grounds of the Aristotle University of Thessaloniki(Greece)

^d Eratosthenes Etching of an ancient seal identified as Eratosthenes. Philipp Daniel Lippert Dactyliotheec, 1767

^e [Henderson\(2002\)](#)

^f If AC is a diameter of a circle and B is a point on the circle, the angle $\angle ABC$ is a right angle.

^g https://en.wikipedia.org/wiki/Aristarchus_of_Samos. https://ia601507.us.archive.org/9/items/in.ernet.dli.2015.185082/2015.185082.Greek-Mathematics---li_text.pdf



26 Visual deception through the perspective of parallel sun rays ^a

The interpretation of observations stands or falls with good or false suppositions. Discovering tacit suppositions should be the main task of philosophy.

Herakleitos ('panta rhei', 'everything flows' as Plato summarised his thought 3 centuries later) lived shortly after Anaximandros in Efesus, no more than 50 km north of Miletus. He regarded fire and war as a primordial cause, perhaps also as the source of energy creating the opposites in the indefinite apeiron of Anaximandros.

This resembles Hegel's dialectic 25 centuries later:
every thesis evokes its antithesis, leading to a synthesis that evokes an antithesis on its turn. In modern physics, every particle has its anti-particle. Colliding, they disappear as energy. The reverse, Herakleitos' fire then could make them reappear.

After the indefinite apeiron of Anaximandros, the later pre-Socrats presupposed more tangible 'primal things', such as air, earth, water, and fire (matter and energy), precursors of Mendeleev's periodic system of elements (1869).

You may imagine a *will* of gods in the existing reality, and tell stories about their conflicting wishes as the cause of everything, but to ask *how* they realize them and to reconstruct that *skill* is a big step to a religiously independent causality. Ahead of Aristotle, the divine 'final cause' seems already to be replaced by (1) 'material', (2) 'formal' or (3) 'efficient' kinds of cause.

According to Greek mythology, Prometheus ('Forethinker', the master craftsman god), betrayed to men the divine secret of fire and science. It is as if he recommended the people:

- 1 *represent* materials as combinations of primal substances,
- 2 *reduce* their space to points, lines and planes (geometry), and
- 3 *generalize* their repetition to workable concepts (in words and numbers).

These representations, reductions and generalizations enable to simulate an existing or a desired reality, in order to design it as if you were a god. Technique is a condition for knowledge: you must be *able* to know before you can know. Only *after* that 'designing' you may 'empirically' check whether that design as a hypothesis corresponds to the observed reality.

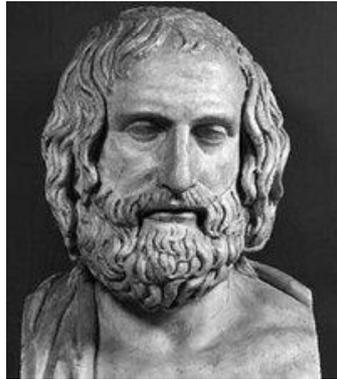
You may, however, also design and realize *deviating* realities yourself. Then, you need tools of imagination such as language, mathematical operators, similar to binders, knives, or sieves. In the 14th century, Ockham also had a 'razor' that resembles a statement attributed to Einstein: "Make everything as simple as possible, but not simpler than that."

^a Photograph by Ton Wisselius

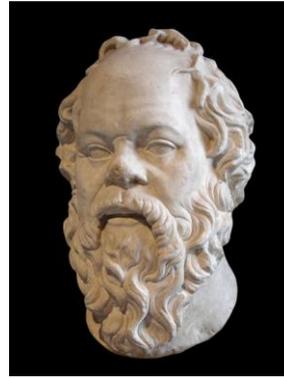
§ 10 PLATO'S DIALOGUES ENABLED SCIENTIFIC DEBATE



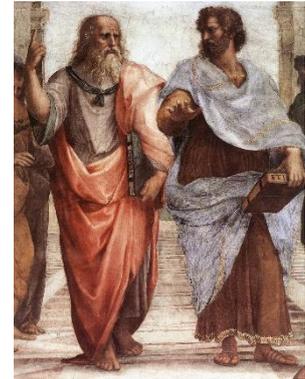
27 *Virtue as a goddess*^a



28 *Protagoras?*^b



29 *Socrates*^c



30 *Plato and Aristoteles*^d

Defending trade interests in various cultures resulted in a culture of hearing, rebuttal and judgments based on arguments in order to separate as friends keeping your trade relationships. You could learn from 'sophists' how to be right in a court hearing. The 'fair debate' as it still appears today in court sessions and university promotions, contains useful sophistic rules:

1. one proposition at a time is being examined for its tenability;
2. regardless of your personal opinion, you agree who will defend the proposition (in the *role* of defender) and who will attack it (in the *role* of opponent),
3. the opponent challenges the defender to clarify the proposition on the basis of improbable interpretations ("Do you mean by this statement, that ...?");
4. the opponent proposes a common basis ("Do you agree that?");
5. if the defender accepts the common basis, then the opponent attacks by pointing out a possible contradiction between the proposition and the agreed common premise;
6. the proponent defends by an attempt to refute the assumed contradiction.

Sophists had the name to talk straight everything that is crooked, but they are the precursors of Plato's dialogues, Descartes' doubt and Poppers falsifiability.

According to Popper a proposition that cannot be contradicted, is by definition not scientific. There is no pro and contra, no counter-learning, no control, no criticism or dialogue possible. In this sense playing Herakleitos' war in a debate, is also the father of science.

Sophists didn't make a name with their own system, but with their method.

The famous sophist Protagoras ("Man is the measure of all things") was embarrassed ('aporia') by Socrates in Plato's dialogue 'Protagoras' when he defended that 'virtue' can be taught, and that he might ask money for teaching.

To the amusement of youthful bystanders, Socrates also embarrassed dignitaries in the streets of Athens with his annoying questioning of what 'virtue' actually is.

He did not leave own writings, but his student Plato expressed his thoughts in dialogues.

As the cultural center of the Greek world, Athens remained more orthodox than its colonies, where dissidents fled with their locally unacceptable views. Socrates was convicted in Athens on charges of blasphemy and spoiling the youth. He did not flee, but chose the poison cup.

^a Virtue as a goddess Personification of virtue (Aretè) in Celsus Library in Ephesus, Turkey

^b Protagoras, as he is often published, but in fact a marble bust of Euripides.

Roman copy of a Greek original from the 4th century BC. Museo Pio-Clementino in Rome

^c Socrates A marble head of Socrates in the Louvre (copy of bronze head by Lysippus)

^d Plato and Aristoteles, detail of Rafaël Santi(1510)Stanza della Segnatura(Rome)Vaticaan

The Greek language made possible to independentize an adjective, the property *of* an object (such as 'wise' to 'wisdom', 'virtuable' to 'virtue', even personalized as a goddess **Fig. 27p23**). If you regard such words as real, independent objects (medieval 'realism'), then (like Socrates) you may continue to inquire their 'essence'.

Every explanation, however, requires adjectives, bound by examples.

I share Poppers reluctance against such 'essentialism'^a.

Words are just collective names that we have invented ourselves (medieval 'nominalism').

Similarly, I cannot share Plato's view that our reality is only a projection of ideas ('idealism'). On the contrary, actual things project themselves in our mind, and when those impressions repeat, we invent generalising words for them. The success of Plato in the Christian world is understandable when you read in the gospel of John 1: "In the beginning was the Word."

Moreover, Plato's hero Socrates, and Jesus Christ both were martyrs by their own conviction. This creates a sense of responsibility for their relatives. Dante (1265-1321) tells in his Divina Commedia how the not baptized gentiles Socrates, Plato and Aristotle did not end up in Hell. They had received their own place next to Heaven, even though they were pagans.

I may reject Plato's idealism, but he has made the dialogue of the sophists a standard of literary expression, philosophy and science. A dialogue avoids one-sidedness.

Opposing views get their own respected face and power of persuasion.

The similarities and differences of insight per character lead to the analysis of their overlaps or mutual exclusion that lead to logical conclusions with conjunctions such as 'and' or 'or'.

Plato's student Aristotle elaborated this logic into a separate scientific discipline.

The convincing truths of mathematics as a world of ideas that may develop independently from reality and yet seem to project itself to that reality everywhere, was an important argument for the idealistic view. You may, however, imagine mathematics also as a set of techniques, derived from our experience with everything that repeats itself in reality *and* in our mind.

Mathematics distinguishes different types of repetition, such as making equal steps (line), with equal deviation (straight or circular), with equal units counting, counting back, multiplying, integrating, and differentiating.

Equations then make different formulations at both sides of the '=' sign equal.

What repeats itself in the real world can be counted and numbered.

Conversely, a mathematical product may be realized in a repeated production. What does not repeat, the one-time or unique, cannot be counted. It only can be told. The unique does not lend itself to generalization and therefore not to a predictive science that relies on repetition.

For generalization, mathematics is a technique simulating all types of repetition and similarity. It supposes differences *between* the quantities that can be counted (variables), but equality *within* those variables (units).

^a Popper (1976)

§ 11 ARISTOTELES ENABLED EMPIRISM AND LOGIC

Unlike Plato from Athens, his student Aristotles from Stageira ('the Stagirite') no longer assumed that you, as a midwife, only have to redeem the ideas that are still sleeping in a student in order to give birth to knowledge (as once 'proven' by Socrates).

Not all knowledge of the world can be present already as an idea in every student.

This probably has been also apparent from the strange objects of which no one had any idea before, that Aristoteles' pupil Alexander the Great sent him for his collection during his conquest up to the Indus. Aristotle taught to trust your own senses and to process that variety of impressions to usable knowledge using only 4 innate word categories^a and 4 kinds of judgment.

Categories:

substance,
quality,
quantity,
relation.

Judgment forms:

affirmative - negative,
general - special ,
some - one-off,
necessary - possible.

31 Aristoteles' categories and judgement forms

With different word categories: substance, quality, quantity and relation, you can make a judgment in a sentence with subject and predicate: affirmative or negative, general or special, some or one-off, necessary or ... *possible*.

From a general judgment (major) and a special judgment (minor) you may derive a third judgment, a conclusion (deduction).

A general judgement is preliminary a generalization from many examples (induction).

Deduction

Major: If I am in Delft,
then I am in The Netherlands.

Minor: Well, I am in Delft.

Conclusion: I am in The Netherlands.

Induction

Aadorp is a place in The Netherlands,
Aagtdorp is a place in The Netherlands,

...

...

Zwolle is a place in The Netherlands.

So: All places are in The Netherlands.

32 Aristoteles' logic: the combination of judgements

In observable reality, however, no number of observations is sufficient for 'complete induction'. If you add 'London is a place in England' to the 4000 from Aadorp to Zwolle in The Netherlands of **Fig.32**, then the conclusion 'all' has already been falsified.

Induction, a general judgment, therefore always deserves doubt, a search for counter-examples.

In mathematics, however, 'complete induction' is accepted if you can imagine to repeat the same operation infinitely. For example, you *approach* zero by repeated halving.

You never *reach* zero, but you may accept zero as the final result ('limit') of an imaginary infinite times repeated operation of halving.

For Plato, general ideas produce the special cases (idealism); for Aristotle, the general is a set of special cases (empirism). Yet the platonic idea ('eidos' is literally 'visual form') comes silently back in Aristotle as the form in which a substance (material or content) takes shape.

^a Aristoteles(-330) writes 10, but they can be traced back to these 4.

The pure, substance-free form is an ideal (geometrical) idea, a mold able to force a substance in its form, while any substance has resistance to change its form.

Movement is also a change of form (distribution in space), against which matter will resist. Then, movement must have an unmoved mover, the infinitely good and beautiful against which substance resists. The material resistance against form is the cause of all imperfection opposed to a final divine or human will.

Aristotle distinguishes four types of cause^a:

- 1 form cause**, the perfect mold;
- 2 material cause**, the resistance of matter;
- 3 efficient cause**, the unmoved mover, *source* of motion;
- 4 final cause**, a divine or human will.

33 Aristoteles' causalities

The resistance is a precursor to Newton's mass inertia. For Newton, however, not the movement of a mass itself, but its acceleration or change of direction has a cause (attraction or repulsion). Newton did not need a form~ or final cause. Mass resists against movement (material cause) *and* attracts by gravity or repulses at collision (efficient cause).

The basic concepts of Aristotle's physics are space, time, substance, cause and movement. He assumes a *goal directed* efficiency.

Physics	Biology	Humanities
goal directed	entelechy: soul-steered	layered
Space	Unmoved mover, the soul	Vegetable nourishing
Time	(active form)	
Substance		Animal feeling
Cause	Moved body	
Movement	(passive substance)	Human thinking

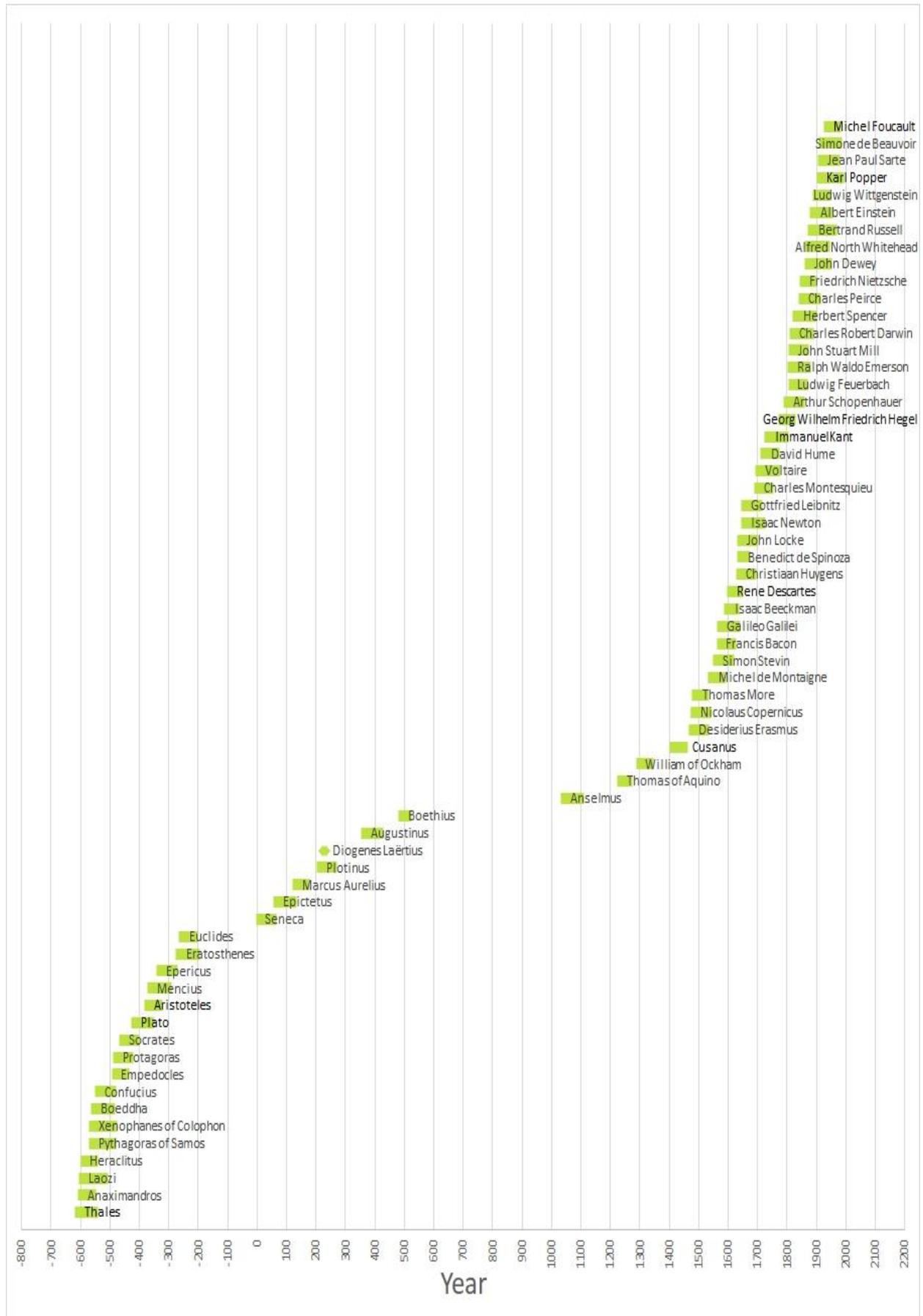
34 Aristoteles' physics, biology and anthropology

For his biology, the soul is the unmoved mover, the cause of form (entelechy). It is a precursor of the genes (a library of recipes for form generating processes in any cell) in current biology. The body is the moved, but resisting substance, the tool (organon) of the soul. A human has a plant-nourishing, animal-feeling and human-thinking layer.

The large series of surviving works of Aristotle (transmitted to the Western world by Islamic writers) has the character of an encyclopedia containing all knowledge of that time. That great design of Aristotelian science dominated the literate world until the Renaissance with an almost inviolable authority.

There has been apparently little need for more philosophy in the Middle Ages (*Fig.35p27*).

^a Aristoteles(-335?) p17

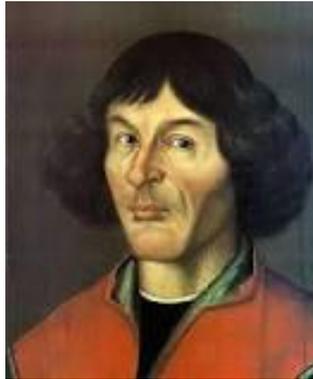


35 Philosophy shows a gap in the Middle Ages ('Dark Age')

§ 12 DESCARTES' DOUBT ENABLED CERTAINTY



36 Cusanus^a



37 Copernicus^b



38 Descartes^c



39 Newton^d

Descartes is considered to be the founder of modernism.

Two centuries before Descartes, however, at the end of the Middle Ages, Nicolaus Cusanus (1401-1464), a German lawyer, philosopher, mathematician, inventor, astronomer, humanist, theologian and cardinal, already testified of far-reaching modernism and tolerance^e.

This advocate of accurate measurement and weighing, denied apparent mathematical counterparts such as straight and round with mathematical arguments ('coincidentia oppositorum').

The prominent role of mathematics in his work up to his theology made him even more rational than Descartes.^f He considered all religions with great tolerance as parallel paths (not crossing) to the same God at an infinite distance. So nobody really can *know* God ('docta ignorantia')^g.

As a roman catholic cardinal *and* connoisseur of the Islam and its Koran he envisioned a peaceful theological dialogue between different religious traditions.^h A little later, the Reformation brought about the polarized Christianity Descartes had to deal with.

Cusanus left his birthplace Kues on the Moselle a still existing retirement home with the library of his own and other medieval manuscripts, and left Deventer a house for poor students. His modernism, however, was not widely shared, as that of Descartes did two centuries later.

Copernicus dared to doubt about Aristotle, and Descartes joined the growing choir of doubters. They dared to think for themselves instead of following the authorities without sufficient criticism, as Kant had to advise again two centuries later.

If you simply learn by heart what you learn, then you will not *understand* it, get a *grip* on it from *outside*, do something with it, contrast it, counter-learn, check whether it is true: doubt.

Descartes' paradox that you can derive certainty from doubt is an example of Russell's paradox: a set of all sets cannot contain itselfⁱ. Similarly, the set of all *doubts* cannot contain itself. If you look at that set from the outside, then there is no doubt about the *fact* that you doubt.

Similarly, you cannot think about thinking with the same thoughts you think *about*. Understanding is different from what should be understood.

^a Cusanus Relief on his tomb in S. Pietro in Vincoli, Rome

^b Copernicus, Nicolaus Copernicus portrait from Town Hall in Toruń

^c Descartes, Paris Louvre Museum Richelieu, 2nd floor, room 27

^d Newton, Portrait of Newton at 46 by Godfrey Kneller, 1689 Institute for Mathematical Sciences, University of Cambridge

^e Müller(2013)

^f Dijksterhuis(1975) p248 has a clear overview of Cusanus' ideas.

^g Cusanus(1440)

^h Cusanus(1453)De Pace Fidei(WWW)

ⁱ As an element of a set *with all sets*, it no longer contains all sets. This paradox is described in Russell(1903).

It is remarkable that Russell (1946) *History of Western Philosophy* (Cothen 1990) Servire in his chapter on Descartes on p588 of the Dutch version, himself did not notice that this thinking about doubt is an example thereof.

Descartes' "Cogito ergo sum" is less convincing by circularity, if you realise:
"I think, so *I think* I am". 'I am' is also a thought after all.

You cannot talk *about* concepts using the same concepts. For that 'meta-language' you need other concepts. May be therefore, Descartes advised to talk *about* quantities in symbols. By doing so, he prepared the use of algebraic expressions. Descartes invented *outer* coordinates (a meta-language) for geometry and thereby prepared the development of analytic geometry.

The use of symbols and coordinates is Descartes' most important lasting contribution to science. He derived his prestige from the application of mathematics in his sometimes pioneering, yet immature physics, but finally he has remained best known as the philosopher of rationalism.

Descartes had learned practically everything there was to be learned from the Jesuits in Paris. Every idea, no matter how unlikely, had been worked out by some authority in the past. What can you be sure of, how should you check that? By continuing to doubt yourself!

Travelling he found the most improbable and mutually contradictory views in other cultures. At the same time, he had to admit that such views were shared by very intelligent people. Each individual mind was able to check a mathematical proof *without* external authority.

Mathematics turned out to be the only area in which this individually developed certainty was finally shared by everyone as 'evident', clear and well-distinguished ('*clairément et distinctement*'). That is not surprising if it involves only repetition, similar in matter *and* mind.

In the winter of 1619, Descartes, 23 years old, withdrew to Germany as a recluse for a few months 'in a well-heated room', asking how this mathematical evidence could also be achieved in areas other than mathematics.^{a,b} He decided to:

- 1 never accept anything from authority if you have still any reason to doubt it;
- 2 divide each problem into so many parts as possible and required, to solve it;
- 3 start with the simplest, but look for connections that may complicate that simplicity;
- 4 making summaries and overviews everywhere so complete that you do not to skip anything.

In dealing with others, however, he would have to live with uncertain beliefs and customs that he did not want to condemn before he himself was completely certain of their inaccuracy.

To that end, he decided to:

- 1 obey the customs of the country, but also your own religion; stay in the middle of extremes;
- 2 be as determined as possible once you have decided on views, even if you still have doubts;
- 3 rather conquer yourself than destiny; rather change own wishes than the world order (stoic);
- 4 consider in succession the activities of people in this life in order to choose the best.

He did the latter by traveling around for nine years until he decided to settle in the Netherlands, the first republic of Europe after Venice, in order to

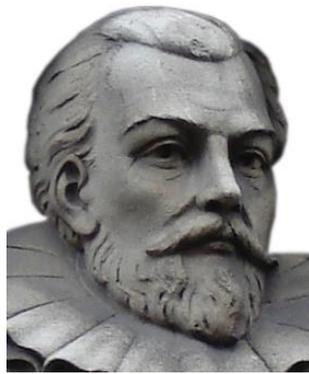
"avoid all the places where I could have acquaintances and to withdraw here in a country where ...because of the long duration of the war such an order has been created that it appears that the armies that are maintained there, serve only to be able to enjoy the fruits of peace with greater security; and where amid the crowd of a very active people who are more concerned about their own business than curious about those of others, without missing the comforts found in the most visited cities, I have been able to live as lonely and withdrawn as in the most remote deserts."

^a [Descartes\(1637\)](#) French:[Discours de la methode](#) English:[Discourse on the Method](#) . The first three parts are an entertaining, modest autobiography with a wealth of wise examples. In the fourth part, however, it becomes less accessible and less convincing metaphysics, in the fifth part an outdated description of biological facts as proof of the inanimate mechanics of the body and the animal as a machine, and in the sixth part the explanation why he did not dare to publish parts earlier in detail in view of the then recent conviction of Galilei.

^b By the way, [Cusanus\(1440\)](#) applied mathematics on religion already two centuries before.



40 *Frederik Hendrik v. Oranje*^a



41 *Simon Stevin*^b



42 *Baruch de Spinoza*^c



43 *Christiaan Huygens*^d

However, it had been also the country where the prince of Orange protected him against attacks of straight-line Protestants, where he met Simon Stevin (in several ways ahead of Galilei) and his friend Beeckman (in several ways ahead of Newton), where the microscope was invented and the telescope (which Galilei improved in order to discover the moons of Jupiter), where Spinoza grinded lenses and worked out his 'Ethics' mathematically^e, where Christiaan Huygens admired and corrected him.^f

In The Netherlands, he designed a metaphysical world view based on two evidences:

- 1 Individual doubt proves that you exist as a thinking being.
- 2 That doubt also proves your own imperfection.

That implies a sense of perfection outside of you (his 'proof' of God's existence).

How these two 'evidences' lead to his idea of a complete separation between immortal spirit and mortal body (cartesian dualism) is beyond me. That distraction does not excel in rationality. The small, doubting, imperfect, thinking ego is in Descartes's view in contrast with the great, perfect certainty of God's spirit.

Science is the *pursuit* to that divine comprehensive certainty.^g If that doubt and the ensuing certainty is 'mind', then where does the 'matter' that we perceive come from? Is matter a divine creation that moves along (co-agitates) with the divine thought as a world soul (entelechy)?

If that bound matter has a substance other than the free spirit, then how can the spirit take hold of our body? Spinoza soon rejected that dualism.

Now that we have learned machines to doubt with switches (transistors) and finally even to think by material artificial intelligence, to me that debate seems to be outdated.

Descartes' 'Rules for the mind' seem to me more important to science than his metaphysics. From 1620 he wrote the 'Regulae ad directionem ingenii' but never published them himself. They only appeared in 1684^h for the first time in Dutch and in Latin only in 1701. The first sentence made the greatest impression on me:

"People, as soon as they recognize any equality between two things, have the habit to suppose that equality in everything, even in which those things differ."

^a Frederik Hendrik van Oranje, painting by Gerard van Honthorst, Rijksmuseum in Amsterdam

^b Simon Stevin, Statue on the Simon Stevinplein in Bruges, Belgium, by Eugène Simonis

^c Baruch de Spinoza, Herzog August Bibliothek in Wolfenbüttel. Copy in The Hague Historical Museum on loan to the Jewish Historical Museum in Amsterdam

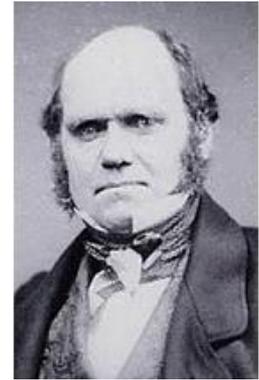
^d Christiaan Huygens, oil painting by Caspar Netscher 1671, Museum Boerhaave in Leiden

^e [Spinoza\(1677\)](#) in English: [Ethics](#)

^f [Dijksterhuis\(1975\)](#)

^g As elaborated earlier by Cusanus(1440) in a more rational way, referring to mathematics of infinity.

^h [Descartes\(1684\)](#) [English](#) .

44 Leibniz^a45 Hume^b46 Kant^c47 Darwin^d

This undermines the usual generalization of heterogeneous sets in words such as 'people' in statistics of medical science and biology. You cannot apply a conclusion about one equality between objects to those objects if they may differ in other characteristics.

After Aristoteles and Cusanus, Leibniz is the first to distinguish, apart from 'truth', the modality of *possible* worlds that is crucial for designers, but further he followed Descartes.

Hume had stressed: back to the facts, first look for yourself, no a priori's, categories and suppositions in advance! Even a causal relationship is a mental supposition.

The senses only observe a *sequence* of events.

The mind reduces the infinite variety of impressions in manageable generalizations.

Kant, however, gave idealism a place back in science supposing innate 'a priori' ideas in his still popular and often cited design of science. Next to ideas of *space* and *time*, located in the senses, he supposes 24 ideas, a priori present in the mind. These ideas are required to make 'knowledge' possible. 'Judgments' attach the property of a 'Category' to an 'object'.

	Categories	Kinds of judgement
1 Quantity	Unit Multiplicity Allness	General Special Singular
2 Quality	Reality Negation Constraint	Affirmative Denying Infinite
3 Relationship	of inherence and subsistence (substantia et accidens) of causality and dependence (cause and effect) of community (interaction between active and passive)	Categorical Hypothetical Disjunctive
4 Modality	Possibility, Impossibility Existence, non-existence Necessity, Coincidence	Problematic Assertory Apodictic

48 *Twenty-four a priori categories and kinds of judgment according to Kant*^e

Twenty-four a priori ideas is already less than what Plato and Socrates assumed as hidden in everybody's mind, but it is again more than the eight axiomatic premises of Aristotle.

^a Leibniz, preserved at the Hannover Regional Library

^b Hume, by Allan Ramsay, 1766 National galleries of Scotland Edinburgh

^c Kant, Painting by Becker, 1768 Portrait at the age of 44, Marbach, Schiller-Nationalmuseum

^d Darwin, Photo taken around 1855 by Maull and Polyblank for the Literary and Scientific Portrait Club

^e [Kant\(1787\)](#) I §9, §10

Moreover, in order to judge apart from the senses, you also should suppose an *ability* to judge (to choose an *appropriate* adjective for a given noun). And, an overarching 'reason' from self-chosen ideas must determine what is 'appropriate'. This adds again two more a priori's.

Kant supposes this multitude of instances to be part of a unity: the subject ('I', 'you', '(s)he'). The unity of an individual is a crucial supposition in any of Kant's 'proofs'. The subject, however, may be a multitude.^a

Identity is flexible. A subject plays different roles in different contexts. It develops, and must be learned in childhood *a posteriori*, composed, adjusted and stabilized in order to remain a recognizable subject in communication with others. Identity is *chosen* from a multitude of possibilities to become unique and continuous.^b So, Kant's 'unity' is not *a priori* present.

Moreover, how could you imagine after Darwin, that once an animal suddenly became an intelligent human with coincidentally 26 mutations and the implementation of all these traits simultaneously?

Kant's kinds of judgement and categories may be philosophically interesting and useful to be distinguished, but there are overlaps. For example: quantity is a quality (one of many other qualities) of some object. A quantity supposes a quality (to be measured). A priori's are undisputable and unnecessary suppositions. Following Kant this way loses scientific relevance.

After Kant, science separated from philosophy. It concentrated on well-defined objects, operations, experiments, *reliable* observation and *valid* reasoning, but still searching for *truth*. Who, however, cares for *possibility*-finding, for *design*? A neglected task of philosophers.

The common concept of 'valid reasoning', the formal truth-based *logic*, disables a broader view on possibility (design). Attempts to include possibility in a 'modal logic' is flawed by subordinating possibility to truth. It is not true to be possible. It is possible to be true (**Fig.2p6**). An animal is not a dog. A dog is an animal. Design requires an addition to logic (**Chapter3p46**).

Science looks for a stable *difference* in a *changing* context, an *object* of research, *separating* its components, *combining* them in a model, an image simulating a supposed reality. That supposes design: *making* (imagining) such a *combination* (composition) out of components *separated* (selected) from available *objects* resisting *change*, remaining *different* from their context.

These are not *categories* a priori present in the mind, but suppositions successively constructed upon only one a priori condition: *difference* (§ 7 p14).

^a A dissociative identity disorder or schizophrenia may be a normal condition, oppressed by a culture that counts on agreements. **Minsky(1985)** assumes a multitude of judgmental actors within one individual. **Bob Dylan(2020)** has sung "I contain a multitude".

^b Some experiments with children in a series of publications, summarized in **Piaget (1966)**, can be interpreted this way, even though Piaget himself claimed to be a Kantian. The quest for own identity (difference from the rest and continuity in itself) is a burning question for recognition within a growing population. Group identity (nation, city, work, family) may support one's own identity, but within the group, this question repeats itself most urgently. It determines the choice of behaviour in every context.

§ 13 SCIENCE OBSERVES DIFFERENCES RESISTING CHANGE

Hestia^aDemeter^bHermes^cDionysos^dApollo^eAthena^f

49 Greek Olympic gods

An environment with many differences trains the ability to think in alternatives. A limited imagination does not tolerate alternatives, wants to preserve, conquer, level out. The Greek birthplace of our science offered many differences at different levels of scale.

On a large scale there was the **difference** between Europe and Asia, as a border spun out in numerous islands. That difference aroused cultural exchange and trade, but the advancing Persian empire threatened the small independent city-states. They joined forces. When Persia was repelled in Maraton (-490), the differences on a smaller scale came to the fore again.

The Dorian invasion of shepherds and farmers around -1200 settled in the south of the Peloponnese around -950. From -800 to -700 Sparta was a 'prosperous and hospitable cultural centre for music, singing, dancing and poetry'^g. Men and women were treated equally. The Spartan upbringing proved its superiority at the Olympic games.

Sparta rarely opted for overseas colonization. From -700 onwards, the battle raged for fertile interior land. Sparta's attempts at expansion led to her proverbial perfection in warfare and to the democratic participation of the warriors ('hoplites') so often summoned from the people. The Greek gods were widely respected and consulted for political and military decisions.

The Dorian Peloponnese differed from the Ionian distribution over islands and colonies. After -500 each united around Sparta or Athens in the Peloponnesian or Delian league. They came into conflict (the 'Peloponnesian Wars' in which Socrates fought bravely). Precisely in this bloody -5th century Athens gave the Greek heritage its most exuberant form.

Sparta won, *but prevented the destruction of Athens*. Sparta soon lost its hegemony to Thebes. In turn Thebes was devastated by Macedonia, which then extended Hellenic culture to the Indus.

On a smaller scale, everywhere in Greece there was a **difference** between interior and coast, between agriculture and overseas trade, between the rule of Demeter and Hermes. In the small city-states, and on the islands, these contrasting cultures were exposed to each other every year at harvest festivals. There, Dionysos' wine let both step out of itself (ek stasis, ex sistence).

The bacchant freed her- or himself from the suppositions required by a daily imposed role. Outside of that role, daily life is called into question. With masks, different roles were played.

^a Hestia Giustiniani in the Museo Torlonia Rome

^b Demeter in the Museo nazionale romano di palazzo Altemps

^c Hermes of Praxiteles bearing young Dionysos in the Archaeological Museum of Olympia

^d Dionysos in the British museum

^e Apollo Belvedere in the Pio-Clementine Museum of the Vatican Museums

^f Athena of Velletri in the Louvre museum

^g https://en.wikipedia.org/wiki/History_of_Sparta

Back to Hermes' rule on the coast, in the harmony of Apollo or the wise practice of Athens, now drinking parties ('symposia') were held, theatres were built and Dionisian festivals organised.

In Greek mythology, Apollo received a tortoise-shell lyre from Hermes that made them friends. Musical harmony connects by dreamed social harmony. The dance detaches people from the ground in which Demeter and her sister Hestia, goddess of hearth and home, are rooted. But rising too high would cause falling (Ikaros!). Hermes is depicted with wings tied to his feet.

Thales (-624 to -545) had detached flawless geometry from disordered reality. Pythagoras (-570? to -495?) associated this with music. There should be a wisdom outside the arbitrariness of fickle gods. Making that **difference** was the first step in a design of science. With that wisdom of your own, you could **change** an established fact yourself (Prometheus!).

The supposition that every coherent **object** is composed of one or a few elements (water, earth, air, fire, change as such, or an indefinite 'apeiron') was a step towards new *combinations*. Whatever **separation** you suppose, you can **combine** those basic components as you see fit. Anaximandros' indeterminate 'apeiron' allows to imagine arbitrary materials for *composition*.

Aristotle criticized the concept of apeiron as an empty explanation for the origin of everything. Yet this was the precursor of the indefinite *variable*, the 'x' that yields an 'y' for every x. Pericles led Athens (-469? to -429) *without a determinate appointment* as 'first man' of the city. With his friend philosopher Anaxagoras, he shared the idea of Anaximander's indefinite apeiron.

He designed Athens as the radiant center of Greek culture. That intention remained the same, but as a great orator, warlord and statesman, he used different components. The components of his design were not only buildings, but also people. In the 'golden age of Pericles', the Acropolis was realized *and* (under aristocratic protest) a radical democracy.

Plundering by oligarchic Sparta drove the peasants of Attica within the walls of Athens. There a plague broke out, by which Pericles also died (-429). The power of Athens was broken. But *Sparta did not destroy it*. Culture continued to flourish there. Plato was born two years later and replaced the human-shaped gods by abstract ideas. Aristotle did that by his science.

However, the religion of the Greek pantheon and its myths continued to be confessed into Roman times. Criticism of the unethical behavior of gods still could be paid for with your life (Socrates). Finally, Greek polytheism was replaced by one ethically 'good' God. This unambiguity in the Bible and later the Koran left less freedom of thought and imagination.

It provided more security, but it also led to aggression against dissenters ('heretics'). The certainty was threatened by different interpretations of the Holy Scriptures. From 1000 onwards, Plato and Aristotle were used for more rational interpretation ('scholasticism'). They were not contrary to the Christian faith according to church fathers as Augustine and Aquinas.

Cusanus (1401 to 1464) still granted the Islam a way to God with mathematical arguments. From 1517 onwards, the protestants separated from the catholics. This led to sharpening, fanaticism, genocide and bloody wars on both sides that could last 30 or even 80 years. Science then had to formulate cautiously, to conceal some observations and opinions.

Copernicus published a mathematical model in 1543 in which the earth was not the center. That was against the teachings of the church and Aristotle, but as a model it did not claim truth. In 1616, Galileo defended that model on the basis of his own observations. He was convicted by the Inquisition and also Copernicus' publication was banned after all.

Therefore, Descartes decided in 1633 not to publish a similar study on physics. His dualism between body and mind had already met resistance, even by the Protestants. In 1641 he defended methodical doubt in order to arrive at certain knowledge. It was one of his dangerous publications that were posthumously banned by the Catholic Church (1663). In 1450, Cusanus had been still able to express himself in a more modern way with impunity^a.

Descartes (1637) designed an analytic geometry with coordinates and characters for variables^b. This made it possible to express classical geometry in algebraic terms. That opened the way to the design of differential and integral calculus. Newton's draft of it in 1669 was only published posthumously in 1711, but Leibniz *published* his similar invention earlier (1684).

Descartes distinguished between the geometric figure and its representation with coordinates. Newton's groundbreaking design of mechanics distinguished mass m and weight f . This also led to concepts that were difficult to define differently, such as force $f=m*a$ and momentum= $m*v$. Newton and Leibniz formulated *change* with indivisible small successive *differences* dy/dx .

Such forms of distinction made more far-reaching representations of *objects* possible. After 1700, science was no longer limited to the hobby of a few literate well-to-do. Religious objections were dropped. After Newton, science was recognized as a common cultural asset.

The growth of empirical science was only possible through new technology, new instruments, designed to experiment, observe and measure. Their goal was *to know*, even if it had no other practical application or social use. Franklin (1752) proved that lightning could be distracted as electricity, but insight into the *use* of electricity only arose in the next century (Faraday, 1831).

Euler and Lagrange took physics and mathematics to a higher level. Franklin, Galvani, Volta, and Coulomb gave a first understanding of electricity. Lavoisier founded modern chemistry. Linnaeus classified life forms, and Jenner came up with the first vaccination. Hutton gave geology more time than previously imaginable. Herschel and Laplace innovated astronomy.

Watt's steam engine (1769) as a *technique* embarrassed science. That invention changed the world, long before thermodynamics understood its efficiency. Heat was now converted into kinetic energy. Coal, oil and gas replaced man and horse. After 1800, an explosion of industrial applications motivated the growth of science more than metaphysical philosophy.

Gauss provided mathematics needed for electrical engineering, statistics, curved surfaces and astronomy. Mendeleev (1869) arranged the elements with open places for the new discoveries. Evolution(1859), organic chemistry, microbiology^c, vaccinations (Pasteur, Koch) saw the light.

In 1800, no one could foresee the usefulness and importance of electricity for the coming age. Ampère (1820) discovered and amplified magnetism around a live wire by winding on a coil. Faraday (1831) generated electricity by moving a magnet (dynamo) and vice versa (motor). Maxwell (1865) formulated radiation as a rolling wave in an electromagnetic field.

In 1900, Lord Kelvin considered physics to be almost complete, but the new century taught otherwise. Einstein (1905-1915) put Newton's space and time into perspective and formulated mass as energy. Quantum mechanics (1900-30) and nuclear fission (1938) opened a look at subatomic particles. After 1930, physics has not known such radical and decisive breakthroughs.

^a Müller(2013)

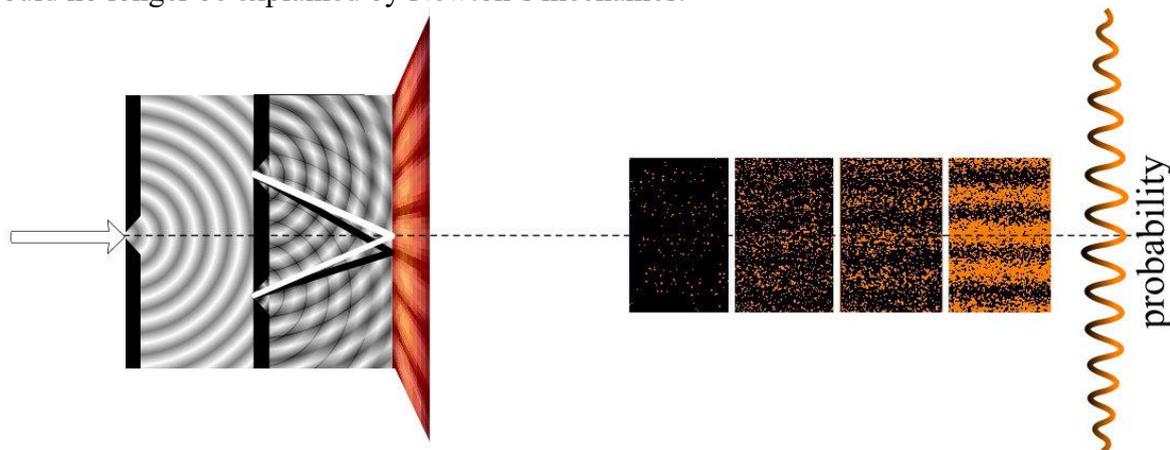
^b Stevin (1594) did that earlier.

^c Opened by Antonie van Leeuwenhoek as early as 1674.

New plastics (Bakelite 1907^a), superconductivity (1911), antibiotics (Penicillin 1928), the atomic bomb (1945), the transistor (1947), the unravelling of DNA structure (1953), the solar cell (1954), new vaccines (1955), rockets leaving the earth (1957), nanotechnology (1990) were mainly *technical* breakthroughs that used, questioned and supplemented the results of science.

After 1900, physics passed the limits of what is observable. It had to rely on what could still be calculated, even if it was no longer conceivable with analogies from daily life ('anschaulich'^b).

Scientific certainty was undermined by the *proven* relativity of space and time (Einstein 1905), physical uncertainty (Heisenberg 1927) and undecidable math (Gödel 1931). Some phenomena could no longer be explained by Newton's mechanics.



50 Light through two slits interferes 51 Electrons (particles) also interfere as waves

Light projected through two slits onto a **screen** shows an interference **pattern** (**Fig.50**). Light rays of equal length (white) reinforce each other. They extinguish each other with a difference of half a wavelength (black). Young (1805) seemed to prove that light is a wave phenomenon. Jönsson (1961) repeated the experiment with electrons: particles also interfere (**Fig.51**).^c

How could electrons from different slits 'know' where they should or should not land? Until 1989, the experiment has been repeated more often, now with the supply of electrons one by one. To know at which slit they passed, they were detected there, *but then the interference disappeared*. The *observation* itself disturbed the wave-like probability path of the particles.

The radiation intensity of a black body^d increases with its temperature. At each temperature, that power varies by frequency f (= speed of light/wavelength = c/λ). Raleigh and Jeans (1900)^e calculated an *increase* by f , but Wien (1896)^f had already formulated a *decrease* at higher f . Planck (1900)^g finally successfully limited the frequencies f to the multiple of a *constant* h .^h

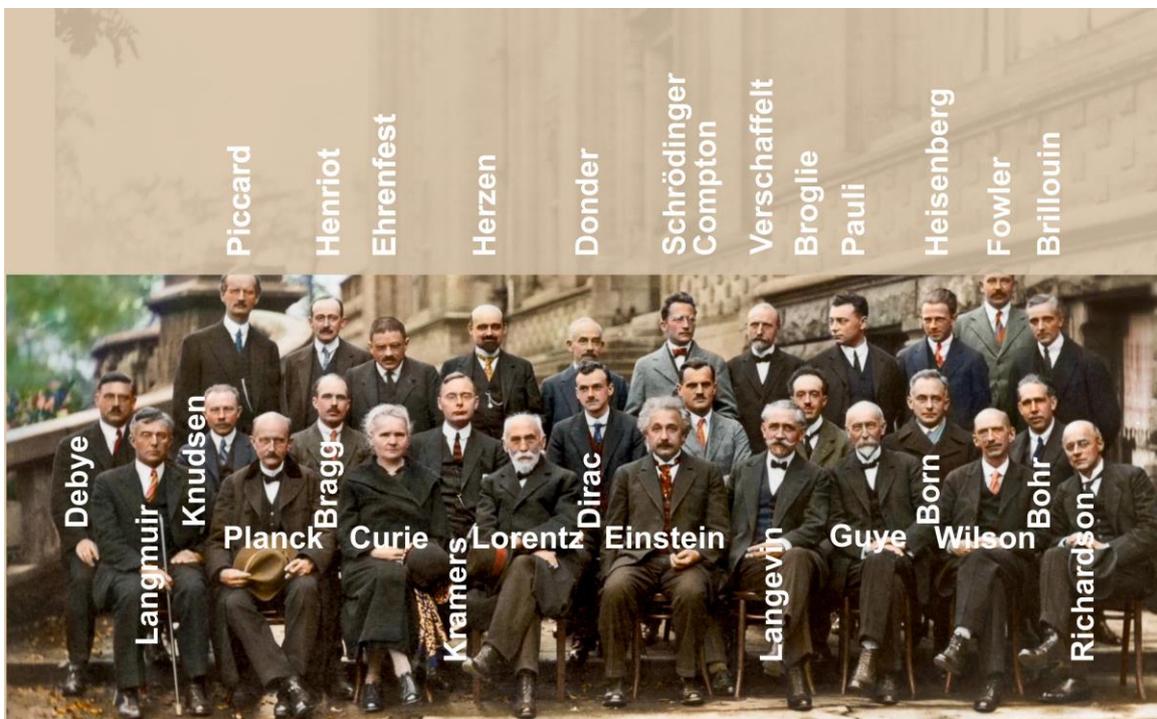
This made $E = h \cdot f$ the smallest transferable energy quantum, the beginning of quantum theory. Light now had to be represented as a stream of loose particles ('photons') with wave properties. Every observation requires photons. These disrupt the course of subatomic particles and make them uncertain. What remains for science is probability (to Einstein's dismay).

^a Once preceded by the invention of celluloid in 1869.
^b Weizsäcker(1943); Weizsäcker(1959)
^c <https://nl.wikipedia.org/wiki/Tweespletenexperiment>
^d A body that absorbs all frequencies and emits them when heated.
^e Rayleigh(1900)
^f Wien(1896)
^g Planck(1900)
^h The 'Planck constant' $h = 6.62607015 \times 10^{-34}$ J/Hz

Einstein's 'annus mirabilis' (miracle year) 1905 opened in March with the first^a of five publications that would change our worldview. It explained how light can release electrons from an atom: $E_k = h \cdot f - W$ (the principle of the solar cell). In this, W is the energy needed to release the electron and E_k is the available electrical energy. For this he received the Nobel Prize 1921.

In April, he obtained his PhD on the size of atoms.^b In May he explained the Brownian motion.^c In June, he wrote the *special* theory of relativity.^d In September, he explained this as $E = mc^2$.^e In 1915, he deduced the deflection of light by gravity in his *general* theory of relativity. When objects remained visible behind the eclipsed sun in 1919, no one doubted anymore.

Bohr (1913) designed a model of atoms with electrons in shells circling around a nucleus. This raised numerous questions, which were finally explained from the motion of particles by Heisenberg (1925) and from waves by Schrödinger (1926). That was the new quantum theory. They had the same result, but they did not yet take Einstein's relativity into account.



52 Participants of the 1927 Solvay Conference in Brussels^f

At the Solvay International Conference 1927 (**Fig. 52**) the founders discussed the new theories. Dirac(1928) extended the new quantum mechanics with Einstein's *special* relativity, predicting antimatter (such as the positron, discovered in 1932). He designed a comprehensive notation in 1930, but Einstein's *general* relativity (gravity as curved spacetime) was still missing.

In 1935, Schrödinger formulated the possibility of 'non-local' quantum entanglement. Bell (1960) made this mathematically testable and Aspect (1981) proved it experimentally. This not interceptible 'communication faster than light' already plays a role in the development of quantum computers, but it still cannot be explained properly.

^a [Einstein\(190503\)](#)

^b [Einstein\(190504\)](#).

^c [Einstein\(190505\)](#) .

^d [Einstein\(190506\)](#) .

^e [Einstein\(190509\)](#)(*Annalen der Physik*)18 p639–641.

^f Coloured by Sanna Dullaway. <https://www.sannadullaway.com/about>

Quantum theory still required a fixed space-time. Gravity supposes unfixed space-time. In the 1930s, Bohr, Pauli, Heisenberg, Dirac, and Oppenheimer lost hope to include gravity.^a Before the war, however, Kramers did point to a new path: 'renormalization'. After the war, Feynman and Dyson renormalized mass and charge indeed, but gravity was not 'renormalizable'.

Anyhow, renormalization predicted new particles that were also observed in particle accelerators. These particles could be thought as composed of even smaller 'quarks', fitting in a symmetrical system (Gell-Mann 1961).

The Standard Model, summarizing all observed particles and their interactions, still misses a 'graviton' that may explain gravity. It has not yet been observed (if it is observable at all). But the gravitational *waves* predicted by Einstein in 1915 were observed and measured in 2015.

Transistors, microchips, semiconductors, superconductors, lasers, MRI scanners, PET scans, nanotechnology, atomic clocks, sensors, solar cells, nuclear fusion, numerous new catalysts and chemical reactions, would not have come about without (insight into) quantum physics. Quantum computing promises to find even more new materials and medicines.

Yet the public appreciation for physics and its technical results diminished. The nature of their progress is difficult to imagine and incomprehensible without mathematics. You have to *believe* in that progress, but an atomic bomb as an effect is terrifying. You are defenceless against a political 'elite' that haughtily appeals to science.

'Know-it-all' people blame you for climate change, depletion of raw materials and epidemics. 'They will find something on it' no longer applies. Without raw materials, any technique is idle. Your children inherit an eaten-out, overpopulated world, a struggle of all against all. If you don't accept that, then the only way out is denial and alternative truth.

What is true? 'Algebra is just an opinion.'
Appealing fake news overgrows scientific explanation.
Conspiracy theories see a secret science and technology in the hands of a rogue government ('They know more'). The democracy then is only a concealing theatre of 'the elite'.

People know enough. People *don't want* to know more. Games give more fun than science. New politics cut back on education and a science 'full of manipulative scaremongering'. No more fact checking. Denial and lying-with-the-fist is the new normal. Health care workers are being shot at, but protesters still call on their knowledge and skills when they are injured.

Indifference is lack of difference. Which difference may make anyone 'wanting to know' again? We live between birth and death. That 'inter-esse' may arouse anyone's interest. It raises central questions in any culture, particularly if it is threatened by approaching disasters and war. There are answers that promise a life after death. Erasing that difference creates indifference.

A walk through fields and forests recreates the image of life: young replaces old, fed by death. Why do we live and die? What is the *difference* between life and death? Closer observation may bring us in a perpetual state of wonder, the seed of science. The ever-new biological discoveries surpasses every human fiction.

^a Heilbron ed(2003), 'Quantum field theory'

Priestley^aLavoisier^bIngenhousz^c

Calvin

53 The inventors of $CO_2 \rightarrow C + O_2$

In an abiotic environment, biotic processes are physically improbable^d. Shielded by a cell membrane, however, physically improbable chemical pathways become possible.^e In 1950 Calvin^f reconstructed the improbable cycle by which plants use CO_2 (**Fig.261**p147). The atmosphere then gets back O_2 (Priestley, 1774, Lavoisier, 1777) and C-bonds deliver organic fuel, partly stored fossilizing. Animals reconnect C with O_2 to CO_2 (Ingenhousz, 1779).

That connection delivers energy. The energy for the *separation* is extracted from sunlight. This manufacturing process (photosynthesis) is a form of **metabolism** at the smallest scale. It takes place in cells *within* cells (chloroplasts). Each chloroplast can contain millions of photosynthetic units and a single tree leaf again can contain a million of chloroplasts.

Single-celled blue-green algae (cyanobacteria) are among the oldest organisms on earth.^g As a prototype of the chloroplast (**Fig.259**p146), they brought oxygen (O_2) into the atmosphere, allowing new life forms to emerge. Plants may have incorporated these photosynthetic bacteria into their cells, because chloroplasts have their own genetic code separate from the cell nucleus.

Cyanobacteria provided the atmosphere with enough oxygen only through massive **reproduction**. Reproduction supposes that the organism has a **specialism** for multiplication. That in turn presupposes an **organization** that regulates when and under what circumstances one or the other process becomes active. *Organization* therefore supposes **regulation**.

Regulation here is the availability of specific processes initiated by signs. The sign to unblock a process can be a changing environment or an arriving code. I conclude a strict order of conditions that any living organism must fulfil (§ 7p14). Metabolism enables (↑) regulation ↑ organization ↑ specialization ↑ reproduction.

Metabolism provides biotic material and energy. Regulation adapts different metabolisms. Organization gives them a common effect. Specialization separates functions in space or time: the caterpillar is a specialist in feeding, the resulting butterfly a specialist in *reproduction*. Differences in each biotic condition creates millions of species ('biodiversity').

^a Priestley portret by Rembrandt Peal in New-York Historical Society

^b Lavoisier portret by David in The Metropolitan Museum of Art (The Met) in New York City

^c Ingenhousz portret by Cunego in the British Museum London

^d 'Improbable' here means a 'low probability'.

^e Alberts cs(2004) is a detailed overview of the astonishing wonders of cell biology.

The numerous illustrations demonstrate that images are essential for biological understanding.

^f Calvin cs.(1950-1957)

^g <https://en.wikipedia.org/wiki/Cyanobacteria>

Within a species, the individuals differ. They grow up in different environments.^a
How do we distinguish humans from animals? For archaeology, it is the use of tools.
The often mentioned differences such as self-awareness, language, technology, free will, planning^b, morality, creativity can be summarized or derived from a difference in **imagination**.

Every individual is unique, reacts differently to the environment, other people's behaviour, food, medication, and plays different roles.^c Biodiversity is expanded with a conceptual diversity.
What then could you generalize, abstract, classify? This complicates the human sciences.

Exceptions are neglected by generalization, but just these may have a major impact.
Design can change usual suppositions. The invention of agriculture ended the culture of hunting and gathering. The invention of the steam engine brought about the industrial revolution.

Economic science begins with the study of biotic conditions: metabolism, regulation, organization, specialization and reproduction, but its predictive value is limited by changing cultures. Between micro-, meso-, or macroeconomics, you can reason up or down.

Founder Smith (1776) argued that self-interest from the bottom up gives the greatest prosperity. This results in a liberal policy of free market and little regulation. That increases the difference between the rich and the poor. So, socialist politics advocate more regulation and government. A fully government-organized economy is known as a planned economy.

Sociology is closer to the cultural conditions at different scales. According to the founders Saint-Simon (1822), Comte (1842) and Durkheim (1901), social *structure* determines the individual. They advocate a science-based structure. Weber (1909,1925) on the other hand, takes the social actions of *individuals* as a starting point. The difference is an in- or outward view (**Fig.8p9**)

Sociology has a multitude of theories and methods. They may apply to specific levels of scale in space and time. The sociology of 10 individuals is not the sociology of 100.
Moreover, in different social contexts, the same individuals play different roles in which they consider themselves bound by different rules.

History may be described with different sociological suppositions. World history is different from that of a family. The usual emphasis on leading individuals and their impact is different from an emphasis on social structures, cultures, or ecological conditions and their impact.

Measurements in the humanities may result in commercially useful averages. Exceptions cannot be summarized in scientific laws ('nomothetic'). They can be described per case ('ideographic'). They may become hypes, but which of the numerous exceptions will make the difference?

The design of human sciences must first see and make a *difference* to be able to generalize.^d
It starts with the distinction between levels of scale in space and time.
What is true at one level of scale may be false at another scale ('scale paradox' **Fig.9p9**).

^a The study of one species (humans) already requires 32 medical specialties:

[EU Member States\(2008\)b94 mb-01-31-2008--list-of-diplomas-certificates-and-other-titles-of-specialist-doctor\(EU\)14858](#)

^b **Harrison;Weiner;Tanner;Barnicot(1970)** suppose the ability to oversee a series of actions, of which only the first is immediately executable and only the last is effective.

^c **Galjaard(1994)** stresses the difference of individuals.

^d **Descartes(1684)** In English: [Rules for the direction of the mind](#) first line: 'Whenever people notice some similarity between two things, they are in the habit of ascribing to the one what they find true of the other, even when the two are not in that respect similar'

§ 14 SCIENCE SUPPOSES A VERBAL LANGUAGE

Design *constructs* models that may be realized. Science^a *re-constructs* objects^b in models. From prehistoric times, people have made models of reality in drawings, sculptures and stories. Classical Greek sculptures reached a more realistic reconstruction in detail than ever before. They show the art of precise observation. That is also the primary condition for reliable science.

Sculptures, however, do not model change. Stories do, but these suppose a design of language. A human language is linear, based on successive sounds, referring to objects and changes. Nouns refer to objects, verbs refer to change^c. A noun cannot refer to a unique object in as much detail as a sculpture. It may refer to some common characteristics in a heterogeneous set.

Counting, however, supposes a homogeneous set of *equal* elements.

The language of mathematics also has nouns (variables) and verbs (operators).

The '=' sign refers to an *equal* overall result by *different* operations (formulas)^d at both sides. The choice of variables, however, should obey a logic. They should not overlap.

The set 'people' may contain women *and* men. According to formal logic, however, the conjunction 'and' (\wedge) means the *overlap* of two sets: people being both female *and* male.

The set 'people' then contains *three* subsets: women, men, and both at the same time.

The logical conjunction of all three then is 'inclusive or' (\vee): people are women *or* men.

But that should not be understood as 'women *or* men' with an exclusive '*or*' (\oplus^e , *either...or...*).

Formal logic makes a difference between *conjunctions* such as \wedge , \vee , and \oplus .

The coherence of a *sentence* ('grammar') requires more than a logic of conjunctions.^f

The coherence of a *set* of sentences requires more than proposition logic.

Nouns and verbs in a *coherent* sentence enable to (re)construct changes. $C + O_2 + e_a \rightarrow CO_2 - e_b$ is a sentence in chemistry. The ' \rightarrow ' sign indicates the overall change of *connecting* (+) actions into a *separating* (-) result.^c The added activation energy $+e_a$ is required to start the reaction; $-e_b$ is the energy *separated* (-) by the connection, but *delivered* (+) outward^g.

Since $e_b > e_a$, the *outward* energy $e_b - e_a$ is positive, but the sentence with $-e_b$ is *inward* coherent. This sentence, however, is not the whole story. C and O are seldom available as single atoms, these have to be *separated* first from some connection. So, $e_a > 0$ also hides a separation.

A scientific model (e.g. a set of sentences) will never *cover* the observed reality completely, but it may be approached by refining additions such as adjectives and adverbs.

It may *become* a reality, by 'realizing' a spoken or written plan.

For 3D realization, the linear sentence 'table top + 4 table legs \rightarrow table' is not a full instruction. Lines in a drawing indicate the required separations or connections. Three 2D drawings may define the *position and size* of objects simpler than a lengthy text. But, the *sequence* of the required constructive *actions* still requires text (eventually referring to drawings) or a movie.

A computer program (a branched linear text), however, may instruct a robot to make a table, but that text does not describe the table (the result). It directs the movements of arms and grippers.

A genetic code does not describe a result (an organism) either. It does not even prescribe single movements. It prescribes a behaviour, dependent on the environment (e.g. unlocking messages).

^a In this paragraph 'science' includes the humanities.

^b 'Object' supposes an observation focused on what differs in all directions from the rest, but changes less. ('object constancy' § 3p8).

^c 'To be' and 'to have' refer to a change approaching zero.

^d The distinction between overall change (the equation) and changes in detail (formulas) is an example of the scale paradox (Fig. 9p9).

^e In the next chapter I will use the visually more expressive sign ' $\triangleright\triangleleft$ ' instead of \oplus for 'exclusive or'.

^f This study argues for more distinction of scale and a conditional order of nouns or verbs.

^g The counter-intuitive minus sign is an example of the inside-outside paradox (Fig 8p9).

A living *cell* has a library for actions to be applied in a given environment.

Larger *organisms* have special sensors for the environment, determining their overall action.

That requires a neural system sending messages for action to specific internal organs or cells.

The language of these messages may require only verbs (commands), not nouns or conjunctions.

These messages are not coherent sentences, but they do have a strict sequence.

They do not even *describe* an action. Their sendings (*de*)*block* a set of parallel or serial actions.

The final action is preceded by an array or a web of intermediate (interfunctional) reactions (chemical pathways). The sequence is conditional: prior x enables y.

Science supposes a language. Our common language falls short in expressing natural processes.

It is refined by numerous neologisms in many scientific specialisations. It hides, however, tacit suppositions (§ 4, particularly p10 and 11), hampering imagination in design or science.

Drawings appear to indispensable, but in scientific publications they are still subordinate to text.

The text itself, its language, deserves a critical contemplation. It stresses objects (as nouns), where the language of nature applies primarily verbs. Biotic objects may slowly change into totally different appearances (e.g. the metamorphosis of an insect from egg, larva, pupa, into imago). The question may rise if it is still the same *object* if they have so little in common.

An embryo shows *the same* individual continuously changing into a *different* object.^a

Some milestones in the development get a name, a noun, a nounified verb or both: ‘fertilised cell’, ‘dividing cells’, ‘morula’, ‘blastula’, ‘gastrula’ (*Fig.293*p159). But then, it becomes more and more difficult to choose milestones and to name the next stages without subsequent images.

Moreover, in any other species the next stages become different. An overall change contains numerous smaller partial changes, still not identified. Refining our language with ever more names cannot be a feasible way. The main problem is, that science cannot cope with diversity. This counts even more in the humanities, where biodiversity increases by a conceptual diversity.

The philosophic design of science requires extension, stressing *possibility* instead of truth or probability, *conditions* instead of the one called ‘cause’, a ‘genetic language’ emphasizing **verbs** instead of nouns. Computer languages may be on the way. There, the logical conjunction ‘if x is true, then y is true’ has become action logic: ‘if x is true, then **do** y (, else **do** z).

But ‘if true then **do**’, is not true or false (not a ‘proposition’). So it does not fit truth based logic.

However, the command **do** tacitly supposes that y and z are *possible*. It supposes ‘if x is true, then y is possible’^b, or (because truth must be possible) ‘if x is possible, then y is possible’.

Such statements are most relevant for design. So it is worth the effort to check suppositions.

Questions are not true or false either, but they are the source of any science and design.

Their start is not logical, but there may be a logic of suppositions.

Questions suppose the possibility of an answer, a model fitting an object not yet understood^c.

^a See for example **Harris(2022)**

^b Not the reverse! An animal is not a dog. A dog is an animal. Truth must be possible, but possible is not necessarily true.

^c Under-standing, sup-position, hypo-thesis have the same roots in English, Latin and classic Greek language.

§ 15 QUESTIONS ARE NOT TRUE OR FALSE, ANSWERS ARE

'Truth' supposes a model, fitting many observations. Knowledge supposes such models.

A question supposes an object (*physical or not*^a) without a fitting model.

It supposes a questioner **Q**, *aware* of an unknown object. What kind of awareness is that?

It supposes a respondent **R** 'knowing' the object, or **Q**'s own study answering the question.

In order to get the intended answer, the question requires a clear *circumscription* of the object.

Known properties of the object (exterior and context) *outline* the unknown interior of the object.

Adding your suppositions, possibly refuted by the respondent, point to a more accurate answer.

'What'~, 'How'~ and 'Why' questions ask for description, internal and external function^b.

They may refer to a truth, its possibility, its effect or desirability. Let us take an example:

(1)q What's that? r It is a thermometer.

(2)q How does it work? r It measures infrared radiation.

(3)q Why do you use it? r To compare the temperatures of my floors, walls and ceilings.

These questions **q** and their answers **r**, hide suppositions^c.

A question may arise still unspoken, but once uttered, it supposes a language or physical signs.

Its verbal formulation should circumvent paradoxes and barriers (§ 4p9, § 14p41).

R supposes the same vocabulary as **Q**, and encounters the same paradoxes and barriers.

It should be clear that I do not search for *definitions* of words or their 'meaning' (semantics).

I search for necessary underlaying (other) suppositions *enabling* to imagine their concept.

Definitions describe 'in other words' raising the same questions about *their* definition.

(1)q 'What is that?' hides suppositions.

Any question **q**, supposes a questioner **Q**, pointing or referring to an object ('that').

'Object' supposes *difference* from the rest, and stability (low *change*) in itself ('identifiable').

'Referring to' supposes a *separation* from **Q**, but a connection (little separation) with **q**.

'Pointing to' supposes a physical sign for 'referring to', culturally shared with a possible **R**.

In the question **q** these suppositions are hidden in the word 'that'.

The *difference*, *change*, *object* and *separation* successively enable a *combination*, a question.

'What?' is the core of **q**. It supposes the **possibility** of a model fitting the object.

The *combination* of the model and its object is expressed by 'is', not supposing '=', but 'fits'.

I refrain from the many other suppositions of the words used here (possibility, model, fit, etc.).

In other instances 'Which?', 'Who?', 'When?', 'Where?' have similar suppositions as 'What?'.

(1)r 'It is a thermometer' hides suppositions.

Any answer supposes a **Q** and an **R**, both referring to the same object in **q** ('that' becomes 'It').

However, 'It' supposes more than 'that'. It supposes knowledge **K** about 'that': 'It' \Downarrow **K**('that').

It supposes a *difference*: 'that' *without* (/) and 'It' *with* knowledge: ('that'/**K**) \wedge **K**('that').^d

It supposes a *change* ('that'/**K**) \rightarrow **K**('that') \rightarrow 'It', the known *object*.

It supposes a shared vocabulary including the object 'thermometer' and its suppositions.

It supposes that **Q** knows these suppositions **K**(temperature, quantifying, measuring, etc.).

It supposes that **Q** knows their *combination* in a thermometer.

The noun 'thermometer' with its suppositions then is the model delivered in **R**'s answer **r**.

^a So, models, images and imaginations may be also 'objects' of focus, accessible to questions. You may ask for a model of models.

^b Description concerns content or form (*Fig. 11p13*). Internal functioning supposes an internal *structure* enabling that function.

^c Brought up for discussion by [Collingwood\(1940\)](#), and elaborated by [Hintikka\(2007\)](#) as a part of a science concerning questions called 'erotetics'. They speak about 'presuppositions' as *sentences* with logical operators, presupposing each other.

What I call 'suppositions' here, concern single words, not being true or false, but enabled by a staircase of successive suppositions.

^d A teacher cannot always empathize with the student's ignorance, its possibly useful, lacking, irrelevant, or even blocking suppositions.

The verb 'is' in the sense of 'fits' is followed by 'a', supposing 'one of the many ever observed'. It supposes that the model does not fit with other objects (e.g. a laser weapon or water pistol). I refrain again from the many other suppositions of the words used here and in the following.

(2)q 'How does it work?' hides suppositions.

'Work' is a verb, supposing an input and a *different* output at the boundary of an object.

It supposes *change* within a less changing structure: a set of stable connectors and separators.^a

'It' supposes the identification of an *object* 'that' as 'it' in (1)r adding **K**.

'How?' supposes that the *object* can be *separated* in components and *recombined* in a model.

In other instances 'How' may be followed by other verbs (e.g. 'do you do', 'to construct' etc.).

(2)r 'It measures infrared radiation' hides suppositions.

R supposes that **Q** now shares the answer (1)r.

'Infrared radiation' supposes a shared vocabulary similar to that of (1)r about a thermometer.

'Measures' supposes *different* magnitudes (#): #infrared radiation (in) and #temperature (out).

It supposes a *change* (a conversion) from #radiation into #temperature in the *object* 'It'.

As **Q** already did in its question (2)q **R** supposes also that the object can be *separated* in components and *recombined* in a model. **R** may show **Q** an electric circuit as an answer.

(3)q 'Why do you use it?' hides suppositions

'Why?' and 'use' suppose an external function of the object, *different* from internal functioning.

A function supposes *change*. It supposes action with the object as an interfunctional tool.

'You' supposes the use of **R** only, otherwise the question should be 'What is it used for?'.

Could (3)q be replaced by 'What do you use it for?' (not a 'What?', but a 'What for?' question)?

No, 'Why?' is wider and consequently ambiguous. **R** may interpret it in different ways.

(3)r 'To compare the temperatures of floors, walls and ceilings' hides suppositions

'Floors, walls and ceilings' suppose environments of the object *different* from the context of questioning and answering. 'Compare' supposes possible *differences* (of temperatures).

'To' supposes an aim or a cause. It could suppose 'I want to', 'I had to', 'They asked me to' etc..

It could be followed by further 'Why?' questions 'Why did you want to|had to|were asked to?'.

QUESTIONS RAISE QUESTIONS ABOUT QUESTIONS

This list of suppositions in three types of questions and their answers, is far from complete.

It is, however, sufficient for preliminary conclusions and questions *about* questions.

Firstly, an answer supposes a question: $r \Downarrow q$; **r** is true or false ('a proposition'), but **q** is not.

Secondly, 'how?' and 'why?' suppose 'what?'. Answering 'what is it?' enables next questions.

Q's knowledge **K** may increase by (1) < (2) < (3), if the answers are true. So, **K** is variable.

If $r \Downarrow q$, then $q \Uparrow r$: a question enables an answer and **q** directs **r**. What is a good question?

A good question is accompanied by explicit suppositions of **Q** prior to the answering.

Q Assuming **r**'s may reveal hidden suppositions of **Q**'s vocabulary. That directs **r**.

If **Q** says 'What is that?', then (observing the object), s(he) could suppose a laser weapon.

If **Q** adds that supposition to **q**, possibly refuted by **R**, then that directs to a more accurate **r**.

If **R** accepts them with 'yes', then **Q** does not learn anything. Only 'no' changes suppositions.

If **R** says 'It's a thermometer', then **Q** could still suppose a well-known mercury thermometer.

The deviating observation then may motivate **Q** to ask a further question: 'How does it work?'.

If **R** answers by showing its electric circuit, pointing the components and their (inner) functions, then that is literally an ex-planation, laying out separate components in a plane (ana-lysis).

Now, **Q**'s suppositions change again. S(he) learns much, but that may not motivate a 'Why?'.

^a However, the structure of Biotic objects may change substantially (metamorphosis p.40). That complicates subsequent identification.

Does any 'How?' ask for an explanation? (e.g. 'How do you do?', 'How is it constructed?')

I assume yes. I did not yet encounter a counterexample.

'What?' asks for identification. 'How?' asks for explanation. What does 'Why?' ?

It asks for an *external* function, be it a cause in the past or an aim pointing to the future.

Q asked 'Why do you use it?'. **R**'s 'I want to compare ...' is an aim.

If **R** answered 'They asked me to compare ...'. Then that is a cause. The cause is a request.

Is any question a request for answer? Is a request always a question?

Is 'Help!' a question? Is rescuing an answer?

Questions *about* questions are a crucial part of any philosophy of science ('Erotetics'). Current erotetics searches the *logic* of questions and answers and their 'presuppositions' as *sentences*.^a

Questions cannot be true or false. So, how could common logic then be applied on questions?

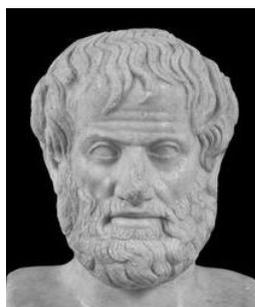
Words on their own cannot be true or false either, but suppositions *enable* them in a strict order.

Separate *words* already have their own 'suppositions' (as I called and studied them here).

That requires more than the current logic of conjunctions *between* words in a sentence.

^a [Bentham cs\(1994\)](#)

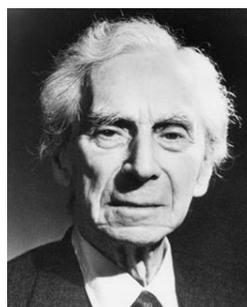
3. LOGIC SUPPOSES A LINEAR LANGUAGE



54 Aristoteles^a



55 Frege^b



56 Russel^c



57 Gödel^d

Leading designers of the contents of this chapter

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^a Akropolis Museum. Aristoteles(-330) 6 titles Together called 'Organon' introduced logic as a science.

^b [Frege\(1879\)](#) formalised logic.

^c [Russell\(1903\)](#) supposed logic to be the final basis of mathematics.

^d [Gödel\(1931\)](#) proved a fundamental incompleteness of logic in mathematical proofs.

What is the designerly content of logic? Which discoveries are actually inventions, designs of a model? Does logic cover a broader field of possibility beyond probability or truth?

This chapter takes some distance from common logic, considered as *the* a priori basis of our rational thinking. I conclude:

Logic supposes a human language, and that is a human creation.

Logic then may also be understood as a design, based on experience with sets.

After millions of years of hunting and gathering we have got some experience with sets.

Words name sets, specified by predicates in propositions. Logic detaches their overlaps.

Logic formalises the art of combining sets (words) with conjunctions, but our capacity of thinking (co-action, co(a)gitare) includes more. The limited fixation on truth values loses sight of *questions* (p44) and, within a linear language, of *possibilities* that are not (yet) true or false. The ability to design, requires more space than the common logical space.

‘If x is true then y is *true*’ is something else than ‘If x is true then y is *possible*’ or ‘If x is *possible* then y is *possible*’. What is true must be possible, not the reverse (**Fig. 2p6**). Current modal logic accepts ‘It is true to be possible’ instead of ‘It is possible to be true’, but possibility has no truth-value before the possibility is realised. Truth has a possibility-value.

What then is a possibility-value? Possibility is most relevant for design.

Possibility has many more values than true or false, depending on suppositions about physical, ecological, technical, economic, cultural or governmental conditions at different levels of scale.

Biotics is not a *part* of Abiotics, Biotics are *possible* by Abiotics.

‘If Biotics then Abiotics’ ($B \Rightarrow A$) would mean ‘If alive, then not alive’, a contradiction.

Fig.12 p12 intends to say something else: $B \Downarrow A$ (‘B *supposes* A’) or $A \Updownarrow B$ (‘A *enables* B’).

The exercises 1-4 p55-57 may clarify the difference between \Rightarrow and \Downarrow in other instances.

Since Aristoteles, a proposition is divided in a Subject and a Predicate (a property).

The predicate, however, hides a verb, ‘is’, or it may be simply a verb (e.g. ‘The cat sleeps’).

Verbs disturb formal logic.

The problem is signalled by Russell(1903) and studied by Langer(1927)^a, but not solved.

After Langer, the verb is simply neglected in, and banished from, logic as ‘a problem of syntax, semantics or of pragmatic speech-act’.

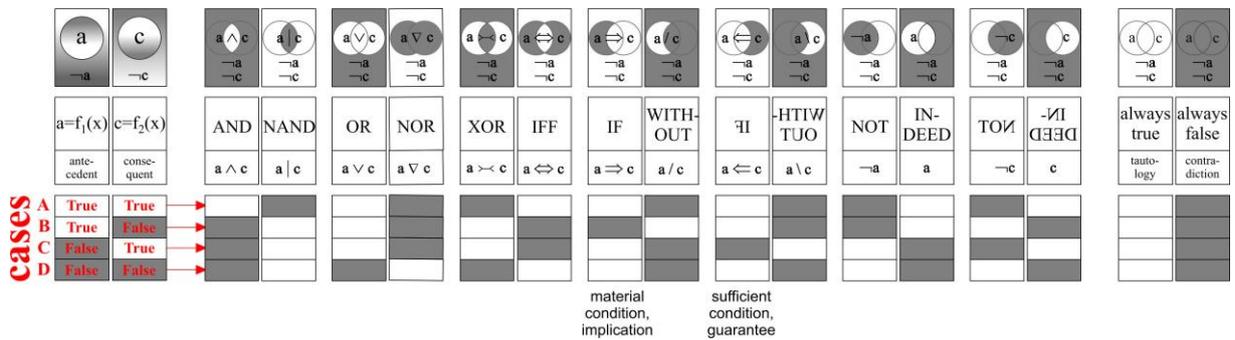
But verbs, not conjunctions, are the core of verbal language (§ 14p41).

This could be a flaw in the design of logic as *the* very basis of rationality.

^a [Russell\(1903\)](#),p47-52, [Langer\(1927\)](#).

§ 16 FORMAL LOGIC IS LINEAR, LANGUAGE~ AND TRUTH BOUND

THE LOGICAL SPACE IS LIMITED TO VERBAL LANGUAGE



58 Truth table of 16 conjunctions^a

If you point to a cylinder, and say 'it is circular' then bystanders may either say 'yes' or 'no'. The first is a judgement 'true', the other 'not true' ('false'). Each adjective, referring to an object, has a positive or negative 'truth value' (true or false). That value only exists in verbal language.

The usual logic excludes a third possibility (true *and* false) as a 'contradiction'.

So, in a common logical sense, a cylinder is circular or it is not circular, not both.

Symbolic logic uses the symbol '¬' for 'not' and '∧' for 'and'. If you abbreviate the judgement 'it is circular' as 'c', then $c \wedge \neg c$ ('circular and not circular') is an inadmissible contradiction.

This logical prohibition, however, shows the *linear* limitation of a verbal language such as logic.

A 'perpendicular' symbol ('⊥') could make that contradiction allowable: $c \wedge \perp \neg c$.

If you add a second judgement 'it is angular' ('a'), then $c \wedge a$ avoids the contradiction.

That, however, is not valid if c is ¬a. So, linear logic depends on suppositions about a and c.

The 'logical space' consists of four 'cases': for example **A** angular *and* circular, **B** angular *and* not circular, **C** not angular *and* circular, **D** not angular *and* not circular.^b

In the upper left corner of **Fig.58**, the logical space of 'a' (for example 'angular') and 'c' (for example 'circular') is displayed and subdivided below to **4 combinations** of 'a', '¬a', and 'c', '¬c'. These can be true (white) or not true, false (gray). The functions $a=f_1(x)$ and $c=f_2(x)$ express that a and c should participate in the *same* set x (e.g. a cylinder). This is known as 'relevant logic'.

As soon as a and c are linked with conjunctions, their *sequence* as antecedent (a) and consequent (c) is decisive. One of the **cases A, B, C and D** may be 'the case'.

Wittgenstein(1918) began with the famous phrase: "The world is all that is the case."

The *logical space*, however, contains *all cases*, even if they are not 'the case'.

If you now put a conjunction between a and c, then that combination will have its own truth value, represented in the top row of **Fig.58** as white (true) or gray (not true, false). You may draw them as subsets with every combination in their logical space. In the bottom rows they are specified for each **case A-D** from both a and c true until both false. That may surprise.

If a and c are both *false* (**case D**), a combination 'a∇c' ('a nor c') is still *true*.

This applies to more conjunctions (the white cells in the bottom row). 'If a then c' (' $a \Rightarrow c$ ') is true even if both a and c are false. This allows to say 'if blood is blue, then the earth is square'.

^a Peirce ed.(1883) was the first to design such a truth table, but Wittgenstein(1921) made it popular. Except Peirce and Wittgenstein, Russell(1912) is also called as an inventor.

^b With every new qualification ('predicate') that number of cases doubles.

PREDICATE LOGIC CORRECTS THE FALSE USE OF CONJUNCTIONS AND JUDGEMENTS

In common language the word 'and' is used for both predicates together (angular *and* circular). A better conjunction then is 'or' (\vee), if that at least does not have the meaning of *exclusive or* (\vee 'either ... or' $\succ-\prec$): 'Do you want jam *or* cheese on your bread?' (not both). The symbols distinguish them better than words.

So, conjunctions are not always used unequivocally, especially when a sentence has more conjunctions. For example: 'Do you want cheese and jam on your bread or cheese and hail and water or milk and if milk then cold or warm?'

With symbols, phrases with a large number of conjunctions can be handled correctly ('valid').

If you assign properties ('predicates') of an object with a conjunction (a 'judgment'), then a contradiction can occur with an imprudent use of conjunctions.

Sentence 1: "Shapes are circular and not circular" is such a contradiction, but it may be intended as sentence 2: "There are circular and there are not circular shapes".

In order to avoid the contradiction of sentence 1, the word 'and' could be replaced by an exclusive '*or*' ($\succ-\prec$).

That, however, changes the meaning of sentence 1, not precisely meant in sentence 2.

Sentence 1 contains a hidden generalizing supposition: 'For all shapes applies: ...'.

Sentence 2 does explicitly *not* generalize by the phrase 'There are...!'

That makes it a safe statement. In logic, this distinction is provided by 'quantifier symbols' $\forall x$ ('For all x') and $\exists x$ ('There are x's' or 'There is an x'), followed by ':' ('for which applies').

Sentence 1 in symbols now reads: $\forall a: c \wedge \neg c$ (contradiction) and sentence 2: $(\exists a: c) \wedge (\exists a: \neg c)$.^a

PROPOSITION LOGIC COMBINES JUDGEMENTS INTO CONCLUSIVE PROPOSITIONS

From separate judgements you may deduce another statement as a conclusion.

'Proposition logic' distinguishes different distractions, such as induction, deduction and abduction (**Fig.59**). A general 'major' and a more specific 'minor' is followed by a conclusion.

Induction	Deduction modus ponens	Deduction modus tollens	Abduction
Aadorp, Aagtdorp, ... and Zwolle are places in the Netherlands.	If I am in Delft, then I am in the Netherlands. ($D \Rightarrow N$), well, I am in Delft. (D)	If I am in Delft, then I am in the Netherlands. ($D \Rightarrow N$), well, I am <i>not</i> in the Netherlands. ($\neg N$)	If I am in Delft, then I am in the Netherlands. ($D \Rightarrow N$), well, I am in the Netherlands. (N)
So: All places are in the Netherlands. (\forall)	So: I am in the Netherlands. (N)	So: I am not in Delft. ($\neg D$)	So: I am in Delft. (D)

59 Some kinds of logic reasoning

Induction cannot yield a definitive *truth*, but at most a *probability*, how ever many observations you may do. The inductive conclusion of **Fig.59** counts about 4000 examples from Aadorp until Zwolle proven to be true ('verifications'). It shows, however, how generalising with a short-sighted supposition ('in the Netherlands') can lead to a wrong conclusion.

^a Quantifiers were introduced by [Frege\(1879\)](#)

One observation, such as 'London is a place in England', may prove the conclusion to be false. According to Popper^a, you must always formulate a scientific conclusion in such a way that everyone can refute it with a counterexample ('falsification'). Any inductive conclusion then is basically provisional (a 'guess').

Induction is generally accepted as a scientific method if there are sufficient falsifiable examples for a statistically acceptable conclusion ('reliability') and logically sound reasoning ('validity'). If in a mathematically defined sequence of numbers *any next case* has the same effect, then it is accepted as valid 'complete induction'. Infinitely halving the previous number ends up in zero.

Deduction leads to a true conclusion if both first statements (the 'major' and 'minor') are true. Mathematics, starting with its axioms and definitions as suppositions declared to be true ('premises') and leading to successive conclusions, is a clear example of repeated deduction.

In **Fig.49** only two examples of *deduction* are given: 'modus ponens' and 'modus tollens', but there are more logically valid modes. In this examples, the 'major' takes the form of 'In all cases ... (\forall)', the 'minor': 'There is a case for which ... (\exists) applies'.

Induction has only observations 'There are cases for which applies ...' (\exists).

Abduction is logically not valid, but is applied in practice, for example in case of justice:

Major: "If you have raped her, then I can find your DNA on the spot." (raped \Rightarrow DNA),
Minor: "Well, I found your DNA on the spot." (DNA)
Conclusion: 'So you raped her.'

60 An example of abduction

Abduction logically produces no truth, but it does offer a possibility (compare **Fig.59** p49: 'so I am in Delft'). This kind of reasoning may help designers in their search for possibilities ('heuristic value').^b These possibilities, however, are limited only to the cases that are included in the major-premise. That is not an acceptable limitation of possibilities for designers.

AN IMAGE MAY CONTAIN CONTRADICTIONS

Now back to the predicates. 'True' in one direction can be 'false' in another direction. If you judge 'c' ('circular') while looking at a cylinder from one side, then looking from another direction I may judge ' $\neg c$ ' ('not circular'). In many judgements the direction tacitly plays a role.

The verbal language supposes one direction by itself, one route in an image where many routes are possible. With verbal language alone you cannot distinguish directions. You may introduce a change of direction saying "Another approach is ...", but that does not determine the direction. It requires an image to distinguish directions.

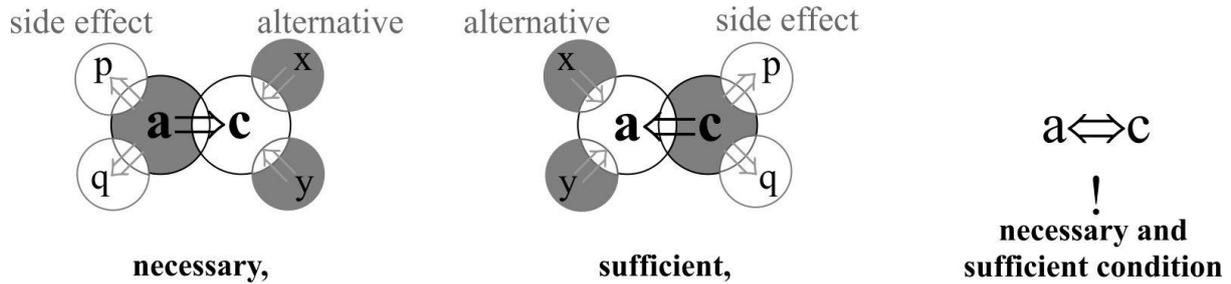
You can of course make a sentence such as 'The bridge is open, but closed perpendicular to the connection'. With 'perpendicular' (\perp), however, you then forcefully refer to a spatial representation in which directions can be distinguished.

I even suspect that 'direction' is supposed in every word, and therefore *must* refer to an image. A verbal language refers; images show. That does not exclude that both may be misleading.

^a [Popper\(1934\)](#)

^b [Dorst \(2013\)](#) p5, for example, interprets induction, deduction and abduction as forms of: what!+how?=Solution, what!+how!=Solution, and what?+how!=Solution. The exclamation marks and question marks here have the meaning !=Determined' or '?=Undetermined'. According to Dorst, in the last form (abduction) the designers also lack the exclamation point for 'how' (what?+how?=Solution). Designing is then the art of questioning both 'what?' and 'how?' to be answered.
The question is, whether a reference to logical reasoning forms helps or restricts design.
In § 18 p48 onwards I will summarize the restrictions.

§ 17 'IF' DIFFERS



61 Different logical conditions



A 'NECESSARY CONDITION' ('IMPLICATION' \Rightarrow) IS NOT NECESSARY

A 'necessary condition' has alternatives

If you take the car (a), then (c) you definitely will ride. if a then c, $a \Rightarrow c$
 If you take the train (x) or (y) the cycle, then you also will ride. $x \Rightarrow c$ or $y \Rightarrow c$
 'If' (the condition a) is not necessary, the consequence (c) is.
 So taking the car (a) is not necessary to ride (c). There are alternatives x,y,...for a.

A 'necessary condition' has side effects

If you take the car (a), then (c) you need a drivers licence. if a then c, $a \Rightarrow c$
 You should also not have drunk too much alcohol (p) and (q) you also need a warning triangle in your car. $a \Rightarrow p$ or $a \Rightarrow q$.
 So, taking the car has not the one consequence of needing a drivers licence (c).
 There are side effects p,q,... than the strictly linear c.



A 'SUFFICIENT CONDITION' (\Leftarrow) IS NOT SUFFICIENT

The logical arrow turns around, but the logical sequence of antecedent 'a' first, from which follows a consequence 'c' remains the same.
 The 'sufficient' condition is therefore not a completely reversed 'necessary' condition.

A sufficient condition has alternatives or additional requirements

You only then can ride (a) if you take the car (c). only then a if c, $a \Leftarrow c$
 You can, however, also take the train (x) or the cycle (y). $a \Leftarrow x$ or $a \Leftarrow y$
 So, the ability to ride is not a sufficient condition ('guarantee') to take the car (c).
 There are alternatives x,y,... for c, or additional requirements (e.g. licence, %alcohol, triangle).

A sufficient condition has side effects or additional requirements

You only then can take the car (a), if you have a driver's license (c). only then a if c, $a \Leftarrow c$.
 Instead of the ability to take the car (a), you can also identify yourself (p) or get a job (q) if you have a drivers licence. $p \Leftarrow c$ or $q \Leftarrow c$.
 So, to be able to take the car (a) is not the only thing guaranteed by a drivers licence.
 There are side effects p,q,...for a, or even additional requirements.



A 'NECESSARY AND SUFFICIENT CONDITION' (\Leftrightarrow) EXPRESSES EQUIVALENCE

The equivalence ' $a \Leftrightarrow c$ ' (' $a \equiv c$ ', 'a iff c', 'a if and only if c') does not mean 'a is c' (identity) or $a = c$ (numerical value). In logic $a \Leftrightarrow c$ concerns the same *truth value* (Fig.58p48). So, if a and c are both true or even both false, then ' $a \Leftrightarrow c$ ' is true. For example 'if and only if blood is red, then the earth is round', just as 'if and only if blood is blue, then the earth is square', are 'true'.

A CAUSE IS A CONDITION, BUT A CONDITION IS NOT ALWAYS A CAUSE

'If a house, then a roof', or its double negative equivalent: 'No house without roof' concerns a timeless result, there is no *action* in time *causing* that result. It may be a simple fact.

The action is eventually *motivated* by such a result: 'If you build a house, then you have to make a roof, *because* no house without roof'.

Compare this with what I earlier called 'action logic' in computer software.

A roof is not the *cause* of a house. It is a *possibility condition* for a house.

'If you let it go, then it falls', however, suggests a causal sequence, where the previous example was purely conditional.

Common logic, however, tacitly refers to time. In $a \Rightarrow c$ is 'a' *antecedent* and 'c' *consequence*. 'Then' in 'if...then', has a connotation of temporal sequence.

'Not without', however, sounds purely spatial, and the truth table of 58p48 shows *spatial* equivalents in order to *explain* logical operators by overlapping sets.

I suppose 'No change without difference' or 'No time without space'.

After all, a process must *take place*'. I would like to change 'everything changes' (attributed to Herakleitos by Plato as 'everything disappears', or 'everything flows') into 'everything differs'.

That allows me to represent 'cause' as a special case of 'condition'.

Every 'cause' is a condition that something can happen, but not every condition is also a 'cause'.

Assume we read in the newspaper: 'The collision was *caused* by the driver losing control.'

That sounds plausible, until an extraterrestrial descends next to us and says: 'Nonsense! A collision is caused by two objects moving towards each other on the same line! '.

If he is right, the newspaper is wrong, because if two objects did not move towards each other, there would have been no collision, even when one of the drivers had lost control.

But there are still more circumstances to think of, where one of the drivers loses control over the steering wheel without causing a collision. If the cars had stopped, if the petrol had run out just before the collision, a breakdown in the engine occurred, a gust of wind had blown one of the cars off the course, an earthquake had opened a deep ravine between them, and so on.

If all other conditions preventing a collision are met, then the missing condition (a driver has control over the wheel) is called the 'cause' of the collision.

It is, however, a 'cause of failure' in a process you expected to function normally.

Design supposes more conditions than one cause

Every cause is surrounded by many other conditions that must be fulfilled in order to make something *possible*. The last added condition is often called 'cause' ('the roof made the house').

One 'if ... then' strain is not sufficient for use in the multidimensional space.

There are all kinds of preceding roots (conditions) and subsequent branches (consequences): a 'tree of causality', or even a forest full of such trees together.

That enables to imagine rare possibilities.

There are always many conditions (side-by-side, 'horizontally') at the same time, each with their own 'vertical' context of trunk and tree structure, in order to make something happen (or make it at least possible). That's what designers, managers and ecologists know about.

A linear language often ignores the other 'side-values' ('c' if 'a' or 'p' or 'q' or ...) as if they remain the same in all cases ('ceteris paribus'). These are all side streets disrupting the line of argument in verbal language. You may add 'p ... z' as 'sufficient conditions' at 'a' in the logical formula, but how do you know whether this is actually 'sufficient'? Their number is basically infinite.

If you have enough seed, sun, water and minerals, you can grow a tree ... if it is not eaten by animals or fungi, cut down, catches fire, and so on.

These are all positive (if ... then) and negative (if not...then) conditions that do not yet result in a tree, but make it *possible*. What else is possible under these conditions? Which unnamed, but easy to realize conditions I can add? What is then more possible? Typical designer's language.

LOGIC OVERLOOKS MULTIDIMENSIONAL CONDITIONS OF POSSIBILITY

'If a then c' ($a \Rightarrow c$), and 'only then a if c' ($a \Leftarrow c$) are assertions that can be only true or false. What is true must be possible, but what is possible still does not have to be true (**Fig.2p6**).

It can be *made* true (realized). Truth claims concern a small subset of a much larger set of possibilities. These possibilities are largely untrue or very improbable, but just that is the field of designers. Designers are looking for possibilities that are not (yet) true or probable, otherwise they make only copies, reports or prognoses.

Before a possibility is realized, you cannot say: 'It is true that it is possible', because truth is a subset of possibility just as dogs are a subset of animals, and you cannot say 'An animal is a dog' either. You can say, 'It is possible that it is (or becomes) true', just as you can say 'A dog is an animal'. This applies in general ($\forall \text{ dogs: dogs} \Rightarrow \text{animals}$).

Not for all animals applies 'if animal then dog' ($\neg \forall \text{ animals: animals} \Rightarrow \text{dogs}$).

In a special case you may still say: 'There is an animal for which applies: 'if this is an animal, then it is a dog' ($\exists \text{ animal: animal} \Rightarrow \text{dog}$). The reverse ' $\exists \text{ dog: dog} \Rightarrow \text{animal}$ ' is trivial.

In the meaning ('semantics') of 'dog', ' $\forall \text{ dogs: dog} \Rightarrow \text{animal}$ ' is already decided.

FUZZY LOGIC ALLOWS DEGREES OF TRUTH

Values between true (1) and false (0), are allowed in common language ('half truth') and applied in AI. It is not considered further here.

MODAL LOGIC MAKES POSSIBILITY SUBORDINATE TO TRUTH

If you are looking for conditions to make something possible, 'modal logic' offers two new operators (necessarily \square and possibly \diamond). If a statement 'c' (for example, 'nothing goes faster than light') must be true in all circumstances ('in all possible worlds^a') then 'c' is necessarily true (' $\square c$ ').

An assertion 'c' (for example 'it is freezing') being not true now and here ($\neg c$), *can* be true in other seasons, in other parts of the world, in any future~ or even possible world.

Possibly 'c' ($\diamond c$) is defined as 'not necessarily untrue' ($\neg \square \neg c$).^b So, possibility is defined by truth based operators and variables (\neg, \square, \neg, c), and consequently *part* of truth based reasoning.

If you accept that anything true must be possible, not the reverse (**Fig.2p6**), then this definition is not acceptable. 'Must' *supposes* 'can', not the reverse.

Moreover, the modal verb 'must' (the operator \square) is subject to a wide range of suppositions^c. If possible worlds necessarily 'must' be logical (relatable), credible (doxastical), existable (metaphysical), nameable (analytical), knowable (epistematic) or tolerable (deontical), then 'must' requires accepting less or more of these suppositions in the modal logic.

^a Introduced by [Leibniz\(1710\)](#).

In order to answer the always pressing question why an infinitely good and almighty Creator has allowed evil into the world (theodicy), Leibniz argues that He has chosen the 'best of all possible worlds'. Leibniz also invented the infinitesimal calculus (integrating and differentiating), in other words, the useful handling of infinities in mathematics gave him a reassuring analogy in religion.

^b [Hughes\(2005\)](#) p17.

^c [Divers\(2002\)](#) p4.

A common view is the 'alethic' vision: there are no worlds that do not meet logic, our idea of 'being' ('metaphysical') and the generally applicable laws of nature. These conditions are only 'descriptive' in our linear verbal language. In images there is perhaps more possible.

The modal logic includes different systems such as 'K', 'T' and 'D'.

System 'K' includes all propositions of propositional logic plus \square and \diamond .

System 'T' adds that if p is necessary, then p is always true ($\square p \Rightarrow p$). From this it can be proven that what is true is at least possible ($p \Rightarrow \diamond p$). That is not yet fixed in 'K'.

System 'D' adds to 'K' that what is necessary is also possible ($\square p \Rightarrow \diamond p$).

A logical claim, however, can only be true or false. The statement $a \Rightarrow \diamond c$ ('If a is true, then c is possible') then contradicts the view that truth is a subset of practical possibilities.

If 'possibility' is a modality, then a part, and therefore 'truth', is also a modality.

A modal logic that understands 'truth' itself as a modality, cannot take formal logic as a starting point and must look very different. This is certainly not to say that formal logic is useless, but it has its limitations and it is not 'a priori' innate.

§ 18 DESIGN REQUIRES MORE DIMENSIONS THAN THE LOGIC SPACE

IF TRUE, THEN POSSIBLE

Current logic is limited to 'truth values'. It does not include \perp paradoxes (**Fig. 7p9**).

The apparent contradiction then is considered to be inadmissible.

Necessarily 'if a then b' also suggests that there is no alternative to b.

The common logic focuses on conjunctions and adjectives, predicates instead of the central *verb* (or it had to concern the actionless 'is' that assumes a metaphysical 'being' in assertions, propositions). The 'being true' comes first, the 'making true' or 'realise' is left out.

Such reductions block design thinking. How to construct an action-oriented modal logic, in which 'truth' itself is a modality, I will leave to others, but I can define 'practically possible' for the time being as 'what can be realized through action'. That requires a new operator.

A non-language-bound, and therefore not assertion-bound, but action-related 'possibility condition', is definitely something else than a truth condition. I write that possibility condition as $c \Downarrow a$ ('c supposes, is possible, by a'). For example: Culture \Downarrow Biotics \Downarrow Abiotics, where ' \Downarrow ' means 'is supposed in' or 'is made possible by'. 'Makes possible', or 'enables' then gets the symbol \Uparrow : Abiotics \Uparrow Biotics \Uparrow Culture (**Fig. 13p12**).

The 'supposes' operators *include* the truth-valued implications: Culture \Rightarrow Biotics \Rightarrow Abiotics, in case there are no alternatives (necessity).

According to **Fig. 61p51**, however, there are explicitly other alternatives x, y ... instead of 'a' making 'c' *possible*. Four exercises in the next section study when \Downarrow and \Uparrow are required.

That ' $c \Rightarrow a$ ' is the only (or strictly necessary) possibility for c or a is not acceptable for designers in their search for nonlinear sideward^a possibilities. Unfortunately, this 'necessity' is often assumed as self-evident by 'scientifically trained' truth-bound advisors and experts.

If a designer wants to present a possibility as feasible, then ' \exists possibility: possible \Rightarrow true' is not the right statement. 'If animal then dog' is not valid either. ' \exists possibility: possible \Leftarrow true' ('then possible if true') is also not acceptable for searching possibilities that are not yet true (realised).

'If ... then ...' is assumed in every design, but in common logic the meaning is different and inadequate for designers. The modality of common logic is not desirability or possibility, but

^a Compare de Bono(1967)

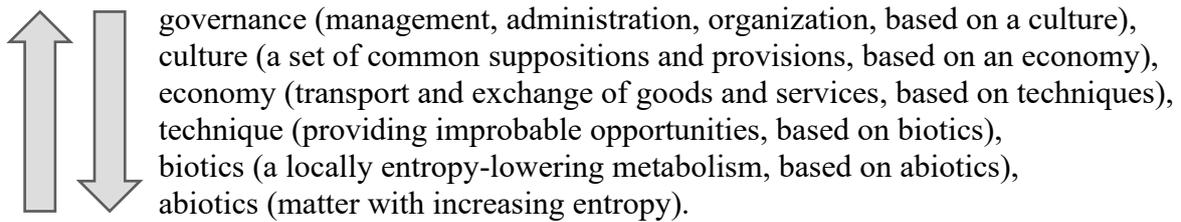
'truth'. What is 'true' is certainly possible, but not everything that is possible is also true. Truth (or more general probability) is a *part* of possibility (**Fig.2p6**).

EXERCISE 1. MODALITIES ARE LOGICAL IMPLICATIONS.

Implying true \Rightarrow probable \Rightarrow possible \Rightarrow imaginable allows stating 'desirable' \Rightarrow imaginable, problems as probable \wedge \neg desirable and aims as desirable \wedge possible \wedge \neg probable (**Fig.10p10**). So, the usual logical operators are sufficient for modalities.

EXERCISE 2. LAYERS OF CONTEXT DO NOT IMPLY (\Rightarrow), BUT SUPPOSE (\Downarrow) EACH OTHER

Before there is a design, before there is an *object* to analyze afterwards, there is a *context* making a design realisable, possible. Is there a conditional sequence as supposed in (**Fig11p12**)? I distinguish the following layers of context with primitive definitions in brackets:



These may have an \uparrow or \downarrow conditional stacking. Which is right?

The necessary condition cuts off possibilities

Suppose first: 'governance \Rightarrow culture \Rightarrow economy \Rightarrow technology \Rightarrow biotics \Rightarrow abiotics'.

This means: 'if governance then culture, if culture then economy' and so on.

In the first glance I indeed can hardly imagine governance without a shared culture ('not without' is the same as ' \Rightarrow ', see **Fig.58p48**). Governance implies a collection of shared self-evident suppositions: a language, agreements, a division of tasks, availability of facilities and their rules.

However, a dictatorial management or governance with coercion or death threat does not presume all that. A governance that withholds information does not share its concealed suppositions in a common culture either. And what about steering robots? So, I still can imagine a governance without culture.

After that, I can hardly imagine a culture without economy: 'livelihood through transport and exchange of goods and services'. Without that, every culture will go under. Culture is then necessarily a subset of each economy (culture \Rightarrow economy).

However, a culture whose livelihood falls away, may fall back in hunting and collecting (perhaps even robbery) with direct individual consumption and thus without economy, but still with a (slightly changed) culture (keeping language, religion, etc).

Children also do not have to be part of the exchange of goods and services (labor) by transport for many years. The elderly do so on the scale of the family. This also applies to sick people and families who cannot provide for their livelihood. It may be provided outside of them by an economy and a care system *on a larger scale* keeping a family culture intact.

The scale on which you give 'economy' and 'culture' a meaning therefore plays a role. Respecting the scale paradox (**Fig.9p9**) you cannot always change the level of scale in an argument. So I keep reasoning at one level of scale.

This way I can imagine a culture without economy on a family scale.

The implication 'governance \Rightarrow culture \Rightarrow economics' does not apply completely if you keep the same level of scale in the argument.

For the following layers of context I may also come up with such falsifying examples.

The sufficient condition is not sufficient

Then take: 'governance \Leftarrow culture \Leftarrow economy \Leftarrow technology \Leftarrow biotics \Leftarrow physics'.
 This means: 'then governance if culture', 'then culture if economy', and so on.
 That is possible, but not necessarily true.

The inverted implication \Leftarrow therefore is not useful if you want to leave unrealized (still untrue) possibilities open to designers. Culture may make governance *possible*, but not necessarily *true*.

If you take 'bringing cups to the kitchen and do the dishes' as a part of 'living by transport and exchange of goods and services', then a family also has a family economy, but that does not necessarily enable a family culture. This applies entirely to hermits, but there are also examples from cultural anthropology. And, could you speak of 'culture' in an ant colony?

An ant colony in any case clearly has a form of 'livelihood through transport and exchange of goods and services'.^a So I can imagine an economy without culture. This way I can also come up with 'However ...' falsifications where the 'sufficient condition' \Leftarrow does not suffice.

Design requires a possibility condition

I prefer 'Governance \Downarrow culture \Downarrow economy \Downarrow technology \Downarrow biotics \Downarrow physics': 'governance is possible by culture', 'culture is possible by economy', and so on.
 You may read 'is possible by' as 'supposes' if it concerns imagination.

In the opposite direction you can use \Uparrow ('culture makes governance possible' or 'enables governance').

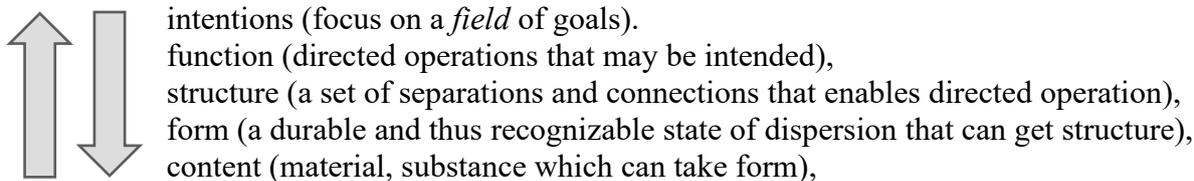
In a special case (\exists) you can still hold 'this governance necessarily implies a culture' (\Rightarrow).
 The possibility conditionals \Downarrow or \Uparrow include \Rightarrow or \Leftarrow , without becoming \Leftrightarrow .

Releasing the *necessity* from 'if ... then', is a liberation for a designer who seeks possibilities instead of truths or necessities. The tacit, but common, supposition of truth and necessity, plays the leading role in every communication. A good designer questions current suppositions and only comes up with something new if some suppositions are omitted or replaced ('reframing').

The question 'can I imagine x without y, but instead with z?' increases imagination.

EXERCISE 3. LAYERS OF OBJECT DO NOT IMPLY (\Rightarrow), BUT SUPPOSE (\Downarrow) EACH OTHER

The previous exercise concerned layered characteristics of the design *context* (Fig.12p12).
 This exercise studies the conditional sequence of 'layers' of the design-*object* (Fig.11p12):



A *design process* does not have to follow any conditional sequence itself. There are as many design methods as designers. One starts with the material or the form ('means-oriented design'), the other with the function or intention ('goal-directed design') and each method then jumps back and forth between all these layers in order to constantly change them into a coherent concept.^b

Its *realisation*, however, starts with gathering materials, then give them a form (e.g. a brick wall), a structure (e.g. cement) in order to keep that form, detailing parts for different functions (e.g. rooms) and at last fulfilling the intentions of the users.

I assumed a 'conditional' sequence. Isn't it simply a logical sequence?

^a An exchange of goods and services is not necessarily tied to a culture with valuation, money, agreements and so on. In nature you will find numerous examples where goods and services are exchanged without a trace of what you can call culture in the sense defined here.
^b [Jong\(1988\)](#)

The necessary condition (\Rightarrow) is not necessary

Assume first the implication: content \Rightarrow form \Rightarrow structure \Rightarrow function \Rightarrow intention.

This is not true. Liquid or gas have a content, but not necessarily a determined form and keeping shape by structure. And, there are structured forms without function or intention.

This applies the more so, for the content of our imaginations.

They do not necessarily have a stable form, structure, function or intention.

In order to 'place' them next to other images, we can *give* them a form, a dispersion in an imaginary space considering possible structures, functions and intentions.

Cicero^a also 'placed' the parts of his argument in different rooms of an imaginary palace as a memory support, chose one route for his speech and then could easily remember that walk during his speech. A designer can even leave rooms empty for the time being, giving them a form without content, without choosing materials, structures, functions or intentions yet.

This may be characteristic of any design skill. A design object nor its components exist before they are designed. Considering different possible combinations of components, you can finally choose the best coherence, and make a proposal for realization.

The realisation itself does not get this sequence with a logical necessity either.

The collected material does not necessarily get a form. A form does not necessarily have a structure, and so on.

The sufficient condition (\Leftarrow) misses opportunities

Assume then the 'sufficient condition': content \Leftarrow form \Leftarrow structure \Leftarrow function \Leftarrow intention.

A content then necessarily exists in so far it has a form, and a form only if it has a structure and so on. This cannot be true in the imagination of a designer.

A designer may draw a shape (contour), still without any idea about the structure keeping it in form. (S)he may describe a structure that still may have all kinds of functions, and so on.

These representations exist only in thought, and that applies to every possibility that has not yet been realized, even if it is not realizable at all.

Truth logic has room for what is not true (an indefinite rest), but it is not a tool to explore that rest as a field of possibilities. In order to explore what is not (yet) true, requires a different kind of conditional. You may guess that my preference for design logic again comes down to \Downarrow .

EXERCISE 4. LEVELS OF SCALE HAVE A CONDITIONAL SEQUENCE: LARGE SUPPOSES SMALL

This exercise investigates whether the sizes of objects (different from the rest and resisting change, coherence) have a conditional sequence. Compare some conditional statements:

1. 'If the object is small, then the object is large.' or its reverse. (contradictions)
2. 'If there are small objects, then there are large objects.' (equivalent to the reverse)
'If there are large objects, then there are small objects.' (not decisive as to sequence)
3. 'If small objects are possible, then large objects are possible.' (if connection is possible)
'If large objects are possible, then small objects are possible.' (if separation is possible)
4. 'If connecting is possible, then separating is possible.' (separation supposes connection)
'If separating is possible, then connecting is possible.' (connection supposes separation)
5. 'If connection enables (\Uparrow) separation, then separation supposes (\Downarrow) connection.'
This is not valid if connection is a special case of (zero) separation (§ 1p4).
6. 'If separation enables (\Uparrow) connection, then connection supposes (\Downarrow) separation.'

Conditional 6 would indicate that 'large' supposes 'small'.

Some other arguments support that proposition.

^a [Cicero\(-55\)](#) p465

Counting starts by one, that supposes a unit.

Astronomers cannot model a universe without stars, atoms or even smaller particles.

The reverse they can. Physicists experiment with particles isolated from the universe.

The current idea about an expanding universe implies a small beginning.

Biologists cannot imagine an organism without cells or even smaller particles.

The reverse they can. Any organism grows from small to large.

At a cultural level I cannot imagine a text without words or symbols, music without notes, or a pictorial composition without components. The reverse I can.

§ 19 LANGUAGE AND LOGIC ARE BUILT ON SUPPOSITIONS^a

LANGUAGE

A Language ↓^b **different** words, ↑ **changes** by verbs, ↑ **objects** by nouns^c ↑ **separations** by spaces and points in the text, ↑ **combinations** in sentences.

B Metabolising observations into text ↓ human co-action^d. **Regulation** ↑ Adjectives and adverbs, **organisation** ↑ logic and grammar, **specialisation** ↑ proper names, **reproduction** of a mental image ↑ voice, writing or drawing.

Entering the **C**onceptual and **C**ultural layer make these primarily tacit suppositions *conscious*.

C Imagination extends beyond observation, ↑ **certainty** and its zero value *doubt*, ↑ **attachment** (words to observations, memory) ↑ a continuity in behaviour, resisting (different from) external change: **identity**.

Recognizable (external) identity and (internally) a self-image enables **interrelation**.

Interrelation enables to *imagine* someone else's (friendly or hostile) thoughts (**empathy**).

That enables **security**↑**loyalty**↑**public identity**↑**influence**.

Published expressions may change shared suppositions (culture).

The *influence* ('influx') from active source into passive receivers encounters the barriers of p9⁺, and a scale paradox (p9⁺) of agreement in a small circle and rejection in a larger one.

Speaking *about* language (in the same language), hides an inside-outside paradox (**Fig. 8p9**).

'I lie' is a double message. If I tell an *untruth*, then it is still *true* that I am lying.

One message is about the action of my lying (true), the other is the lie content (false).

The first ('meta-language') is seen from the outside, the other from the inside.^e

In order to avoid eventual perpendicularity paradoxes (**Fig. 7p9**), verbal language requires sustaining physical sign language. Learning words in childhood depends on images and sign language e.g. concerning *directions* such as 'left' and 'right'. Even adults need additional emoticons expressing the intention or possibility of the primarily truth-based message.

You cannot derive a difference from equalities, but you may combine different differences into a new difference. Language enables to design improbable *combinations* (plans, fiction, poetry), but its linearity and generalisation do not fully cover imagination.

Whereof you cannot speak, you should sculpture, draw, (with gradients) paint or act physically.

^a **A, B, C** and **Fat words** refer to *Fig. 15p15*.

^b Read ↓ as 'supposes' and ↑ as 'enabling to imagine'. If B *supposes* A, then A *enables* to imagine B. If B↓A then A↑B.

^c For example as active subject or passive object around a verb

^d 'Co(a)gito' is latin for 'I think' as a parallel action.

^e A variant of Russell's paradox that a set cannot contain itself as an element. [Russell\(1903\)](#) p101

LOGIC

Logic *supposes* verbal expression, language. "Truth" does not exist without a verbal proposition that fits observations. Even a picture cannot be "true" without a verbal judgment.

Formal logic specifies (makes a difference between) 16 conjunctions such as 'not' (\neg), 'and' (\wedge), or 'if...then' (\Rightarrow), and it decides expressions to be true (fitting observations) or false.

Modal logic^a extends logic with 'possibly' (\diamond) and 'necessarily' (\square), but it allows 'it is true to be possible' ('an animal is a dog'), instead of 'it is possible to be true' ('a dog is an animal' **Fig.2p6**).

Fuzzy logic allows degrees of truth between true (1) and false (0), as allowed in common language ('half truth') and applied in AI. Fuzzy logic is not considered further in this chapter.

A tacit supposition of verbal language and thus of formal logic is its linearity.

Logic forbids contradictions 'x and not x' ($x \wedge \neg x$) or 'if x then not x' ($x \Rightarrow \neg x$), but a cylinder is round *and* rectangular perpendicular to (\perp) its roundness.

So, if logic would contain a \perp operator, then $x \wedge \perp \neg x$ could be allowed.

Logic still hides another supposition. Logic values $a \Rightarrow b$ as true if both a and b are true.

So, it allows 'if blood is red, then the earth is round'. The two judgements, however, do not have anything in common, or as Ryle(1947)^b states: a and b should be of the same 'type'.

You also cannot imagine something 'redder than round'.

Logic contains a variant of the **A**biotic suppositions of language.

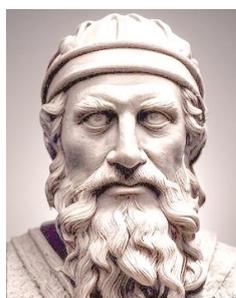
A Logic \Downarrow **difference** of words with a *predicate* (a property) \Uparrow **changes** by conjunctions (logical operators), \Uparrow **objects** as propositions (true or false) \Uparrow **separation** in 'major' (general \forall) and 'minor' (specific \exists), \Uparrow **combinations** as conclusions.

B and **C** remain valid for logic in the wider context of verbal language.

^a Hughes(2005) p17: Possibly 'x' ($\diamond x$) is defined as 'not necessarily untrue' ($\neg \square \neg x$).

^b Ryle(1949) in his introduction calls it a violation of logical rules if you relate different 'logical types' in an assertion. He does, however, not provide rules for that 'type discipline'.

4. MATHEMATICS SUPPOSES EQUALITY AND REPETITION



62 *Euclides*^a



63 *Schooten*^b



64 *Euler*^c



65 *Gauss*^d

With Descartes (*Fig.38p28*) some leading designers of the contents of this chapter

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^a [Euclides Generated with AI By TungYueh](#)

[Euclides\(-300\)Elements](#), until the 20th century a leading textbook on classical geometry, summarising the geometrical inventions until -300.

^b [Schooten portret by Rembrandt National galley of art Wsahington](#)

[Schooten cs\(1659\)](#) translated the French version of [Descartes\(1637\)](#) into Latin and provided it with numerous annotations, suggesting the cartesian coordinate system. As a result, Descartes' foundation of analytic geometry became known to the world.

^c [Euler portret by Emanuel Handmann in the Kunstmuseum Basel](#)

[Euler\(1748\) 2](#) and [Euler\(1765\)](#) coined the still usual expressions $f(x)$, Σ , π , i ($\sqrt{-1}$), and **Euler's number e**. He invented the amazing **Euler's identity** $e^{i\pi}+1=0$ connecting the fundamental mathematical constants 0, 1, π , e (Euler's number), and i (the imaginary unit).

^d [Gauss portret by Jensen, Berlin-Brandenburg Academy of Sciences and Humanities \(BBAW\)](#) [Gauss\(1801\)](#) and [Gauss\(1827\)](#) made decisive contributions to almost every area of mathematics, as well as to physics, astronomy and statistics.

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What is the design content of mathematics? Which discoveries are actually inventions, designs of a model? Does mathematics cover a broader field of possibility beyond probability? This chapter explores some disciplines of mathematics at highschool level. Some conclusions:

Mathematics supposes truth. Truth only exists as an expression. That supposes a language. The search for truth passes many possibilities, often rejected by falsifying experiments, sometimes leading to mathematical models, often no longer imaginable as the objects we are used to at the human scale in space and time.

Mathematics supposes exact equality and repetition (of units, by counting, multiplying, etc.). Geometry enables a language in more directions expressed as separate x-, y- z- t- 'properties'. Calculus makes indivisibly small quantities countable. Probability theory reduces differences into deviations from an average.

Mathematics extends verbal language by reduction. It reduces quality to quantity, supposing that quality has a sequential order with equal intervals. Different quantities suppose different qualities, distinguished by different names (variables).

Repeatedly applying the same operation to its previous result ('iteration'), enables an infinite diversity of images (fractals), but that variety is still less than the diversity of nature. Life does not repeat its operations exactly. Mutations cause an unimaginable biodiversity. Mathematics extends imagination by repetition, but anything unique contradicts repetition.

The quantitative reduction of observed differences and changes requires functions, often adaptable by 'parameters' until they fit many observations as a model called 'true'.. The variety of functions^a, however, still does not cover everything observed. A neural network corrects its parameters and repeats until its output fits a given reality.

The contents of mathematics are *designed* models. Some behave like *discovered* cases. These cases are not the projection of existing mathematical laws (Ἄει ὁ θεὸς γεωμετρῆϊ). On the contrary, similar cases are re(pro)duced by human models enabling predictions. *Equal* behaviour of *different* models of the same case are accepted as a proof of 'truth'.

^a [Abramowitz;Stegun\(1965\)](#) needed already more than 1000 pages.

§ 20 ANALYTIC GEOMETRY QUANTIFIES LOCATION AND DIRECTION

ANALYTIC GEOMETRY SUPPOSES EUCLIDEAN GEOMETRY ^a

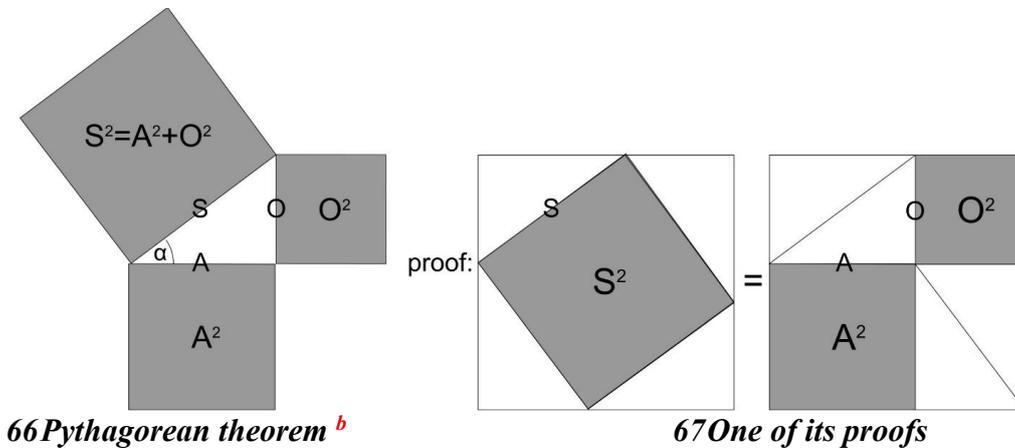


Fig.66 shows a triangle with side lengths $A=4 \perp O=3$. Pythagoras predicts $S^2 = A^2 + O^2$.^c So $s = \sqrt{S^2} = \sqrt{(A^2 + O^2)}$, in this case $s = \sqrt{25} = \sqrt{(9+16)} = 5$. **Fig.67** shows a proof that it counts for any A and O. In any square with 4 of such triangles, the remaining surface is always $S^2 = A^2 + O^2$.

The ratio O/A ('tangent(α)') determines the angle α and the reverse ('arctangent(tangent(α))')^d. The tangent of α does not depend on the size of O or A, but on their ratio. So, it is valid for any o and A with that ratio. If you know α and A, then you can calculate: $O = A(O/A) = A \text{ tangent}(\alpha)$ and thereafter $S = \sqrt{(A^2 + O^2)}$. A right-angled triangle is fully determined by two numbers.

The same counts for the other ratios such as A/S ('cosine(α)'), O/S ('sine(α)') and A/O ('cotangent(α)').^e If you know $\cos(\alpha)$, $\sin(\alpha)$, $\tan(\alpha)$ or $\cot(\alpha)$, then you know $\alpha = \text{'arccos}(A/S)$, $\alpha = \text{'arcsin}(O/S)$ and so on. But, if α becomes rectangular, then S and O become infinite, and 'tangent(α)' loses its meaning as a division of two infinities.

The value of an angle is expressed as part of a circle divided in 360 'degrees' or 2π 'radians'.^f If $360^\circ = 2\pi$ radians then a radian = $180^\circ/\pi = 57.295\dots$ degrees.^g So far, straight line segments and angles have got numbers, based on measurable lengths, ('classical geometry') but it still lacks numbers for points, positions and directions.

Descartes(1637)^h added a separate coordinate system enabling such numbers ('analytic geometry'), based on arbitrarily chosen directions and a point ('origin'), determining 'axes'.ⁱ Lines became sets of points, even describing curves, but adjacent points do not have a size. Adding them into a length required the invention of 'integration' (1684, § 21p70).

These suppositions enabled more complex geometric forms and their transformations than classical geometry.

^a Based on [Euclides\(ca.-300\)Elements](#)

^b Probably known in Babylon(-1800), probably proven bij Pythgoras(ca.-530), but anyhow proven and published by [Euclides\(ca.-300\)Elements Book 1 proposition 47](#).

^c Read S,A or O as Slanted, Adjacent or Opposite side.

^d The addition 'arc' (often abbreviated by 'a') means 'angle, derived from a ratio of lengths', for example $\alpha = \text{atan}(O/A)$.

^e Usually abbreviated to $\cos(\alpha)$, $\sin(\alpha)$, $\cot(\alpha)$. A 'tangent' is abbreviated to $\tan(\alpha)$. A mnemonic for the ratios of cos, sin, tan is 'cASsOStOA'.

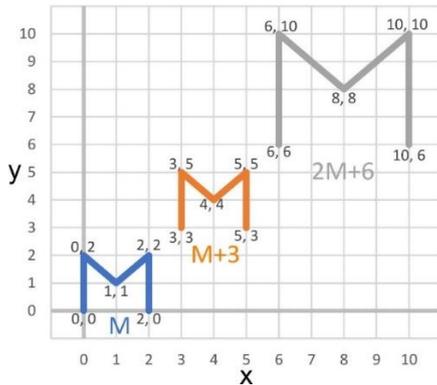
^f $\pi = 3.141592653589793\dots$, the ratio perimeter/diameter of a circle, where diameter = $2 \cdot \text{radius}$. So, perimeter = $2 \cdot \pi \cdot \text{radius}$ or $2\pi r$.

^g 'Radian' may be abbreviated as 'rad'.

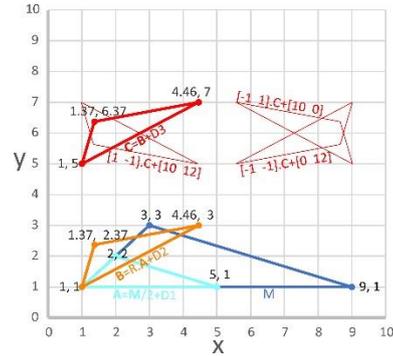
^h [Descartes\(1637\)](#)

ⁱ [Barrow\(1670\)](#) was the first to draw these axes perpendicular.

FIGURES MAY BE DRAWN AS A GRAPH AND TRANSFORMED



68 Coordinates



69 Transformations

You may draw a figure as a graph^a, using pairs of 'coordinates' such as $\begin{matrix} x \\ y \end{matrix} \begin{bmatrix} 0 & 0 & 1 & 2 & 2 \\ 0 & 2 & 1 & 2 & 0 \end{bmatrix}$. Such a list (a 'matrix'^b) can be used in a formula with a single symbol (for example M).^c If $M = \begin{bmatrix} 0 & 0 & 1 & 2 & 2 \\ 0 & 2 & 1 & 2 & 0 \end{bmatrix}$, then M , $M+3$ and $2M+6$ fully describe **Fig.68**. The formulae produce the coordinates of the two 'transformations': $M + 3 = \begin{bmatrix} 3 & 3 & 4 & 5 & 5 \\ 3 & 5 & 4 & 5 & 3 \end{bmatrix}$, $2M + 6 = \begin{bmatrix} 6 & 6 & 8 & 10 & 10 \\ 6 & 10 & 8 & 10 & 6 \end{bmatrix}$.

Using symbols for different (changing) quantities clarifies how they are composed: if $M = \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$, then $M + a = \begin{bmatrix} x_1 + a & x_2 + a \\ y_1 + a & y_2 + a \end{bmatrix}$, $aM = \begin{bmatrix} ax_1 & ax_2 \\ ay_1 & ay_2 \end{bmatrix}$, $aM + b = \begin{bmatrix} ax_1 + b & ax_2 + b \\ ay_1 + b & ay_2 + b \end{bmatrix}$, and $M[a \ b] = \begin{bmatrix} ax_1 & ax_2 \\ by_1 & by_2 \end{bmatrix}$.^d $M[a \ b]$ distributes a row $[a \ b] \rightarrow$ over the rows of $M \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$. But, a 'dotproduct' $M \cdot \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} ax_1 + bx_2 \\ ay_1 + by_2 \end{bmatrix}$ ^e distributes a column 'vector' $v = \begin{bmatrix} a \\ b \end{bmatrix} \rightarrow$ over the columns of $M \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$, and sums the products.^f

$M = \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$ cannot be distributed over $v = \begin{bmatrix} a \\ b \end{bmatrix}$, so you cannot reverse $M \cdot v$ into $v \cdot M$. The vector column should have the same length as the rows of M . Two matrices with the same length and width such as $M = \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$ and $A = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix}$, can be multiplied without a problem: $AM=MA = \begin{bmatrix} a_1x_1 & a_2x_2 \\ a_3y_1 & a_4y_2 \end{bmatrix}$, but a dotproduct, $A \cdot M = \begin{bmatrix} a_1x_1 + a_2y_1 & a_1x_2 + a_2y_2 \\ a_3x_1 + a_4y_1 & a_3x_2 + a_4y_2 \end{bmatrix}$, differs from its reverse: $M \cdot A = \begin{bmatrix} x_1a_1 + x_2a_3 & x_1a_2 + x_2a_4 \\ y_1a_1 + y_2a_3 & y_1a_2 + y_2a_4 \end{bmatrix}$.

Fig.69 reads $M = \begin{bmatrix} 1 & 3 & 9 & 1 \\ 1 & 3 & 1 & 1 \end{bmatrix}$ $A = \frac{M}{2} + D_1 = \begin{bmatrix} 1 & 2 & 5 & 1 \\ 1 & 2 & 1 & 1 \end{bmatrix}$ $B = R \cdot A + D_2 = \begin{bmatrix} 1 & 1.37 & 4.46 & 1 \\ 1 & 2.37 & 3 & 1 \end{bmatrix}$ $C = B + D_3 = \begin{bmatrix} 1 & 1.37 & 4.46 & 1 \\ 5 & 6.37 & 7 & 5 \end{bmatrix}$.

The transformations $\frac{M}{2}$ and $R \cdot A$ alone, also change the location $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ of the triangle. So adding $+D_1 = \frac{1}{2}$ restores $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$, $+D_2 = [0.634, -0.366]$, restores $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$, and $D_3 = [0 \ 4]$ adds the move into $\begin{bmatrix} 1 \\ 5 \end{bmatrix}$.

R rotates A : $R \cdot A = \begin{bmatrix} a & b \\ -b & a \end{bmatrix} \cdot \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} ax_1 + by_1 & ax_2 + by_2 & \dots \\ ay_1 - bx_1 & ay_2 - bx_2 & \dots \end{bmatrix}$, see the next page for details.

You then can mirror C with the y -axis as a mirror: $[-1 \ 1] \cdot \begin{bmatrix} 1 & 1.37 & 4.46 & 1 \\ 5 & 6.37 & 7 & 5 \end{bmatrix} = \begin{bmatrix} -1 & -1.37 & -4.46 & -1 \\ 5 & 6.37 & 7 & 5 \end{bmatrix}$.

Adding $+\begin{bmatrix} 10 \\ 0 \end{bmatrix}$ makes the x 's positive and restores the location right from the y -axis.

Multiplying by $\begin{bmatrix} 1 & -1 \end{bmatrix}$ makes the x -axis the mirror, and $[-1 \ -1]$ does both. In **Fig.69** they are finally moved by $+\begin{bmatrix} 0 \\ 12 \end{bmatrix}$ and $+\begin{bmatrix} 12 \\ 10 \end{bmatrix}$, bringing the y 's and x also into the positive 'quadrant'.

^a Oresme (1350–1360) invented the first graphs visualising the relation of two variables on perpendicular coordinates 'latitudo' and 'longitudo'.

^b Sylvester(1837–1853) introduced the term "matrix", which he used to describe an array from which determinants could be derived.

^c Cayley(1858) defined matrix multiplication, and the inverse of a matrix. See also the history of mathematics of Katz(1993)p623.

^d Vectors (single rows or columns) and matrices (with rows and columns) are usually written bold, matrices in bold CAPITAL.

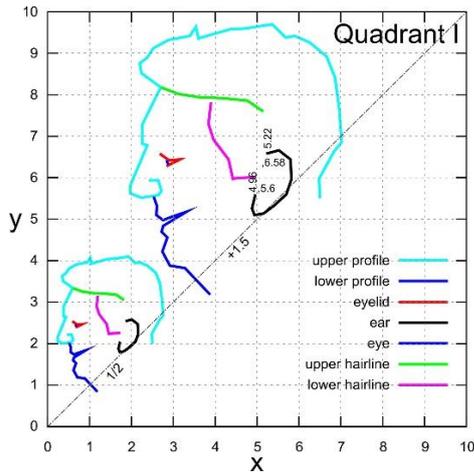
For example: v and M .

^e Simple multiplication signs are omitted in order to distinguish a simple product from two kinds of 'matrix multiplication': the 'dotproduct' (\bullet) and 'crossproduct' (\times), see **Fig.75**p55. A simple product as ax , however, is sometimes made explicit as $a \cdot x$ (with a star-like sign for simple multiplication) if ' ax ' is used elsewhere as a single two-letter variable.

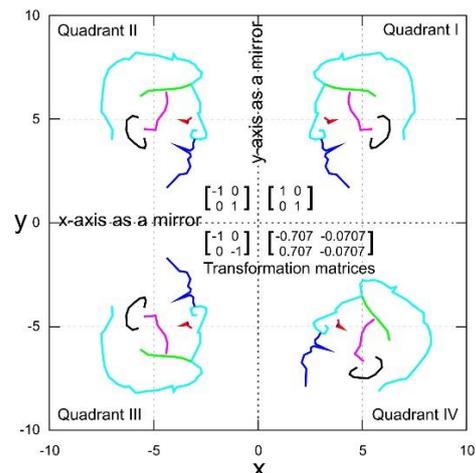
^f The simple multiplication requires a 'rowvector' $[a \ b]M$, the dotproduct a columnvector $\begin{bmatrix} a \\ b \end{bmatrix} \cdot M$. Transposing is noted as $[a \ b]^T = \begin{bmatrix} a \\ b \end{bmatrix}$.

The dotproduct is further explained at page 55.

^f Inventors of the dotproduct: Lagrange (1736–1813), Hamilton (1805–1865), Grassmann (1809–1877).



70 Multiplying x and y equally



71 ... or by different numbers

In **Fig. 70**, the *large* profile is made with 7 coordinate $[x, y]$ lists, for example the list of the ear: $[[3.72, 5.08], [4.02, 5.16], [4.3, 4.94], [4.32, 4.46], [4.2, 4.1], [3.92, 3.84], [3.66, 3.64], [3.44, 3.6], [3.38, 3.76], [3.46, 4.1]]$, but the distance to the origin $[0, 0]$ there, has been increased by adding 1.5 to each list ($[...]+1.5$). So, finally $[[5.22, 6.58], [5.52, 6.66], [5.8, 6.44], [5.82, 5.96], [5.7, 5.6], [5.42, 5.34], [5.16, 5.14], [4.94, 5.1], [4.88, 5.26], [4.96, 5.6]]$ describes the ear.

Dividing the original list by 2 ($[...]/2$) produces the small version, proportionally closer to the origin: $[[1.86, 2.54], [2.01, 2.58], [2.15, 2.47], [2.16, 2.23], [2.1, 2.05], [1.96, 1.92], [1.83, 1.82], [1.72, 1.8], [1.69, 1.88], [1.73, 2.05]]$.

These simple transformations along the diagonal, multiplies x and y by *the same number*.

Other transformations require *different* multipliers for x and y separately.

To this end, the coordinate list, for example the original of the ear in **Fig. 70**, should be ‘transposed’ into a suitable matrix M : $\begin{matrix} x & 3.72 & 4.02 & 4.3 & 4.32 & 4.2 & 3.92 & 3.66 & 3.44 & 3.38 & 3.46 \\ y & 5.08 & 5.16 & 4.94 & 4.46 & 4.1 & 3.84 & 3.64 & 3.6 & 3.76 & 4.1 \end{matrix}$, where x and y are not represented in pairs, but each get their own row for a different operation.^a

A ‘transformation matrix’ $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$ then may be applied on $\begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix}$ by a dotproduct: $\begin{bmatrix} a & b \\ c & d \end{bmatrix} \cdot \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} ax_1 + by_1 & ax_2 + by_2 & \dots \\ cx_1 + dy_1 & cx_2 + dy_2 & \dots \end{bmatrix}$ or $\begin{bmatrix} a & 0 \\ 0 & d \end{bmatrix} \cdot \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} ax_1 & ax_2 & \dots \\ dy_1 & dy_2 & \dots \end{bmatrix}$, editing x and y by *different numbers* (a and d). The zeros make b and c zero, skipping the $+terms$ you do not need.

The simple reduction $[...]/2$ now becomes $\begin{bmatrix} 1/2 & 0 \\ 0 & 1/2 \end{bmatrix} \cdot \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} x_1/2 & x_2/2 & \dots \\ y_1/2 & y_2/2 & \dots \end{bmatrix}$.^b

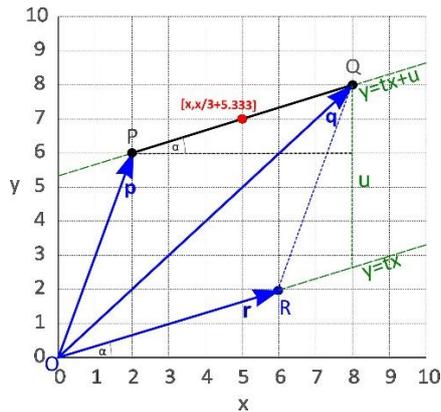
That looks more complicated, but if you want to mirror M with the y -axis as the mirror, then you simply use $\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$ (**Fig. 71** quadrant II), giving all x ’s a minus sign. With $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$, the x -axis is the mirror, and with $\begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$ (Quad.III) both axes are. Moreover, four numbers enable a rotation.

In **Fig. 71 IV** the \cup angle of rotation $\alpha = 135^\circ = 135 \pi/180$ radians = 2.36 radians, applied on an already mirrored I . The \cup rotation matrix is $\begin{bmatrix} \cos(\alpha) & -\sin(\alpha) \\ \sin(\alpha) & \cos(\alpha) \end{bmatrix} = \begin{bmatrix} -0.707 & -0.707 \\ 0.707 & -0.707 \end{bmatrix}$.^c

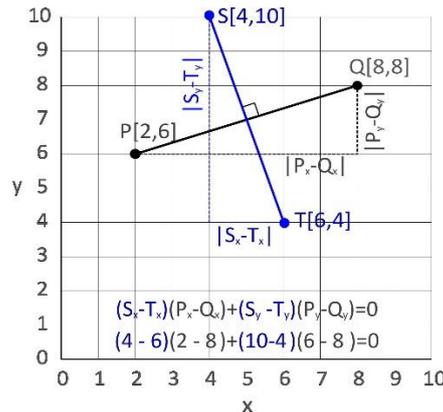
Finally, the figures **71** are moved into a proper location by adding some $[\Delta x, \Delta y]$: $[...]+[\Delta x, \Delta y]$.

POINTS, LINES, ADDING VECTORS AND \perp VECTORS CAN BE QUANTIFIED

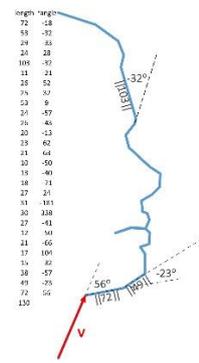
^a Transpose the coordinates back in $[x,y]$ -pairs, in order to make the results readable for a graphics program.
^b So, the matrix $\begin{bmatrix} 1/2 & 0 \\ 0 & 1/2 \end{bmatrix}$ can be replaced by the single factor $1/2$. A single factor replacing a matrix, is called the ‘eigenvalue’ of the matrix.
^c The \cup rotation is $\begin{bmatrix} \cos(\alpha) & \sin(\alpha) \\ -\sin(\alpha) & \cos(\alpha) \end{bmatrix}$ as has been applied in **Fig. 69p52**.



72 Points, lines, vectors



73 \perp Line segments^a



74 No grid

The most simple description of a line is $y=tx$ (Fig. 72). It passes the origin O where $x=0$. Adding something ($+u$) shifts the line into a parallel. The line $y=tx+u$ is the ‘carrier’ of the ‘line segment’ PQ , determined by the points $P[2,6]$ and $Q[8,8]$. Substituting them in $y=tx+u$ as $6=t\cdot 2+u$ and $8=t\cdot 8+u$, solves $t=1/3$, $u=5.333\dots$, then read the line $y=tx+u$ as $y=x/3+5.333\dots$

For any x , any point of PQ or its carrier now is defined by $[x, x/3+5.333\dots]$ or $f(x)=x/3+5.333\dots$. The slope $t=1/3$ is also recognizable as $\tan(\alpha) = |P_y-Q_y|/|P_x-Q_x| = 2/6=1/3$. So, $\alpha = \text{atan}(1/3) = 18.435^\circ$. $PQ = \begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \end{bmatrix} = \begin{bmatrix} 2 & 6 \\ 8 & 8 \end{bmatrix}$ has a length $\| [P]_Q \| = \sqrt{(P_x-Q_x)^2 + (P_y-Q_y)^2} = \sqrt{(2-8)^2 + (6-8)^2} = 6.324$ (Pythagoras).

In Fig. 73, $ST \perp PQ$, because the dotproduct = 0 ($\begin{bmatrix} P_x - Q_x \\ P_y - Q_y \end{bmatrix} \cdot \begin{bmatrix} S_x - T_x \\ S_y - T_y \end{bmatrix} = (P_x-Q_x)(S_x-T_x) + (P_y-Q_y)(S_y-T_y) = 0$).

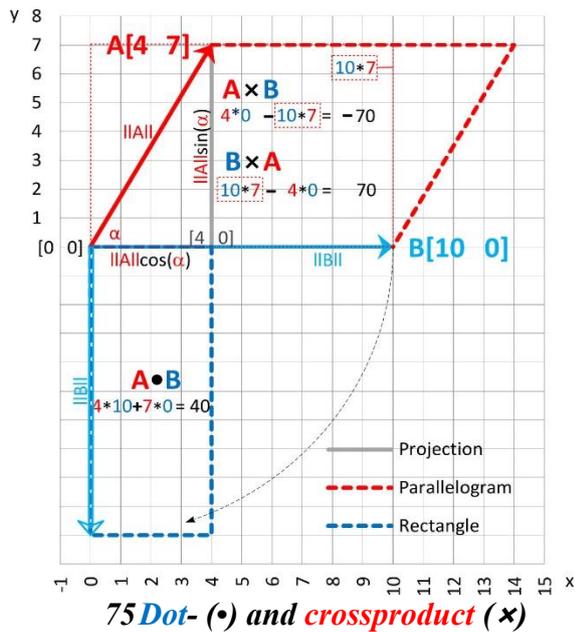
Any $[x,y]$ or $\begin{bmatrix} x \\ y \end{bmatrix}$ describes a point or a ‘vector’^b starting at the origin, depicted as an arrow. Vectors do not only represent lengths with a direction, but also velocities, forces and so on. In Fig. 72, the vectors $\mathbf{p}_{[6]}^2$ and $\mathbf{r}_{[2]}^6$ are added into $\mathbf{q}_{[8]}^8$, always fitting in a parallelogram. A vector, not starting at $O[0]$ (a ‘free vector’), is a line segment $\begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix}$ with a direction.

Simple products of vectors such as $a \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} ax \\ ay \end{bmatrix}$, and $\begin{bmatrix} a \\ b \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} ax & ay \\ bx & by \end{bmatrix}$ behave the same way in any sequence, irrespective if you use columns or rows. A dotproduct^c of vectors produces a single number (‘scalar’), with the same behaviour : $[a, b] \cdot [x, y] = [a, b] \cdot \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a \\ b \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a \\ b \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix} = ax + by$, but if you locate a row after a column, then it produces a matrix: $\begin{bmatrix} a \\ b \end{bmatrix} \cdot [x, y] = \begin{bmatrix} ax & ay \\ bx & by \end{bmatrix}$.

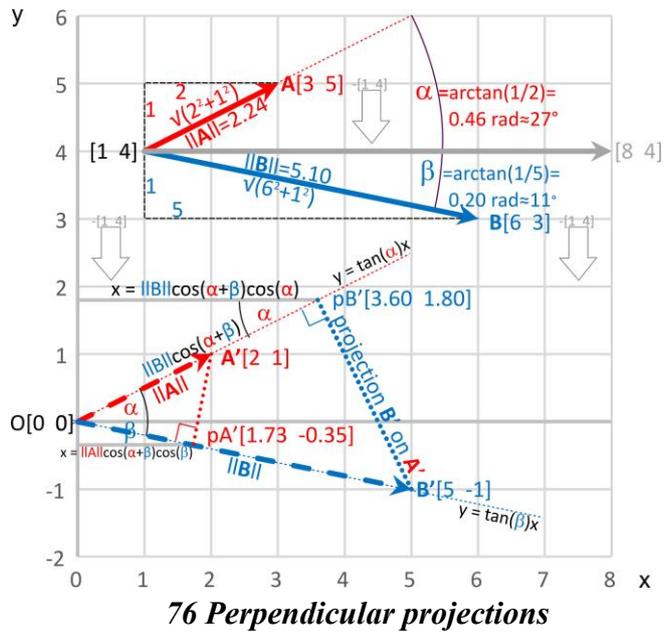
You may move and transform the grid itself, in order to get another perspective with other coordinates of the same (‘invariant’) figure (elaborated on page 69). You even can get rid of any grid, starting with an arbitrary position, direction and length, a totally free vector \mathbf{v} , (Fig. 74) followed by an angle and length again and again (as a navigator in your car does).

^a The sign $|x|$ represents the positive ‘absolute value’ of x . So, $|-1|=1$.
The sign $\|x\|$ will represent the ‘magnitude’ of a vector (in geometry its length).
^b [Euclides\(ca.-300\)](#) used lines with direction and length for geometric translations, the geometric foundation for later vector-like thinking. [Archimedes\(ca.-250\)](#) used lines with direction and length to model mechanical effects. [Newton\(1687\)](#) used quantities with both direction and magnitude for velocity, acceleration, and force. He often represented them as directed lines in diagrams - conceptually vectors, although not formally defined. [Euler\(1736\) I II](#) and [Euler\(1765\)](#) formalized Newtonian mechanics in analytical terms, a major step. [Lagrange\(1788\)](#) used coordinate systems, formalized components of force and motion, anticipating the decomposition of vectors into their components.
^c Also called ‘inner product’ or ‘scalar product’, because between vectors it produces a scalar.

VECTORS CAN BE MULTIPLIED AND PROJECTED



75 Dot- (•) and crossproduct (x)



76 Perpendicular projections

Fig. 75 shows a ‘dotproduct’^a, ‘ $A \cdot B$ ’ = $a_x \cdot b_x + a_y \cdot b_y = 4 \cdot 10 + 7 \cdot 0 = 40$ as a surface of a rectangle. So you can also calculate that by length*width: $\|B\| \cdot \|A\| \cos(\alpha) = 10 \cdot 8 \cdot 0.5 = 40$. If the surface $A \cdot B = 0$, then A and B are apparently **rectangular**: $\alpha = 90^\circ$ or $\pi/2$ rad.

The \perp projection $[[4, 7], [4, 0]]$ on B has a length $\|A\| \sin(\alpha)$. Multiplying that length by $\|B\|$ delivers the ‘crossproduct’^b, ‘ $B \times A$ ’ = $b_x a_y - a_x b_y = 70$, the surface of a parallelogram. If the surface $B \times A = 0$, then A and B are apparently **parallel**.

In Fig. 75 the surface $\|B\| \cdot \|A\| \sin(\alpha) = ‘B \times A’ = b_x a_y - a_x b_y = 70$, but ‘ $A \times B$ ’ = $a_x b_y - b_x a_y = -70$. The crossproduct $B \times A = -A \times B$. A *negative surface*, an opposite direction? As a quantity with a direction it is also a vector, but one rotating positive \cup or negative \cap . Imagine that vector in 3D \perp the plane of Fig. 75 at $[0, 0]$ as a screw, skewed out \cup or in \cap .

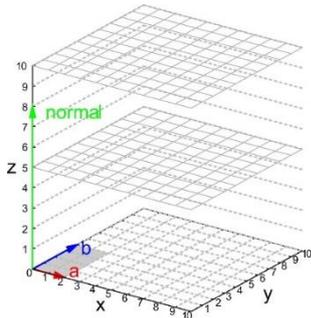
Fig. 76 (above) shows two vectors $A[3, 5]$ and $B[6, 3]$, both starting at $[1, 4]$. Their lengths $\|A\|$ and $\|B\|$, and angles α and β are determined, and will not change by shifts. Fig. 76 (below) shifts A to A' , B to B' starting at the origin $O[0, 0]$. That allows a more simple calculating of the \perp projections $A'pA'$ on B' , and $B'pB'$ on A' .

These projections cross the extended carrier of A' ($y_A = \tan(\alpha)x_A$) and of B' ($y_B = \tan(\beta)x_B$). So if you know coordinate x_B of pB' , then its coordinate $y_B = \tan(\beta)x_B$. But how to calculate x_B ? The right-angled triangle with a slanted side $\|B\|$ and an angle $\alpha + \beta$ has a side $\|B\| \cos(\alpha + \beta)$. It is also a slanted side ‘ s ’ of a right-angled triangle with an angle α and a side $s \cdot \cos(\alpha)$.

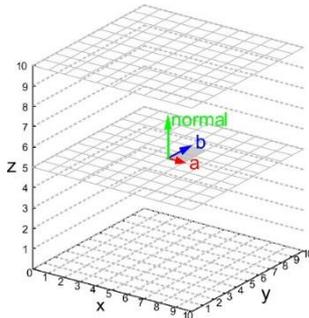
$s \cdot \cos(\alpha) = \|B\| \cos(\alpha + \beta) \cos(\alpha) = 3.60 = x_B$. That's on the line $y_B = \tan(\alpha)x_B$. So the y_B -coordinate = $\tan(\alpha) \cdot 3.60$, and $\tan(\alpha) = 1/2$. You now may draw the end point of the \perp projection of B on A $pB' = [3.60, 1.80]$. A similar approach counts for pA' , resulting in $pA' = [1.73, -0.35]$. Simply shifting all coordinates $-[1, 4]$ brings them back to the original position.

^a Lagrange(1788) laid the foundation of the dot product.
^b Grassmann(1840) in Grassmann(1844) formalized the operations of vector algebra.
 Hamilton(1843) outlined ‘quaternion multiplication’, which in modern terms decomposes into the dot and cross products.
 Gibbs(1901) developed the cross product, based on Hamilton

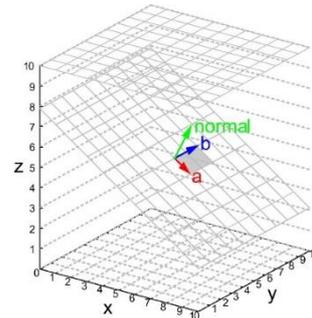
VECTORS CAN BE DECOMPOSED INTO IN 3 DIMENSIONS



77 The normal $\perp a * b$



78 Reduced and displaced



79 Rotated

A third dimension requires vectors with 3 dimensions $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$.

A z-vector \perp **a** and **b** (their ‘normal’), is a crossproduct $\mathbf{a} \times \mathbf{b} = [a_x, a_y, a_z] \times [b_x, b_y, b_z] = [a_y b_z - a_z b_y, a_z b_x - a_x b_z, a_x b_y - a_y b_x]$.

In Fig. 77 $a_x=2$ and $b_y=4$, the others are zero, so the normal $\mathbf{a} \times \mathbf{b} = [0, 0, 8]$ or $\begin{bmatrix} 0 \\ 0 \\ 8 \end{bmatrix}$.

Its length 8 equals the surface of the parallelogram spanned by **a** and **b**.

Fig. 78 halved **a, b**. Adding a displacement $\begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix}$ brought **a, b** and the normal into the middle of the first floor. The new vectors **a** and **b** now span a surface of 2, also the new length of their normal. The reduction is not $\frac{1}{2}$, but $\frac{1}{2}^2$, because the new surface is $\frac{1}{2}$ **a** times $\frac{1}{2}$ **b**.

So, the normal is the crossproduct of halved **a** and **b**: $[1 \ 0 \ 0] \times [0 \ 2 \ 0] = [0 \ 0 \ 2]$.

Rotating 3D requires extended transformation matrices:

Turn x	Turn y	Turn z
$\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\text{angle}) & -\sin(\text{angle}) \\ 0 & \sin(\text{angle}) & \cos(\text{angle}) \end{bmatrix}$	$\begin{bmatrix} \cos(\text{angle}) & 0 & \sin(\text{angle}) \\ 0 & 1 & 0 \\ -\sin(\text{angle}) & 0 & \cos(\text{angle}) \end{bmatrix}$	$\begin{bmatrix} \cos(\text{angle}) & -\sin(\text{angle}) & 0 \\ \sin(\text{angle}) & \cos(\text{angle}) & 0 \\ 0 & 0 & 1 \end{bmatrix}$
80 \mathcal{U}_x -axis	81 \mathcal{U}_y -axis	82 \mathcal{U}_z -axis

rotate first: $\begin{bmatrix} 0.866 & 0 & 0.5 \\ 0 & 1 & 0 \\ -0.5 & 0 & 0.866 \end{bmatrix} \cdot \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1.731 \\ 0 \\ 1 \end{bmatrix}$

and then displace: $\begin{bmatrix} 1.731 \\ 0 \\ 1 \end{bmatrix} + \begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix} = \begin{bmatrix} 6.731 \\ 5 \\ 6 \end{bmatrix}$

83 Sequence of transformations

You cannot reduce and rotate Fig. 77 immediately into Fig. 79.

The displacement itself then would also be reduced and rotated.

Instead, first reduce **a, b** and calculate the new normal in Fig. 77 (with the origin as a starting point), then rotate them around the y-axis (-30°), and finally displace the result into Fig. 79.

Note that in Fig. 79 a new xy plane of **a** and **b** has been drawn.

It has a different direction, it is stretched, projecting the original x units at its bottom.

The x units in the new plane are different from the original x units.

Handling a different coordinate system for the same vector is elaborated on page 69 and next.

a Its logic: $[a_x b_y - b_x a_y, \dots, \dots]$ means $\begin{matrix} \text{multiply} & & \text{multiply} \\ \swarrow & & \searrow \\ & a_x a_y a_z \dots & \\ & \text{and subtract} & \\ & b_x b_y b_z \dots & \end{matrix}$. The cross product is also known as ‘vector product’.

b Here (Fig. 77), the parallelogram is a rectangle at the origin $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$ with two zero’s: $\mathbf{a} = \begin{bmatrix} 2 \\ 0 \end{bmatrix}$ and $\mathbf{b} = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$.

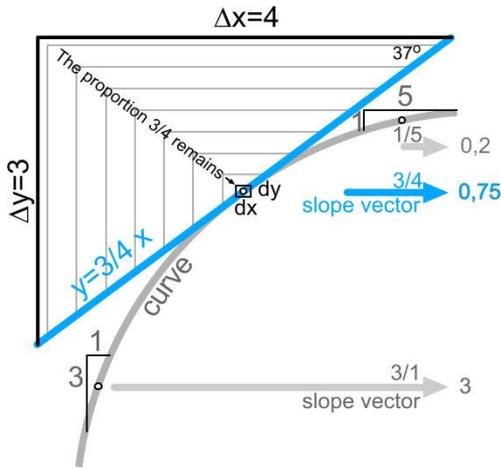
If they move in the xy-plane ($z=0$) into somewhere without zero’s: $\mathbf{a} = \begin{bmatrix} a_x \\ a_y \end{bmatrix}$ and $\mathbf{b} = \begin{bmatrix} b_x \\ b_y \end{bmatrix}$, then the formula would be

$\mathbf{a} \times \mathbf{b} = [a_x, a_y] \times [b_x, b_y] = [a_x b_y - a_y b_x]$ (the sequence is important).

Its absolute |value| is called the 2D ‘determinant’ of **a** and **b**, the surface of a parallelogram (not necessarily \perp).

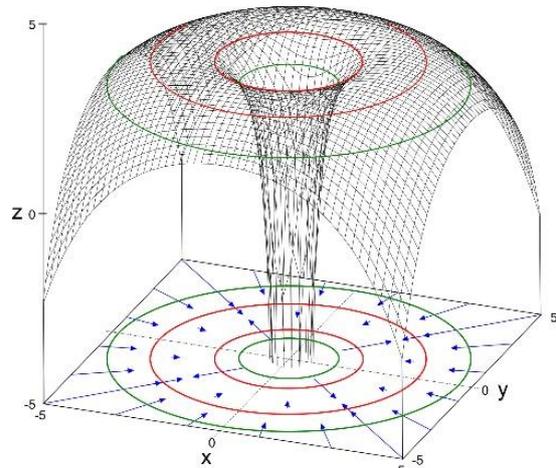
A volume, spanned by three vectors **a, b** and **c**, equals the 3D determinant $= \mathbf{c} \cdot (\mathbf{a} \times \mathbf{b})$, even if it is crooked.

VECTORS CAN REPRESENT SLOPES, AND DIFFERENTIATION



84 Derivatives as slope vectors

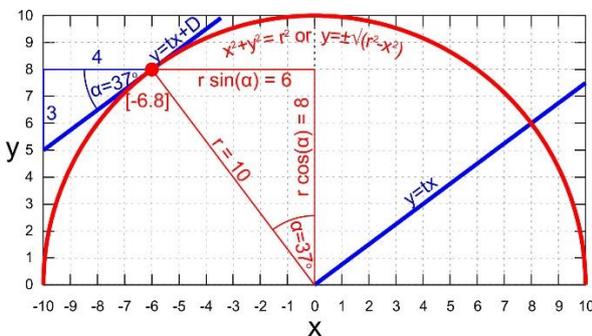
An angle is determined by a ratio of lengths $\Delta y/\Delta x$ (*tangent*), here $3/4$.
 Reduced to an indivisible point without lengths on a curve, their *ratio* still remains as dy/dx , the 'derivative', here also $3/4$.



85 2D vector field of 3D derivatives

You can draw derivatives as '*slope vectors*'.
 The xy plane above is a 2D '*vector field*' of slope vectors, derived from the 3D curved surface at different points, a '*gradient*': a set of derivatives.

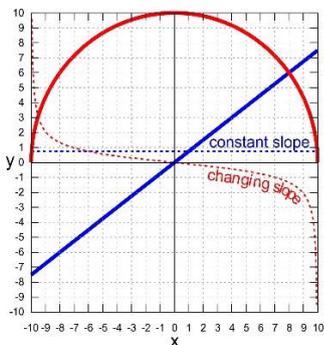
In **Fig.84** an angle of 37° is defined by two \perp lengths: $\Delta x=4$ and $\Delta y=3$ ($\arctan(3/4) \cdot 180/\pi = 37^\circ$).
 Their ratio $\Delta y/\Delta x = 3/4 = dy/dx$, is drawn as a *slope vector s* with a length $\|s\| = 3/4$ (amongst other steeper ($3/1$) or gentler ($1/5$) parts of the slope). The xy-plane of **Fig.85** describes the (steepness of) the overarching 3D object as a 2D vector field.



86 A line touching a circle

In **Fig.84** and **Fig.86**, a line $y_{line} = tx + D$ touches half a circle at $y_{line} = y_{circle} = +\sqrt{r^2 - x^2}$.
 Firstly solve D , the displacement of $y=tx$.
 If $t=3/4$, then $\alpha = \arctan(3/4) = 37^\circ$ (**Fig.86**).

If $r=10$, then a *similar rectangular triangle* within the *circle* is fully determined.
 So, $x=-6$ and $y = \frac{3}{4}(-6) + D = \sqrt{10^2 - (-6)^2} = 8$.
 So, $D = 12.5$, and the point of contact is $[-6 \ 8]$.

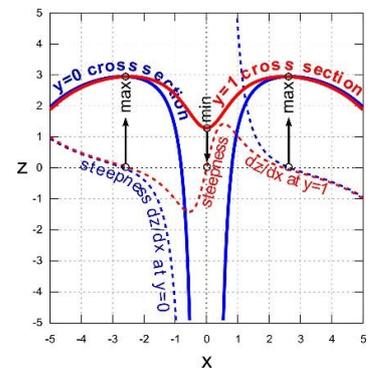


87 Line and circle derivatives

< a constant positive slope $dy/dx = 0.75$,
 and one rising and falling from $y=\infty$ to $-\infty$.
 'differentiated' into derivatives dz/dx

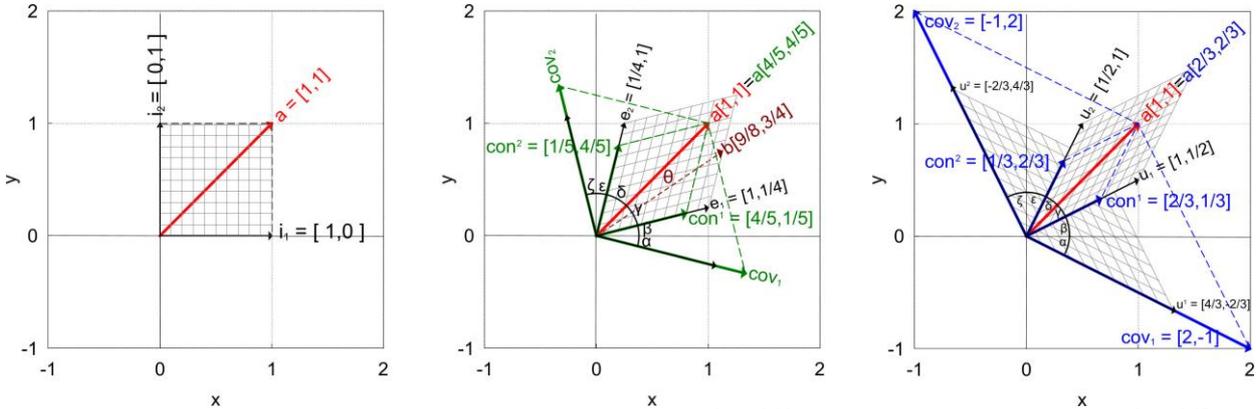
Cross sections $y=0$ and $y=1$ of **Fig. 85**,
 with derivatives $\pm dz/dx$ of rising and falling slopes. >

Note o, the max, min, max 'extremes' at $dz/dx = 0$.



88 Two slices of Fig.85 and their derivatives

THE SAME VECTOR HAS DIFFERENT COORDINATES IN DIFFERENT GRIDS



89 \mathbf{a} on basis $i_k = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} i_1, i_2$ **90** on basis $e_k = \begin{bmatrix} 1 & 1/4 \\ 1/4 & 1 \end{bmatrix} e_1, e_2$ **91** on basis $u_k = \begin{bmatrix} 1 & 1/2 \\ 1/2 & 1 \end{bmatrix} u_1, u_2$

In **Fig.89**, a vector $\mathbf{a}=[1,1]$ is the sum of its components $[1,0]$ and $[0,1]$ coinciding with their units i . In **Fig.90**, $\mathbf{a}=\mathbf{a}=[4/5,4/5]$ defined by ‘contravariant’ components^a \mathbf{con}^1 and \mathbf{con}^2 (decreasing compared to **Fig.89**, if their units increase) or ‘covariant’ \mathbf{cov}_1 and \mathbf{cov}_2 (if both increase).^b

The ratio $\mathbf{con}^1/e_1 = 4/5$ is called α^1 , and $\mathbf{con}^2/e_2 = 4/5$ is called α^2 , or write $\alpha^k = \begin{bmatrix} 4 & 4 \\ 5 & 5 \end{bmatrix}$, where $k=1$ or 2 :

$$\alpha^k \begin{bmatrix} 4 & 4 \\ 5 & 5 \end{bmatrix} \mathbf{e}_k = \begin{bmatrix} 1 & 1/4 \\ 1/4 & 1 \end{bmatrix} = \text{contravariant} \begin{bmatrix} 4 & 1/5 \\ 1/5 & 4 \end{bmatrix} \begin{matrix} \mathbf{con}^1 \\ \mathbf{con}^2 \end{matrix} \quad \alpha^k \begin{bmatrix} 2 & 2/3 \\ 2/3 & 2 \end{bmatrix} \mathbf{u}_k = \begin{bmatrix} 1 & 1/2 \\ 1/2 & 1 \end{bmatrix} = \text{contravariant} \begin{bmatrix} 2 & 1/3 \\ 1/3 & 2 \end{bmatrix} \begin{matrix} \mathbf{con}^1 \\ \mathbf{con}^2 \end{matrix}$$

$$\alpha_k = 1/\alpha^k \quad \mathbf{e}^k = \text{invert}(\mathbf{e}_k)^T \quad \alpha_k \begin{bmatrix} 5 & 4 \\ 4 & 5 \end{bmatrix} \mathbf{e}^k = \begin{bmatrix} 16 & -4 \\ 15 & 15 \end{bmatrix} = \text{covariant} \begin{bmatrix} 3 & -1/3 \\ -1/3 & 3 \end{bmatrix} \begin{matrix} \mathbf{cov}_1 \\ \mathbf{cov}_2 \end{matrix} \quad \alpha_k \begin{bmatrix} 3 & 3/2 \\ 3/2 & 3 \end{bmatrix} \mathbf{u}^k = \begin{bmatrix} 4 & -2 \\ 3 & 3 \end{bmatrix} = \text{covariant} \begin{bmatrix} 2 & -1 \\ -1 & 2 \end{bmatrix} \begin{matrix} \mathbf{cov}_1 \\ \mathbf{cov}_2 \end{matrix}$$

92 Contra- and covariants in **Fig.90** **93** Contra- and covariants in **Fig.91**

The **contravariant** sum $\Sigma \mathbf{con}^k = \mathbf{a}[1,1]$, and the **covariant** sum $\Sigma \mathbf{cov}_k = \mathbf{a}[1,1]$. Also under another basis $\mathbf{u}_k \Sigma \alpha^k \mathbf{u}_k = \Sigma \alpha_k \mathbf{u}^k = \mathbf{a}[1,1]$. The vector \mathbf{a} is ‘invariant’ under a change of basis.

Any angle^d can be calculated:

$\mathbf{e}_k = \begin{bmatrix} 1 & 1/4 \\ 1/4 & 1 \end{bmatrix} \quad \mathbf{e}^k = \text{invert}(\mathbf{e}_k)$ in Fig.90	$\alpha = -\text{atan}(e^{1,2}/e^{1,1}) = 14.04^\circ$	$\delta = \text{atan}(e_{2,2}/e_{2,1}) - \beta - \gamma = 30.96^\circ$	$\mathbf{u}_k = \begin{bmatrix} 1 & 1/2 \\ 1/2 & 1 \end{bmatrix} \quad \mathbf{u}^k = \text{invert}(\mathbf{u}_k)$ in Fig.91	$\alpha = -\text{atan}(u^{1,2}/u^{1,1}) = 26.57^\circ$	$\delta = \text{atan}(u_{2,2}/u_{2,1}) - \beta - \gamma = 18.43^\circ$
$\beta = \text{atan}(e_{1,2}/e_{1,1}) = 14.04^\circ$	$\varepsilon = 90^\circ - \beta - \gamma - \delta = 14.04^\circ$	$\zeta = \text{atan}(e^{2,2}/e^{2,1}) + (\pi/2) = 14.04^\circ$	$\beta = \text{atan}(u_{1,2}/u_{1,1}) = 26.57^\circ$	$\varepsilon = \pi/2 - \beta - \gamma - \delta = 26.57^\circ$	$\zeta = \text{atan}(u^{2,2}/u^{2,1}) + 90^\circ = 26.57^\circ$
$\gamma = \text{atan}(a_2)/(a_1) - \beta = 30.96^\circ$			$\gamma = \text{atan}(a_2)/(a_1) - \beta = 18.43^\circ$		

Note that $\alpha=\beta$ and $\varepsilon=\zeta$ (symmetry), $\alpha+\beta+\gamma+\delta = 90^\circ$ ($\mathbf{cov}_1 \perp \mathbf{con}^2$) and $\gamma+\delta+\varepsilon+\zeta=90^\circ$ ($\mathbf{con}^1 \perp \mathbf{cov}_2$).

Another **vector b** in **Fig.90**, also based on \mathbf{e} , has coordinates $\beta^1 \mathbf{e}_1 + \beta^2 \mathbf{e}_2 = 1 * [1, 1/4] + 1/2 * [1/4, 1] = [9/8 \ 3/4]$.

The cyclic dotproduct $\mathbf{g}_{jk} = \mathbf{e}_j \cdot \mathbf{e}_k = \begin{bmatrix} \mathbf{e}_1 \cdot \mathbf{e}_1 & \mathbf{e}_1 \cdot \mathbf{e}_2 \\ \mathbf{e}_2 \cdot \mathbf{e}_1 & \mathbf{e}_2 \cdot \mathbf{e}_2 \end{bmatrix} = \begin{bmatrix} 17/16 & 1/2 \\ 1/2 & 17/16 \end{bmatrix} = \begin{bmatrix} E & F \\ F & G \end{bmatrix}$ (the ‘**metric**’) fully characterises \mathbf{e} .

Then $[\alpha^1, \alpha^2] \cdot \begin{bmatrix} E & F \\ F & G \end{bmatrix} \cdot \begin{bmatrix} \beta^1 \\ \beta^2 \end{bmatrix}$ implies a **function** $g(\alpha, \beta) = \alpha^1 \beta^1 E + \alpha^1 \beta^2 F + \alpha^2 \beta^1 F + \alpha^2 \beta^2 G$ calculating the lengths

$$\|\mathbf{a}\| = \sqrt{g(\alpha, \alpha)} = \sqrt{2} = 1.41, \quad \|\mathbf{b}\| = \sqrt{g(\beta, \beta)} = 1.35, \quad \text{and the mutual angle } \theta = \arccos\left(\frac{g(\mathbf{a}, \mathbf{b})}{\|\mathbf{a}\| \|\mathbf{b}\|}\right) = 0.119 \text{ rad or } 6.84^\circ$$

^a The superscripts ¹ and ² as in \mathbf{con}^1 and \mathbf{con}^2 are here and further meant as indices (‘tensor notation’), not as exponents e.g. in a quadrat x^2 .

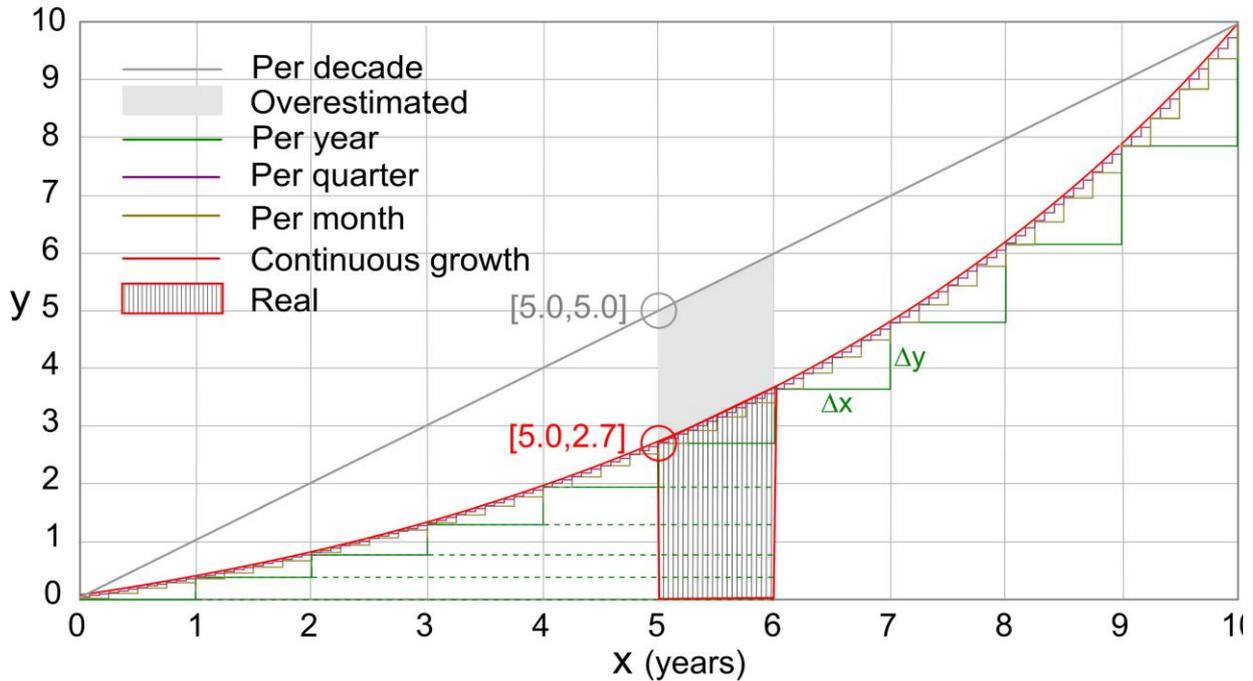
^b Distinguished by **Sylvester(1853)**.

^c The ‘inverse’ of $\mathbf{e}^k \begin{bmatrix} a & b \\ c & d \end{bmatrix}$ is $\mathbf{e}^k \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$. Their dot product, e.g.: $\begin{bmatrix} 1 & 1/4 \\ 1/4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 16 & -4 \\ 15 & 15 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ is a ‘unit matrix’.

Here, the transposition T can be omitted. It has no effect on a symmetric 2x2 matrix.

^d Here, α is an angle, not the earlier mentioned ratio α^k or α_k .

§ 21 CALCULUS DIVIDES AND SUMS INFINITELY SMALL QUANTITIES



94 Increasing growth per period^a

You may measure the growth of a population, your child, your capital or whatsoever per decade, year, quarter, month or continuously. Fig.94 shows an example of growth with an increasing growth rate. The units of the vertical y-axis are people, metres, euro's, or whichever other unit.

The growth per period is shown by right triangles. The smaller the triangle, the more precise. The $\frac{\Delta y}{\Delta x}$ ratio of their rectangular sides (tangent) is the growth rate in the chosen period Δx . Based on a growth of €10 in 10 years you may expect halfway ○ €5 in 5 years, but that is overestimated, because before 5 years ○ it grows slower, and later faster.

In order to calculate your capital after 5 years more precise, you should use smaller triangles. Calculus supposes indivisibly small triangles. At each point of a curve, there is still a slope (see Fig.86p68), noted as tangent ratio $\frac{dy}{dx}$ and known as 'differential quotient' or 'derivative'.

The invention^b has been, that dx and dy are not zero. They approach zero, keeping their ratio $\frac{dy}{dx}$.

If $y=x^2$, then write its derivative as $\frac{d}{dx}x^2$. In Fig.94 curve $y \approx 0.1x^2$, so its derivative is $0.1 \frac{d}{dx}x^2$.

The rules, invented to calculate the derivatives of exponential functions are $\frac{d}{dx}x^1 = 1x^0 (= 1)$, $\frac{d}{dx}x^2 = 2x^1$, $\frac{d}{dx}x^3 \rightarrow 3x^2$ and so on. Factors remain out of the differentiation: $\frac{d}{dx}0.1 * x^2 = 0.1 * \frac{d}{dx}x^2$. Other functions (if they are 'differentiable'!) may have own rules, such as $\frac{d}{dx}\sin(x) = \cos(x)$.

Calculus also sums 'surfaces' of indivisibly thin dx*y rectangles, noted as $\int y * dx$ ('integral').

The rules for $y = x^1, x^2, \dots$ are $\int x^1 * dx = \frac{x^2}{2} + c$, $\int x^2 * dx = \frac{x^3}{3} + c, \dots$, where c is a constant.

So, an integration has many possible results, depending on c.

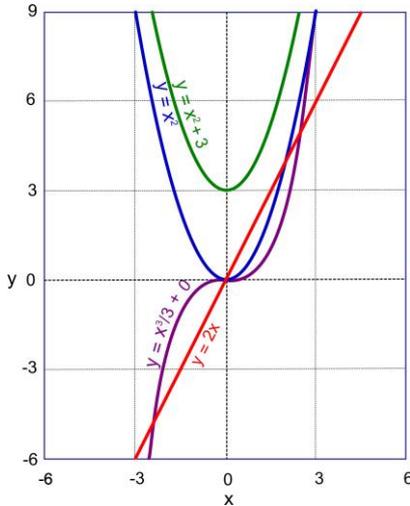
An integral may become infinite, but you may set boundaries to x ('definite integral').

For example, in Fig.94, $\int_5^6 y * dx (= 3.3)$ sums $y * dx$ between $x=5$ and 6.

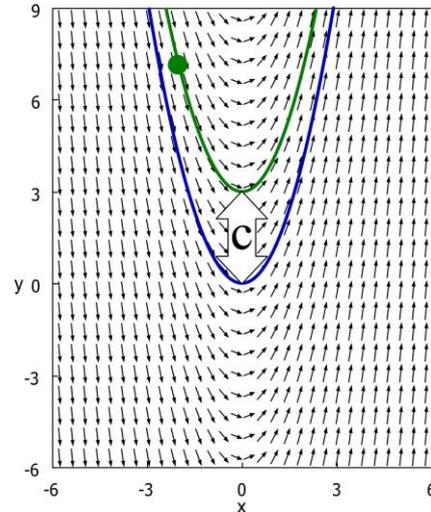
^a The original drawing of Jelson25 (edited here).

^b Newton(1671) (unpublished during his lifetime) and Leibniz(1684) invented the method almost simultaneously, but Leibniz published it earlier and his notation is now common.

DIFFERENTIATING AND INTEGRATING ARE RECIPROQUE OPERATIONS



95 Differentiating and integrating



96 Vector field of $y=x^2+c$

Fig.95 shows $y=x^2$ as a parabola. Its derivative^a $y' = \frac{d}{dx}x^2 = 2x$ is a straight line, showing the tangent value of the slope at any point of the parabola (– means down, + means up). The integral $\int 2x dx = x^2 + c$ brings the derivative $2x$ back to a set of parabolas $y=x^2+c$ (**Fig.96**). The original $y=x^2 + 0$ is one of them, but $y = x^2 + 3$ has also a derivative $y'=2x$.

Fig.96 shows all possibilities to draw a parabola $y = x^2 + c$ with the same derivative $y'=2x$. If you know one point, for example ● [2,7], then $7 = 2^2 + c$, so $c=3$, and the parabola is $y = x^2 + 3$.

So, distinguish:

- the original formula
- its derivative
- the backwards integral thereof
- an ordinary differential equation (ODE)
- solving y in the ODE

Example:

$$y=x^2$$

$$\frac{d}{dx} x^2 = 2x \text{ (the derivative of } x^a = ax^{a-1}\text{)}$$

$$\int 2x dx = x^2 + c \text{ (c shifts the parabola vertically)}$$

$$\frac{d}{dx} y = x^2 \text{ (if you know the slopes of y, then what is y?)}$$

$$y = \frac{x^3}{3} + c \text{ (in Fig.95 } c=0\text{)}$$

‘Differential equations’^b have become crucial tools in science and technology. Solving them, requires specific rules in different cases. I will use them without explaining. Inventing such rules is a main challenge since Newton and Leibniz opened up this field of mathematics ('calculus'). Many (more complicated) ODE's, however, still cannot be solved algebraically.

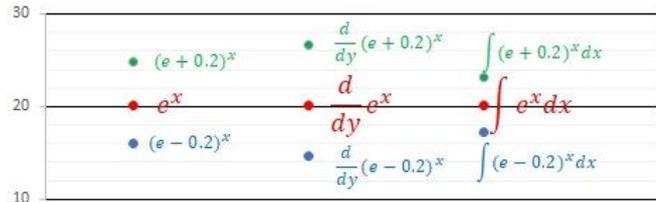
Differentiating and integrating e^x equals e^x

You may be used to logarithms based on 10: $\log(1)=0$, $\log(10)=1$, $\log(100)=2$, and so on. Calculus, however, uses the 'natural logarithm' $\ln(x)$ based on $e=2.718\dots$ ('Euler's number'^c). So, $10^3=1000$, but $e^3=20$. The exponential function 10^x , its derivative $\frac{d}{dx} 10^x = 2.30 * 10^x$ and its integral $\int 10^x dx = 0.43 * 10.0^x$ differ. With base e, however, they are equal: $\frac{d}{dx} e^x = \int e^x dx = e^x$.

^a A derivative of y (e.g. $y=x^2$) is often coded with an apostroph y' (e.g. $y'=\frac{d}{dx}x^2$).
^b [Newton\(1671\)](#) formed the foundation for solving ODEs in mechanics. [Leibniz\(1684\)](#) provided tools and notation that made solving ODEs more accessible and generalizable. [Bernoulli\(1695\)](#) Studied separable and homogeneous equations. [Alembert\(1743\)](#) Applied ODE's to mechanics systematically. [Euler\(1744\)](#) and [Euler\(1755\)](#) greatly expanded the theory and solution techniques of ODE's. [Lagrange\(1788\)](#) Unified differential equations and mechanics in a systematic mathematical framework.
^c [Napier\(1614\)](#) discovered the 'right middle'. [Euler\(1728\)](#), called it 'e' and described its amazing properties for calculus and trigonometry in detail. It is finally called 'Euler's number'. Translation in English: [Smith\(1929\)](#) p95

Fig 97 shows e^x , its derivative, and its integral as the same (20 for $x=3$). That simplifies calculations.

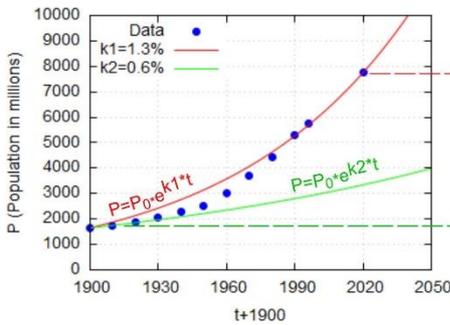
A little difference, e.g. $(e+0.2)$ or $(e-0.2)$ instead of e , already causes *different* outcomes. Any other base such as 10 produces a difference.



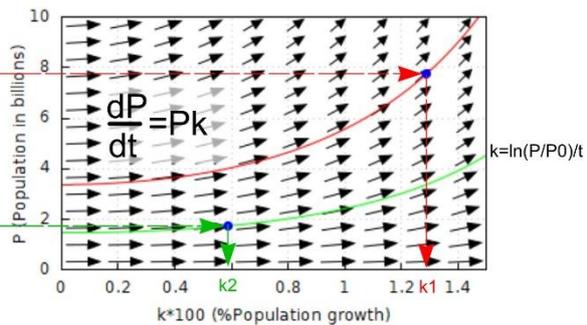
97 *The middle: small differences of e already produce different derivatives and integrals*

CALCULATING POPULATION GROWTH REQUIRES CALCULUS

Estimating the world population of 2050, you should use **historical data** (**Fig.98**). The world population of 1650million in 1900 (P_{1900}) became 1750million in 1910 (P_{1910}). That is 6% growth 'k' in a decade. You may first suppose that a population P_0 will grow with a growth factor $k=0.06$ in a time period (decade) t : $P(t)= P_{1900} + P_{1900}*k*t$.



98 *Population data and models^a*



99 *Their changing growth factor*

From the first 2 data ($P(1910) = 1650+1650*0.06*1=1750$ million), a preliminary model becomes $P(t)=P_0+P_0*k*t$, where P_0 is the initial population in millions and t the time period *in decades*. For 2020 that would predict a population $P_{2020} = 1650 + 1650*0.06*12 = 2850$ million. The world population in 2020, however, has been 7750 million. What's wrong?

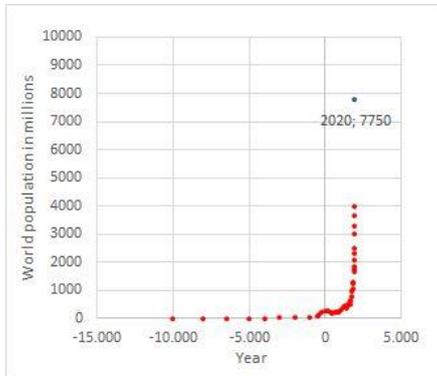
The **data** until 2020 (**Fig.98**) show that the *growth rate k increased from k2 into k1*. Moreover, it does not increase every decade, but every second or every indivisible moment 'dt'. In order to model that, you need calculus. Then, the change of the population dP per moment dt , $\frac{dP}{dt} = Pk$, an ordinary differential equation (ODE), that is a *set of directions* of Pk in **Fig.99**.

A known point (- - or - -) defines the curve. Solving $\frac{dP}{dt} = Pk$ gives $P = P_0 e^{k*t}$, where $k = \ln(P_1/P_0)/t$. If $P_0=P_{1900}=1650$ million, $P_1=P_{2020}=7750$ million, and $t=2020-1900=120$, then $k1 = \ln(7750/1650)/120 = 0.013$. Once knowing k , you can calculate any population from 1990 and further: $P_{1990}(= P_0 e^{k1*t})=1650*e^{0.013*90} = 5\ 316$, or $P_{2050}(= P_0 e^{k*t})=1650*e^{0.013*120}= 11\ 597$ million people. That fits rather well with the **known populations** of 1990-2020 in **Fig.98**.

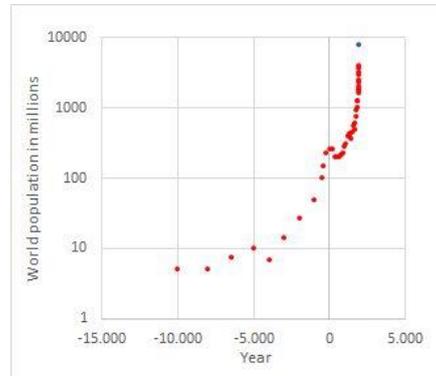
^a Steward(1998)

AN OTHER TIME SCALE MAY REQUIRE A DIFFERENT FORMULA

The future world population (**Fig.100p73**) frightens me. **Fig.101p73** shows details on log scale. It clarifies the reductions after -5000BC and after year 0 we perhaps may face also in our future. The growth is due to human technology. The decline is due to disasters of different kind.

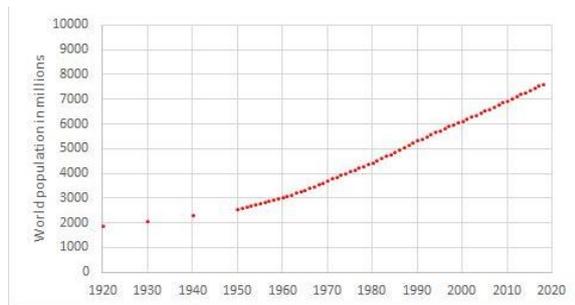


100 World population in 20 000 years^a

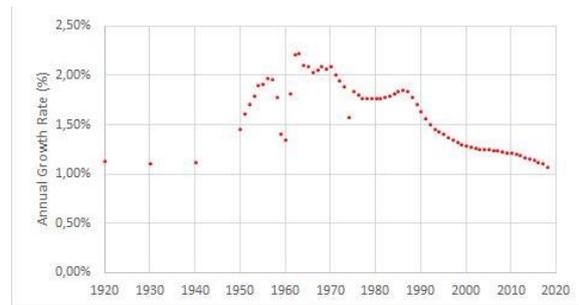


101 on a logarithmic₁₀ scale

Fig.102 shows a recent century in **Fig.100** : a world population doubling in 40 years.



102 World population P in a century^b



103 Growth rates k per year

Fig.103, however, shows declining growth rates k per year after 1960.

That should have a flattening effect on the world population after some generations.

Moreover, the carrying capacity of the Earth sets its limits. Malthus(1803)^c predicted famine disasters, based on exponential growth ($\frac{dP}{dt} = Pk$, solved as $P=P_0e^{kt}$ in **Fig.98p72**).

Verhulst(1845) included a carrying capacity as K in his 'logistic equation':

$$\frac{d}{dt}P = P \left(1 - \frac{P}{K}\right)k, \text{ solved as } P = \frac{K}{1 - e^{-ck}e^{-kt}}, \text{ where } k=k_{\max}.$$

If $k=k_{\max}$ and c are constants, then $-e^{-ck}$ is a constant. Replacing it by 'A', you can write

$$P(t) = \frac{K}{1 + Ae^{-kt}}. \text{ Solving A for an initial population } P_0, \text{ delivers } A = (K - P_0)/P_0.^d$$

Fig.104p74 draws the logistic curve $P(t) = \frac{K}{1 + Ae^{-kt}}$, where $A=(10-2)/2=4$.

The carrying capacity is assumed to be $K=10$ (billion people), and $k=0.025=2.5\%$.

The population in 1920 and 2020 predicted by the logistic model fit nicely with the data of **Fig.98p72**.

^a Average of different sources from <https://nl.wikipedia.org/wiki/Wereldbevolking> .

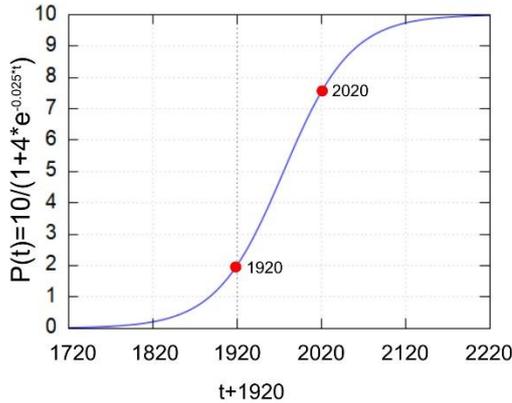
^b From 1975: <https://www.worldometers.info/world-population/world-population-by-year/> up to 1975: https://web.archive.org/web/20150426165332/http://www.census.gov/population/international/data/worldpop/table_population.php .

The estimates, of **Fig 90** show declining growth rates per year after 1960.

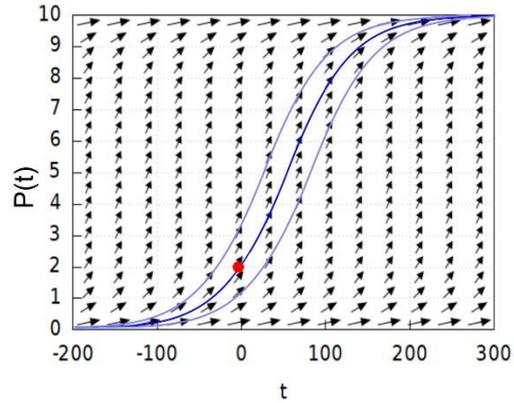
That should have a flattening effect on the world population after some generations.

^c **Malthus(1803)**

^d **Steward(1998)** p540-541 shows this derivation in more detail.



104 A logistic Model 1720-2220



105 Vector field of $\frac{d}{dt}P = P \left(1 - \frac{P}{K}\right)$

Fig.104 predicts, that the world population should be stable in 2220.

The growth rate in Fig.103p73 then should continue to decline in order to reach 0% at last.

There are, however, more processes with effect on the changing world population than birth and mortality. Fig.103p73 shows a dip in the growth rate around 1960, probably due to world wide pessimistic expectations during the Cold War and the new availability of birth control agents. Their effects are difficult to predict.

The dips in 101p73 after 5000BC and the year 0, are probably due to epidemics or famine. Famine may be simulated by predator-prey models taking people as predator, their food as prey.

CALCULUS REQUIRES CONTINUOUS FUNCTIONS

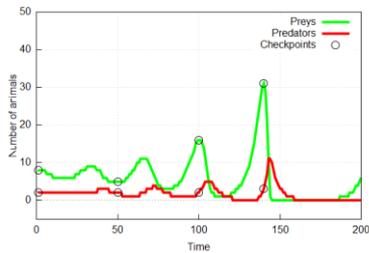
The growth of prey populations followed by those of predators eating them, depends on at least 6 supposed values ('parameters'), resulting in very different predictions, for example:

Initial number of preys:	preys ₁ = 8	Initial number of predators:	predators ₁ = 2
Growth rate preys without predators:	Gpreys= 0.2	Growth rate predators feeding on prey	Gpreds= 0.029
Death rate preys by predators:	Dpreys= 0.1	Death or emigration rate predators:	Dpreds= 0.2

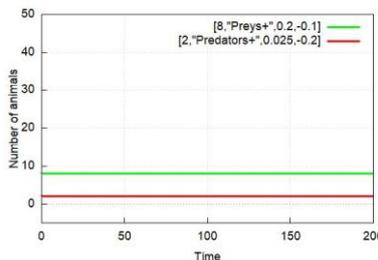
The 'Lotke-Volterra model'^a with such parameters, predicts for time t:

the next population = the previous population + the same * (their growth rate minus their decline):

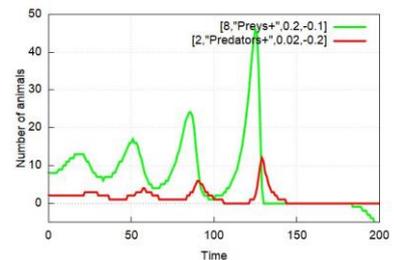
preys _t	=preys _{t-1}	+ (preys _{t-1} * (Gpreys - Dpreys * predators _{t-1}))
predators _t	=predators _{t-1}	+ (predators _{t-1} * (Gpreds * preys _{t-1} - Dpreds))



106 Survival (Gpreds=0.029)



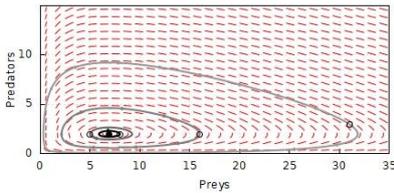
107 Equilibrium (Gpreds=0.025)



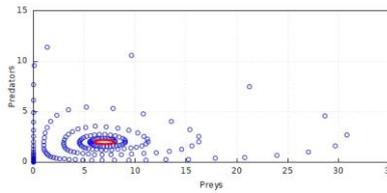
108 Extinction (Gpreds=0.020)

A small change of one parameter (for example Gpreds) already may have great effect. If you decrease the growth rate (fertility) of the predators from Gpreds=0.029 into 0.020, then both animal species die out at last. Fig.108 shows after t=150 even imaginary negative numbers of prey, a clear message of extinction. At Gpreds=0.025 in Fig.107, both seem stable.

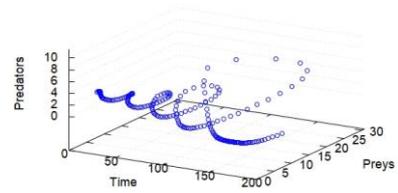
^a Volterra(1926)



109 A vector field around ● [6.9,2] with initial points ○ [5,2], [8,2], [16,2], and [31,3]



110 Repeated jumping to the next cycle



111 Extruded in time

Fig.107p74, suggests a stable equilibrium at [8,2], but it is a ‘dynamic stability’. Predators cannot survive without eating preys, reducing the number of preys. So, it *must* fluctuate, ideally in a repeating cycle around an ‘equilibrium point’ ●. A single ‘initial point’ determines the cycle. From o [8,2], the smallest cycle in **Fig.109** around ● [6.9,2], follows the vector directions.

The second part of Volterra's formula at page 74 describes the *change* of preys and predators as $\text{preys} * (\text{Gpreys} - \text{Dpreys} * \text{predators}_{t-1})$, and $\text{predators} * (\text{Gpreds} * \text{preys}_{t-1} - \text{Dpreds})$. If they do *not* change, then the terms between the brackets are 0. That is the case if the number of preys = $\frac{\text{Dpreds}}{\text{Gpreys}} = \frac{0.2}{0.029} = 6.9$, and the number of predators = $\frac{\text{Gpreys}}{\text{Dpreys}} = \frac{0.2}{0.1} = 2$, together the ‘equilibrium point’ ● [6.9,2] in **Fig.109**.

The other cycles in **Fig.109** apply the 'checkpoints' o of **Fig.106**p74 as initial points o of a cycle. The second smallest cycle may, for example, be described as follows:

1. If 2 foxes eat 3 of 8 rabbits, then there are 5 rabbits left, so you should draw the initial point o [5,2] in **Fig.109**. Through that point you can draw a counter clockwise cycle.
2. The next point: one fox will die if only 5 rabbits are left, and the number of rabbits harrassed by only 1 fox now increases to 7: (7,1).
3. That is again enough for 2 foxes, while the number of rabbits increase further to (9,2).
4. That is enough for 3 foxes bringing the number of rabbits back to 7, point (7,3).
5. Then 1 fox dies by lack of food. The cycle reaches its initial point (5,2), and starts anew.

A few questions arise. What means 6.9 preys in the equilibrium point [6.9,2]? A part of a prey is no prey. Calculus counts with fractions of preys, not their natural whole ('integer') numbers. The graphs may remain valid if you read the population numbers as thousands, but even then, the remaing fractions should be interpreted as gaps in the continuous line.

If the change-terms of the Volterra's formula at page 74 systematically change themselves, then the system may jump every time interval (Δt) into a larger cycle, resulting in a spiral (**Fig.75**). The still fluctuating populations of preys an predators may grow until they reach the carrying capacity of their habitat, resulting in a final extinction of both species at (0,0).

Fig.110 shows a repeated jumping to a next larger cycle in the vector field of **Fig.109**p75.

Fig.111 adds the dimension of time in 3D:

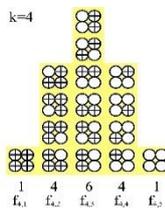
project the curve on the floor (the Preys-Time plane) to get the prey curve of **Fig.108**p74;

project it on the front (the Predator-Time plane) to get the predator curve of **Fig.108**p74.

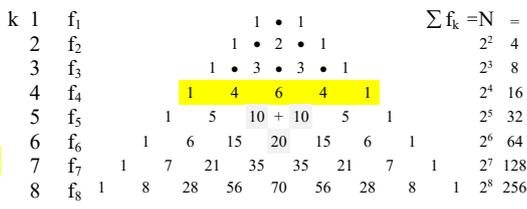
The values are not continuous as it is supposed in **Fig.109**p75. So, calculus does not apply. The spiral has gaps $\Delta t=1$ instead of $dt \rightarrow 0$. The points, however, still do not represent individuals, but moments in time with imaginary fractions of animals.

§ 22 PROBABILITY REDUCES DIFFERENCES INTO DEVIATIONS

BINOMIAL CHANCE DETERMINES HOW OFTEN YOU CAN EXPECT A YES OR NO

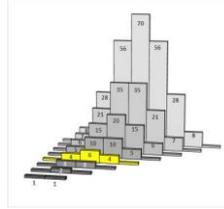


112
Frequencies

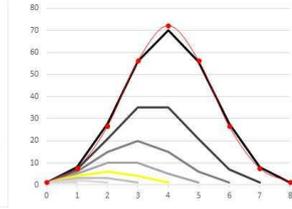


113
Triangle of Pascal

$\sum f_k = N =$	1	2	4	8	16	32	64	128	256
2^0	1								
2^1		2							
2^2			4						
2^3				8					
2^4					16				
2^5						32			
2^6							64		
2^7								128	
2^8									256



114
The frequencies: roughly a clock shape



115
The frequencies: roughly a clock shape

Tossing a coin, cross ⊕ or coin ○ both (bi-nomial) have equal chance or 'probability' $p = \frac{1}{2}$ (50%). Tossing twice ($c=2$), there are 4 possibilities ($N=4$): ⊕⊕, ⊕○, ○⊕, ○○ with each $p = \frac{1}{4}$ (25%). After three times ($c=3$) it is one of $N=8$ combinations: ⊕⊕⊕, ⊕⊕○, ⊕○⊕, ○⊕⊕, ⊕○○, ○⊕○, ○○⊕ or ○○○. With four throws ($c=4$) there are $N=16=2^4$ possibilities. In short: $N=2^k$ possibilities for k throws.

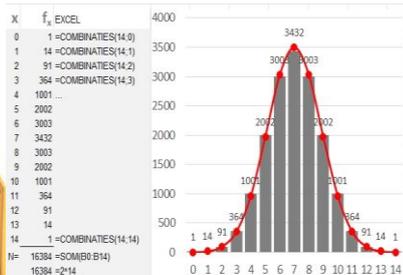
Tossing 4 times (or 4 coins at the same time) you rarely throw ⊕⊕⊕⊕ or ○○○○, most often ⊕○○○ (in different sequences). There is 1 possibility to throw ⊕⊕⊕⊕, 4 to throw ⊕⊕⊕○, 6 to throw ⊕⊕○○, and so on (**Fig.112**). In short, the 'frequency' $f = \{1, 4, 6, 4, 1\}$. Their probability p is f divided by the number $N=2^4$ of all possibilities: $p = f/N = \{1/16, 4/16, 6/16, 4/16, 1/16\}$, or $\{6\%, 25\%, 38\%, 25\%, 6\%\}$ chance.

Pascal^a invented a triangle of numbers to predict the frequencies of each subsequent throw c , by adding two higher numbers each time (**Fig.113**: for example $10 + 10 = 20$). The sum of each row $N = \sum f_{0 \dots c} = 2^c$. In row f_8 ($c = 8$ throws) there are already $N = 2^8 = 256$ possibilities in 9 frequencies. **Fig.115** suggests intermediate values, but the 'binomial distribution' itself is 'discrete'.

Galton^b invented a board (**Fig.116**) with rows of nails simulating the Pascal triangle. After 14 rows, a bullet may choose one of the $N = 2^{14} = 16384$ possible paths. It is then captured in one of the 15 frequency columns numbered as their quantities $f_0, f_1, f_2 \dots f_{14}$. There is only one path to end up in one of the two outer ones (f_0 and f_{14}). Their probability is $1/N=0.006\%$ each.



116
Galton-board^c

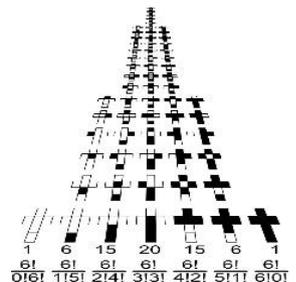


117
 $2^{14} = 16384$ paths distributed over 15 columns

$$\binom{N}{f_x} = \frac{N!}{f_x! (N - f_x)!}$$

$\binom{4}{1} = 4$ possibilities $\binom{4}{2} = 6$ possibilities $\binom{4}{3} = 4$ possibilities
 $\frac{1*2*3*4}{1*(1*2*3)}$ $\frac{1*2*3*4}{1*2*(1*2)}$ $\frac{1*2*3*4}{1*2*3*(1)}$

118
Binomium of Newton: f_x distributions in N^d



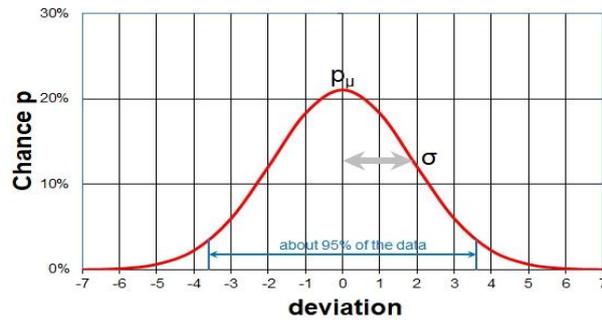
119
64 possibilities to build on 6 locations

There are $3432/16386$ paths (21% chance) to end up in the middle (f_7 , **Fig.117**). Newton^c invented a formula for all possibilities of any f_x in N (**Fig.118**), or for f_x elements on N plots (**Fig.119**). Choosing a team out of a football club with 25 members has 11 out of 25: $\binom{25}{11} = 4\,457\,400$ possibilities.

^a **Pascal(1654)** described the properties and applications of the arithmetical triangle, including binomial coefficients, combinatorial identities and probability applications.
^b **Galton(1889)** p63 designed the Galton Board and later introduced correlation and regression.
^c <https://easymatica.blogspot.com/2015/08/feira-de-ciencias-experimentos-de.html>
^d The symbol '!' is called 'faculty': $0!=1, 1!=1, 2!=1*2, 3!=1*2*3, 4!=1*2*3*4$, and so on.
^e **Katz(1993)** p463 describes how Newton generalised Pascal's triangle and formula. He found a method to include broken integers studying infinit series.

A NORMAL DISTRIBUTION DETERMINES ANYTHING IN BETWEEN

case	x	f	u=x-μ	(x-μ) ²	f(x-μ) ²	Gauss	/N
1	0	1	-7	49	49	3,2	0%
2	1	14	-6	36	504	20,4	0%
3	2	91	-5	25	2275	98,2	1%
4	3	364	-4	16	5824	355,3	2%
5	4	1001	-3	9	9009	965,9	6%
6	5	2002	-2	4	8008	1973,0	12%
7	6	3003	-1	1	3003	3028,7	18%
8	7	3432	0	0	0	3493,8	21% μ
9	8	3003	1	1	3003	3028,7	18%
10	9	2002	2	4	8008	1973,0	12%
11	10	1001	3	9	9009	965,9	6%
12	11	364	4	16	5824	355,3	2%
13	12	91	5	25	2275	98,2	1%
14	13	14	6	36	504	20,4	0%
15	14	1	7	49	49	3,2	0%
N=		16384	Σ(x-μ) ² =	280	57344 = Σf(x-μ) ²		
					16384 = N		
			variance		3,5 = Σf(x-μ) ² /N		
		μ = 7	σ =		1,870829 = √Σf(x-μ) ² /N		



120 Calculating σ from the frequencies of Fig.117p76 and...

121 , ...its normal Gauss distribution^a

If the number of possible outcomes is not the 2 of a coin, or the 6 of a dice, but an infinite or very large number, such as all the lengths of 18mln people, then you need a continuous probability distribution for *all* real numbers, not only discrete integers.

Such a distribution has an infinite number of possible outcomes N for every k observations x and their chances p. Such a 'normal distribution' must concentrate around a mean μ, but extend infinitely to the rare cases.

Gauss invented a formula^b that fills the gaps between the whole numbers, smoothening the broken lines of **Fig.115p76**, and **Fig.117p76**. The average of all deviations x-μ determines how 'flat' the Gauss' formula (**Fig.121**) is, but if - and + deviations compensate each other, then you cannot calculate that average. Squaring them makes all positive.

The square sum of all deviations Σ(x-μ)² is therefore a positive measure for the total of all deviations from μ. That is on average Σ(x-μ)²/N ('variance'). The root of the variance √(Σ(x-μ)²/N) is the 'standard deviation' σ. If you measure the lengths of people in cm, then you get that variance in cm². That is a surface. Then, the square root √(Σ(x-μ)²/N) = σ is again in cm.

The standard deviation σ has some special characteristics. It is the distance from the average to the 'inflection point' where the graph changes from convex into concave.

Within the area between -σ and +σ, you will find 68.2% of the results.

Between -1,96σ and +1,96σ this is already 95%. The 5% rest is called 'exceedance chance'.

Gauss requires to know only μ and σ in order to predict the probability of each outcome.

If you do not know all the N outcomes x, but you know their frequencies f in the neighbourhood of each x (their 'class'), write k instead of x in the formula: σ=√(Σf(k-μ)²/n), where n then is a sample of N. If you know all N results x, then k is x and any f = 1, so you can leave out that frequency.

With the results of a sample n from a much larger mass N you may already estimate μ and σ quite nicely. You then instead of μ, σ, x write m, s, z. Gauss(m, s) predicts all outcomes within 'confidence limits'. Comparing your outcomes with that prediction, you may find deviations that require further explanation.

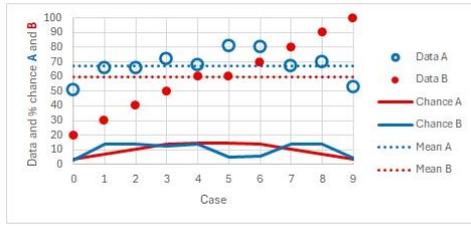
$$\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

^a That formula gives the chance of outcome x.

In Excel: NORMDIST(x;μ;σ;FALSE). With TRUE the cumulative version is calculated.

^b **Gauss(1809)** (latin) [p259 \(english\)](#) formulated least squares and normal distribution as φ(x) := $\frac{h}{\sqrt{\pi}} e^{-h^2 x^2}$. Gauss(1809)Theoria motus corporum coelestium(Hamburg)Perthes;Besser page 212

SAMPLES ALLOW CORRELATING 2 DATA SETS BY PROBABILITY TESTS



122 Data and normal chances

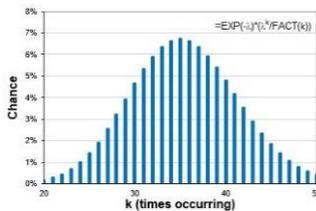
COUNTA(B2:B11)	10	10	n		number of cases
MODE.SNGL(B2:B11)	66	60	mode		most common result
MEDIAN(B2:B11)	67,5	60	median		middle result
AVERAGE(B2:B11)	67,4	60	$\mu \approx m$	$\Sigma z/n$	average
AVEDEV(B2:B11)	6,8	20,0	\bar{u}	$\Sigma(z_i-m)/n$	average deviation
VARP(B2:B11)	85,24	600,0	s^2	$\Sigma(z_i-m)^2/n$	variance
STDEV.P(B2:B11)	9,23	24,49	s	$\sqrt{\Sigma(z_i-m)^2/n}$	sample standard deviation
CHISQ.TEST(B2:C11;expected)	0,0%		χ^2	$\Sigma(x_i-m)^2/N$	standard deviation n = N mass
CORREL(B2:B11;C2:C11)	13,3%		r		A and B still run a 0% chance of being dependent they have a 13% chance of correlation
TTEST(B2:B11;C2:C11;2,3)	41,4%		t		the average is also the same for measurement errors
FTTEST(B2:B11;C2:C11)	0,8%		F		insofar as independent, the variances differ considerably

123 Comparative tests of Fig.122 in Excel

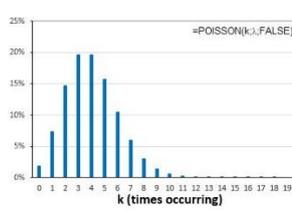
You may compare *two* different sets of data **A** and **B**. For example, **Fig.122** shows two data sets. **Fig.123** shows the differences, and 'tests' of relations between **A** and **B**.

The ' χ^2 -test' ('chi-square test')^a shows the chance that **A** and **B** are related or actually one normal distribution ('dependent'). The r-test shows the correlation. The t-test shows the chance of an equal average, the F-test the equality in variance and therefore in standard deviation. You may conclude all that already from **Fig.122**, but these tests convince in case of many more data.

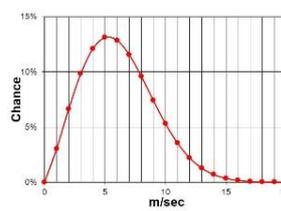
FEW FROM COUNTLESS CASES STILL HAVE A CHANCE TO OCCUR



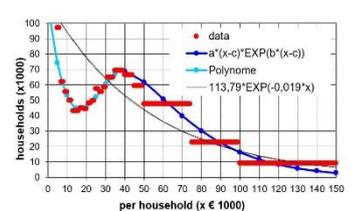
124 Poisson at $\lambda=35,5$



125 Poisson at $\lambda=4$



126 Weibull^b



127 An income distribution^c

A year counts $365 \cdot 24 \cdot 60 \cdot 60 = 31\,536\,000$ seconds. If you stay awake, then you will see about 16 frames per second. These are therefore $N = 504\,576\,000$ observations.

If you see a lightning (1 to 0.0001 sec) on average 4 times a year in 1/16 of a second, then you would calculate a negligible average probability of 4 out of more than 500 million: practically zero. The complementary chance of no lightning strike is practically 100%.

This is a binomial case (cross or coin, yes or no) of whether or not you see a lightning, but the deviations, variance or standard deviation, are useless. How could you know how much chance you run in an entire year, to see none or 10 lightning strikes? Such a probability problem with innumerable observations N in time occurs in insurances, waiting times, and the like.

Poisson invented a formula^d for a given μ (eg 4) with a standard deviation $\sigma = \sqrt{\mu}$ (eg 2) for each period (eg a year). So, you only need to know μ , but with Poisson that is called λ . That formula gives the chance of k occurrences (**Fig.124**).

With an average of 4 lightning strikes per year (20% chance) you have still 10% chance that it will be $4 + 2 = 6$, but on the other hand 15% chance of $4 - 2 = 2$. That skew division 'collides with the zero limit'. A lightning strike can occur 0 times, but not -1 times. If λ is far enough from 0, then the distribution seems to be quite similar to Gauss. However, if the average λ is close to 0 (e.g. 4, **Fig.125**p78), then the Poisson distribution becomes skewed.

^a [Pearson\(1900\)](#) p157-175

^b $P(v, C, a): a * C * v^{C-1} * e^{(-a*v)^C}$

^c $p_1(x, a, f) = a + bx + cx^2 + dx^3 + ex^4 + fx^5$ and $p_2(x, a, b, c) = a(x-c)e^{b(x-c)}$

^d [Poisson\(1837\)](#)

The formula $\frac{e^{-\lambda} \lambda^k}{k!}$

is calculated in Excel with POISSON(k;λ;FALSE). With TRUE the cumulative version is calculated.

NON-NORMAL DISTRIBUTIONS SUPPOSE ASYMMETRIC DEVIATIONS

There are other skewed probability distributions that start at 0, such as the continuous 'Weibull distribution' (*Fig.126p78*), e.g. used for wind velocities (≥ 0 , in a given direction).

The distribution of **incomes** (*Fig.127p78*) is also distorted, but a bureau for statistics may provide data per 'class' (from .. to). In *Fig.127p78* the frequency classes at the higher incomes are large, at lower incomes small. Around €15,000 is a **dent** that would disappear in one large class of €0 to €40,000. The class-middle would then show an 'exponential' downward trend.

Exponential functions are usually written as powers of the number e (*Fig.97p72*). In Excel you write e^x as 'EXP (x)'. If you click on an exponential 'trend line' in Excel for the data of *Fig.127p78*, it draws the continuously falling curve $113.79 * e^{-0.019x}$.^a This 'regression line' therefore deviates considerably from the more detailed data with a bad correlation.

In the formula $a * e^{b * x}$, a and b (the 'parameters') in *Fig.127p78* get the values $a = 113.79$ and $b = -0.019$. You should set these parameters differently each year if the data change. That formula does not *predict* anything yet, but it may be useful in order to estimate intermediate values ('interpolate'). If, after a number of years, you find a trend in the course of the parameters yourself, you can perhaps risk a prediction ('extrapolate').

With a formula $a * (x-c) * e^{b * (x-c)}$ you may approach the data after $x=40$, but before $x=40$ it is totally wrong (in *Fig.127p78* that part is omitted). There ($x < 40$), a 'polynomial' function fits better: $p(x) = 2,3x^0 - 81x + 67x^2 + 0,37x^3 - 0,021x^4 - 0,0004x^5$, but that on its turn does not work after $x=40$.

The two functions combined^b at $x=40$ together describe the data very nice, but if you do not know the trends in all of their parameters, then you still do not have a prediction. In *Fig.127p78* a trend line in a point cloud is drawn as a global relationship between income and its chance. The method of finding such a mathematical relation in a data set is called 'regression'.

REGRESSION REDUCES DEVIATIONS

Suppose a shopkeeper notes the average **price of his products** and his turnover for a few months to find out whether a price reduction is worthwhile (*Fig.128*)^c.

The simplest is, of course, if that relationship shows a straight line $y=ax+b$.

That straight line (reliability $R^2 = 79\%$)^d is only reasonable for those 8 observations, so you may interpolate, but extrapolating may lead to absurdities.

month	price	advertising	turnover
1	4	10	18
2	3,75	10	20
3	3,25	12	24
4	3,75	8	17
5	3	12	22
6	3,5	14	21
7	2,75	20	25
8	3	18	23



The **trend** promises a doubling of turnover $y = -5.6x+40$ if you halve the **price** x . That is dubious, because if the **price line** in *Fig.128* goes to zero (extrapolate to the top left), then the shopkeeper would get a turnover = 40 if he gives away everything for free.

128 Pricing, advertising and sales of a shopkeeper

An advertising expert, to whom the retailer has spent a lot of money each month (column '**advertising**' in *Fig.128*), claims that turnover $y = 0.55x+14$ will increase **from 20 to 25** if you double advertising spending **x from 10 to 20**. The shopkeeper feels that something is wrong. Who guarantees that the increase in turnover is not caused by a simultaneous price reduction?

^a This formula is printed with the 'correlation' curve (eg $R^2 = 81\%$) if you have chosen these options in Excel.
^b Mathematicians do not like this kind of mess.
^c The figures from this list come from **Buijs(2003)** p384
^d https://en.wikipedia.org/wiki/Coefficient_of_determination

What is the relationship between price and advertising with respect to turnover?

If there are more variables in the game, then statisticians switch to 'multivariate analysis'.

There are many kinds of 'multivariate analysis'.^a Let us take 'multiple regression analysis'.

Excel has an add-in for data analysis that provides a formula for this case, for example $\text{turnover} = -4.33 \cdot \text{price} + 0.17 \cdot \text{advertising} + 33.63$. That shows that a price reduction weights much heavier (-4.33) (a steeper slope in *Fig.128* p79) than advertising costs (0.17) for the turnover of this retailer.

The question remains whether these regressions are linear. Perhaps you may approach a better fit by a parabolic, exponential, a polynomial or any other function available in mathematics.^b

In any case, an appropriate choice of functions and variables (such as price and advertising) or the omission of others can lead to false conclusions.

There may be more variables (competition, season, fashion) that pull turnover up or down.

This question is pressing in biological, medical and social applications of statistics.^c

There, it concerns *statistics on heterogeneous sets* of individuals being equal in some aspects, but different in others (already mentioned by Descartes(1684), see p30).

Graunt(1662) studied human mortality statistically for the first time, but Snow(1855)^d found the cause of cholera deaths, the beginning of modern epidemiology and understanding of infection by bacteria and virus. He included the variable of location around a public water tap. The mortal effect of any infection, however, depends on many more environmental and individual variables.

More than 3 coherent variables are difficult to grasp, but we have to deal with them daily.

These cannot be represented in one 2D graph. Many people, however, still make without calculations the right decision intuitively if they have to take many circumstances, parameters with different weights into account.

How do our brains deal with the many data from different senses and memories, weighing them properly? The increased understanding of our neural system led computer experts simulate the functioning of nerve cells (neurons) in an artificial neural network (see § 24p91).

In this century, after a period of trial and error, artificial intelligence has produced useful results.

It recognises 'patterns', not only the known mathematical functions.

It is an *iterative* process in which the weighting of variables by different parameters are repeatedly adjusted ('learning').

Let us first demonstrate that small changes of initial values and parameters may have great effect by 'iteration' (§ 23).

^a **Slotboom(2001)** calls at 'multivariate analysis' the following methods: multiple regression analysis, principal component analysis, factor analysis, canonical correlation analysis, path analysis, variant analysis, multivariate analysis of variance MANOVA, nonlinear multivariate analysis, covariance analysis, discriminant analysis, linear combinations, interaction effects, GLM General Linear Model, cluster analysis and multidimensional scale techniques.

^b Regression is limited to mathematically defined functions.

^c **Graunt(1662)** made early demographic statistics laying the foundation for population statistics and epidemiology.

Quetelet(1835) applied statistics in social sciences and criminology

^d Discovered by **Snow(1855)**

§ 23 ITERATION ENABLES A DETERMINED DIVERSITY



129 Weierstrass^a



130 Koch^b



131 Julia^c



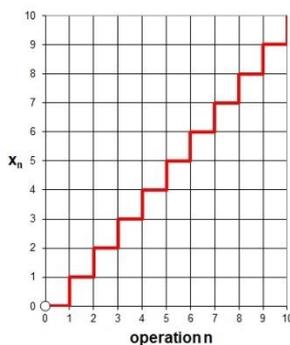
132 Mandelbrot^d

Leading designers of this paragraph

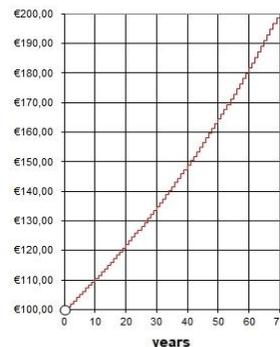
ITERATION HAPPENS EVERYWHERE

If you change a number with a formula and then change *the result* with the same formula, then such a 'feedback' on each previous result is called 'iteration'. The simplest example is *counting*. Its formula is $x_{n+1}=x_n+1$. If x_n is the previous number, then x_{n+1} is the next one.

The number of iterations passed is 'n'. If $x_0=0$, then x_{10} is also 10. So, the result of *counting* is equal to the number of operations 'n'. The number x grows stepwise (**Fig.133**).



133 Counting



134 $x_{n+1} = x_n * 1,01$



135 $y = 100 * 1,01^n$

If you do not add, but multiply, then you get 'interest on interest'.

If you put €100 (x_0) at 1% per year, then after 1 year you get $x_1=x_0 * 1.01=€101.00$, after 2 years $x_2=x_1 * 1.01=102.01$ and after 70 years $x_{70}=€200.68$. That is a doubling in 70 years.

More generally, for every year n is the 'discrete' formula: $x_{n+1}=x_n * 1,01$ (**Fig.134**).

You may also write the result after n years as a 'continuous' formula with an exponent n:

$y=100 * 1,01^n$ (**Fig.135**). That exponential operation does not grow in a jerky manner.

After $n=70$ years, $1.01^{70} = 2,01$ (1.01, 70 times multiplied with the previous result).

The 'argument' 1.01 must be greater than 1 to grow, otherwise your capital will *fall*.

This doubling time of 70 years applies to 0.01 or 1% interest for *each* quantity. In the 'fluid' formula you may make n in smaller steps (even 'dn', indivisibly small). The graph does not rise up jerkily like a staircase per year. With little steps you may also choose $n=1/365$ or $n=2/365$, so your capital will become $100 * 1.01^{1/365}$ after one day, $100 * 1.01^{2/365}$ after two days and so on.

^a [Weierstrass\(1872\)](#) p71-74. Riemann invented the first fractal function (continuous but nowhere differentiable), but Karl Weierstrass proved that his variant was fractal in any detail. It already showed self-similar iterative graphs.

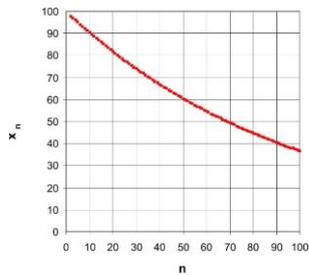
^b [Koch\(1904\)](#) 681-704. Koch found another fractal function known as Koch's snowflake.

^c [Julia\(1918\)](#) based a set of fractals on iterative functions.

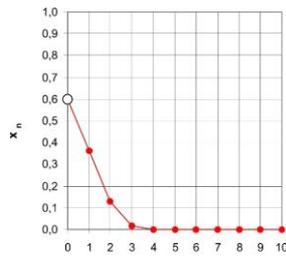
^d [Mandelbrot\(1967\)](#) studied broken curves. In 1975 he coined the term 'fractal': [Mandelbrot\(1975\)](#). He studied and plotted the Julia sets, and in 1979 he introduced the Mandelbrot set: [Mandelbrot\(1982\)](#)

Infinitely iterated adding or multiplying ($n=1 \rightarrow \infty$) results in infinitely large numbers. 'Infinitely large' by multiplication, however, should be larger than that by addition. Such differences in infinity cannot be made visible in any graph. You only know that they have to be different because the one formula grows faster than the other.^a *There are different infinities!*

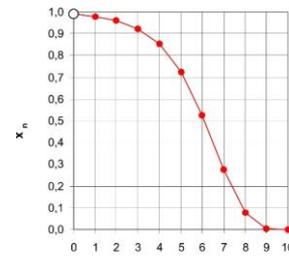
What happens, if you do not take addition or multiplying iterations, but subtracting and dividing? Subtracting makes a 'countdown' ($x_{n+1}=x_n-1$), the limit is an infinite negative number. Dividing, however, the repeated application of $x_{n+1}=x_n/1.01$ on its own result, is actually multiplying by $1/1.01 \approx 0.99$.



136 $x_{n+1} = x_n * 0,99; x_0 = 100$



137 $x_{n+1} = x_n^2; x_0 = 0,6$



138 $x_{n+1} = x_n^2; x_0 = 0,99$

By iteration, the result, $x_{n+1}=x_n*0,99$, will *approach* zero, (**Fig.136**). This formula slows down if you multiply an ever smaller x_n by 0.99. You never come to zero, however often you repeat the operation, but the 'limit' (supposing to repeat infinitely) is simply zero.

Zero seems to 'attract' the result. It is the 'attractor' of this iteration, but not yet a 'strange attractor' that suddenly appears anywhere in the coordinate system, as you will see below in the fascinating images of chaos and fractals.

Repeatedly *squaring* a random number greater than 1, as you could do on an old-fashioned scientific calculator by pressing x^2 each time, shows even faster growth than repeatedly multiplying with the same 1+interest.

With $x_0=1$ it becomes a straight line (-), remaining 1.00, because the square of one is one again.

With x_0 between zero and one ($0 < x_0 < 1$), repeated squaring $x_{n+1}=x_n^2$ fastly *falls* approaching zero.

Fig.137 starts at $x_0=0.6$, but with $x_0=-0.6$ the graph looks almost the same, because already by the first step -0.6^2 becomes 0.6^2 . If you start with $x_0 = 0.99$, then in the beginning it does not go that fast, it becomes something like \surd (**Fig.138**).

A small difference in the 'initial value' x_0 may have major consequences through iteration.^b

REPETITION MAY PRODUCE DIVERSITY

After the unlimited exponential growth of a population predicted by Malthus(1826)^c, Verhulst(1844)^d invented a 'logistic function' (**Fig.104p74**) in order to get a more realistic r figure, when the population meets the limits of the carrying capacity of the land K.

Unexpected graphs may appear, if you subtract a constant from the square ($x_{n+1} = x_n^2 - \text{constant}$).

If you first skip the constant (choosing the constant = 0), and start with $x_0=0.6$, then it approaches 0 already by the third step (**Fig.137**). Starting with $x_0=0.99$ (**Fig.138**), however, it looks like a mirrored (\surd) logistic function (**Fig.138**). But, what if the constant > 0 ?

^a This conclusion is not always valid, but that restriction leads into the specialized mathematical field of transfinite numbers I will not further explore.

^b The result of the iteration $x_{n+1}=x_n^2$ is actually something else than the function $y=x^2$, because that results in a parabola.

^c [Malthus\(1826\)](#)

^d [Verhulst\(1845\)](#) ; [Verhulst\(1847\)](#).

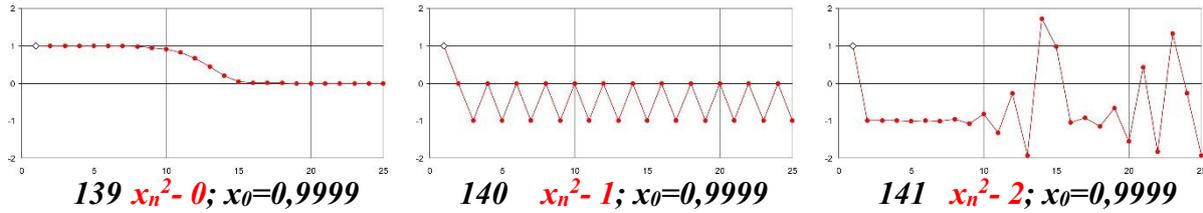


Fig.139 resembles **Fig.138p82**, but in **Fig.139** I chose $x_0=0,9999$ (an even smaller difference with 1). Then, $x_n^2 - 0$ also stays longer near 1 before it goes down approaching zero.

Until $\text{constant}=0.2$ it remains \surd , but if $\text{constant}=1$ (**Fig.140**), then x fluctuates between 2 values. Beyond 1.2, that first becomes 4, then 8 different values, but after 1.3 all values seem to differ. In **Fig.141** the constant is 2, the function has become 'chaos'.

Then it is no longer a smooth function. It has become broken ('fractal') and unpredictable.

So, a very small change of the initial value x_0 or other parameters may yield a very different graph. Your computer may even draw another graph than mine by different rounding offs. Squaring makes any negative number positive, but the subtraction may make it also negative.

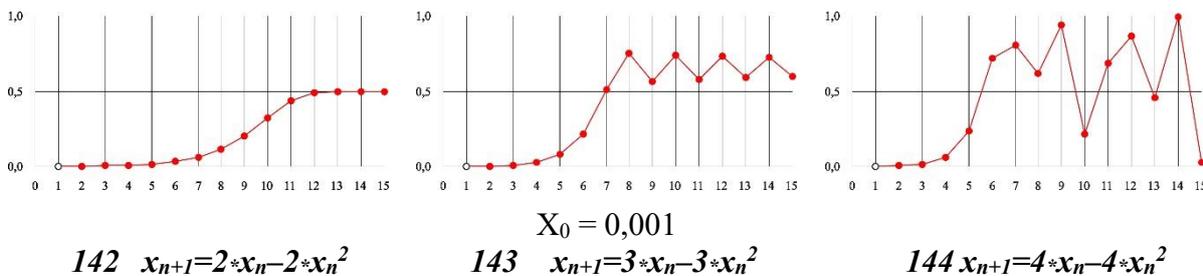
Comparing neighboring values or differentiating and integrating then does not make sense.

The jumping curve is 'not integrable', and rather frustrating for classical mathematicians.^a

I limit myself to iterations with x_0 between zero and one, because then squaring may produce perceptible chaos instead of all kinds of imperceptible infinities.

What happens if you *multiply* the result of squaring with a constant factor? Not much shocking. At low initial values it seems that every next step strengthens the \surd -shape with the same factor, but it remains a \surd form. At an initial value= $1/\text{factor}$ it is a straight line, but at larger initial values the result soon disappears from any drawn graph into infinity.

If you *subtract* x^2 from x and multiply both by a factor 2: $x_{n+1}=2(x_n-x_n^2)$ then with $x_0=0.001$, the curve looks like the \surd 'logistic' curve (**Fig.142**). In **Fig.142- Fig.144**, appear the effect of factors 2, 3 and 4. A factor=3 (**Fig.143**) results in fluctuations, a factor 4 in chaos (**Fig.144**).

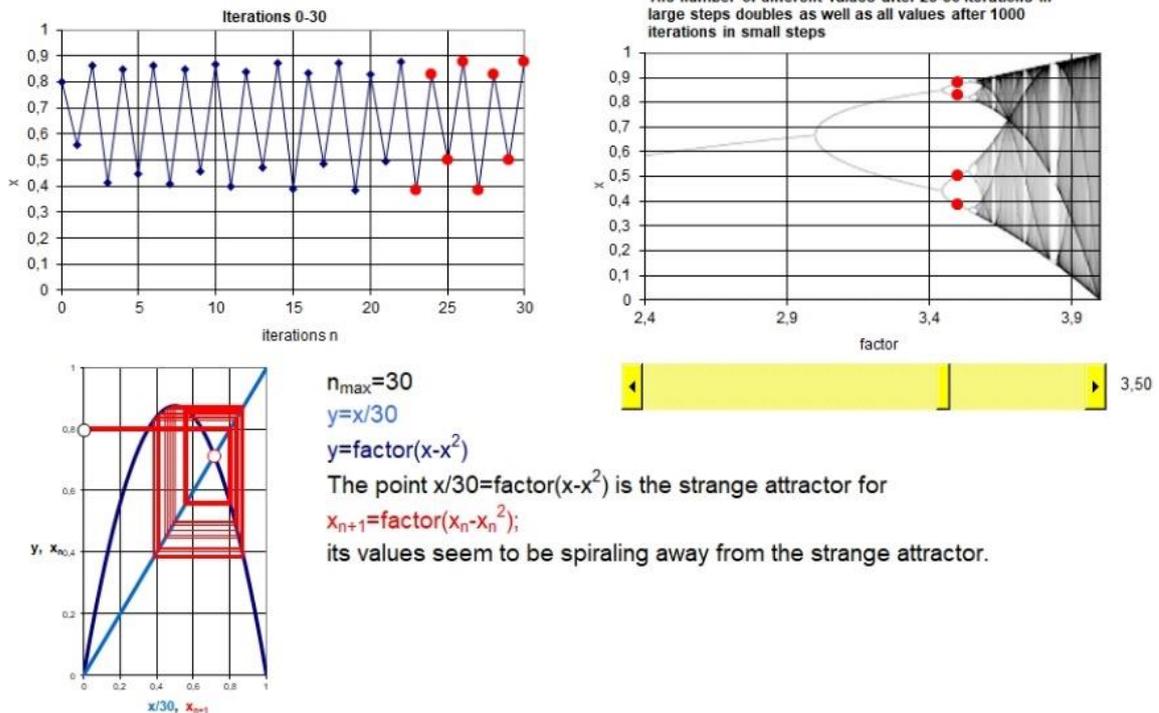


This formula is not the logistic function of Verhulst (**Fig.104p74**). The value of carrying capacity K does not play a role, but it may illustrate three kinds of population dynamics.

Populations often start to fluctuate when they reach the local carrying capacity, and populations that reproduce quickly like insects, often show a chaotic up and down jump.

^a Peitgen(1986) ; Steward(1989) and Tennekes(1990) ; Gleick(1987)

CHAOS HAS SOME ORDER



145 Doubling (bifurcation) of the number of chaotic values x in a fig tree

In 1980 Feigenbaum^a brought some order in the chaos.

Smale^b already had noted that the number of different values x_n in the vicinity of factor = 3.57 doubles after a number of steps and with ever smaller intervals ('bifurcation'), as in a tree whose twigs divide always into two parts (**Fig.145**). After an operation called 'renormalization', each preceding branch with the same shape is 4.669 201 609 times larger.

That tree representation of self-uniformity at bifurcations separated a factor of 4.669 ... from each other, has been appropriately called 'fig tree' honouring Feigenbaum.

That 'Feigenbaum number' occurs in many iterations. This is, for example, useful to understand population fluctuations at the edge of chaos, or if a flow is distributed into ever smaller waves ('turbulence'), such as fluid in pipelines and wind on the earth's surface.

TWO VARIABLES PRODUCE A JULIA SET

Already in 1918, France, Julia^c invented the brilliant formulas $x_{n+1}=x_n^2-y_n^2+p$ and $y_{n+1}=2*x_n*y_n+q$, as x and y coordinates in a plane. If you choose combinations of x_0, y_0 initial values, p and q, then fascinating figures ('fractals') may emerge (**Fig.146p85 - Fig.154p85**)^d.

Any enlargement shows new patterns, sometimes similar to the enlarged.

Julia did not draw his formulas in 1918, but Mandelbrot (p81 note d) did so in 1979 for the first time and revealed their unexpected beauty.

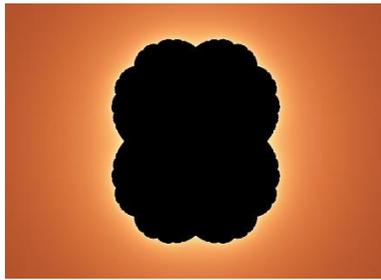
Let us study the influence of the parameters p and q on the resulting figures. These figures already bring a certain order in the chaos of an infinite number of possible Julia figures.

^a Feigenbaum(1978)

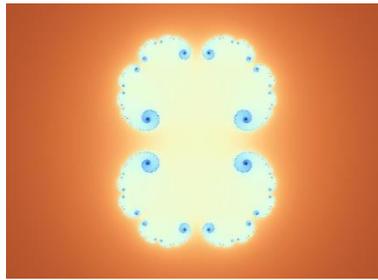
^b Smale(1974)

^c Julia(1918)

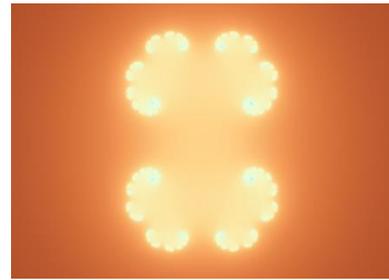
^d For these figures I use <http://fracrive.mimec.org/downloads>



146 Julia $p=0.2; q=0$



147 Julia $p=0.3; q=0$



148 Julia $p=0.4; q=0$

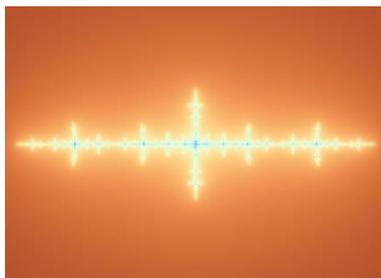
Julia's x and y coordinates: $x_{n+1}=x_n^2-y_n^2+p$ and $y_{n+1}=2*x_n*y_n+q$.

If p and q are both zero, then you get a clean, filled circle, a disk with all points connected to each other. The simulator gives different colors at different degrees of connection. Black usually means that all pixels are filled and connected without gaps. Let's first only vary p and keep q zero.

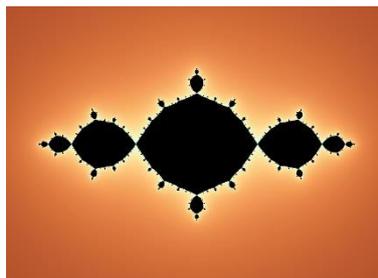
If you choose $p = 0.2$, then that circle distorts to **Fig.146**. In **Fig.147**, at $p=0.3$, parts of it are separated from each other and there are all kinds of spiral details visible that repeat themselves to the smallest details when you enlarge (decreasing the iteration steps) the figure.

In **Fig.148**, at $p=0.4$ everything seems to have come loose.

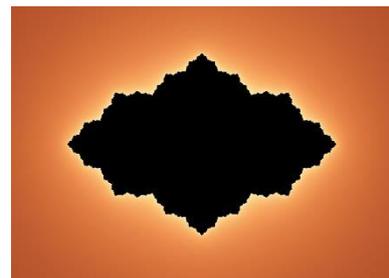
Now the negative values of p . Imagine this series with increasing p 's to be placed before the previous series. I take only a somewhat larger distance between the examples, namely 0.5.



149 Julia $p=-1.5; q=0$

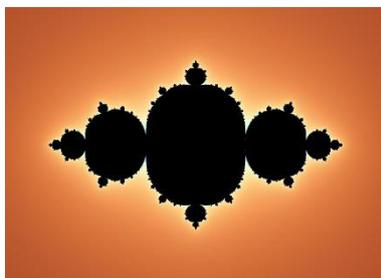


150 Julia $p=-1; q=0$

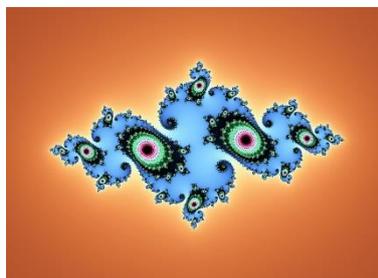


151 Julia $p=-0.5; q=0$

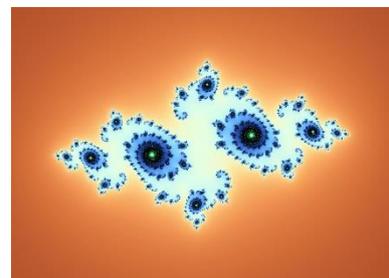
I leave interpreting these differences between positive and negative values of p to the reader. Concerning p , **Fig.152** ($p=-0.75$) is exactly between **Fig.150** ($p=-1$) and **Fig.151** ($p=-0.5$). Let us now vary q with a constant value $p=-0.75$ (**Fig.152** – **Fig.153**).



152 Julia $p=-0.75; q=0$



153 Julia $p=-0.75; q=0,1$



154 Julia $p=-0.75; q=0,2$

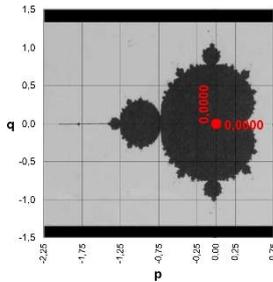
If q varies between 0 and 0.2, q appears to skew the symmetry axes, but at even higher values they also fall apart. The negative values of q fall apart exactly as the positive ones. They also produce the same figures with their negative values, but their symmetry is mirrored by the minus sign.

All these Julia figures have symmetry as a common characteristic. In the area of falling apart, you also often see repetitive spirals. The possibilities are infinite, but limited to pure repetition.

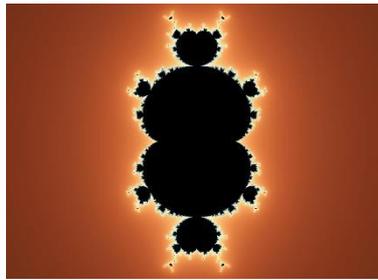
THE MANDELBROT SET IS A CATALOGUE OF COHERENT JULIA-IMAGES

Julia has been forgotten by his fellow mathematicians for 60 years, until Mandelbrot(1977)^a invented the idea to depict p and q in a graph on an x - and y -axis, and to visualise the boundaries where Julia figures fall apart from each other (**Fig.155**). It became the famous Mandelbrot set (**Fig.155**) and Julia was back in the spotlight again, but he died in 1978.

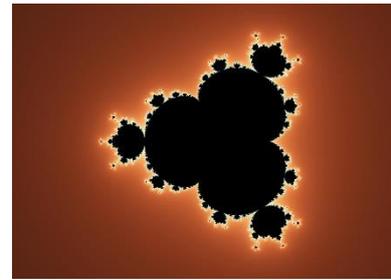
Each point in this set is a combination of p and q , producing a different Julia fractal. The black area represents solid shapes. At the edge you will find the most fascinating fractals. You can endlessly enlarge any fractal by taking smaller steps.



155 p and q in the Mandelbrot set

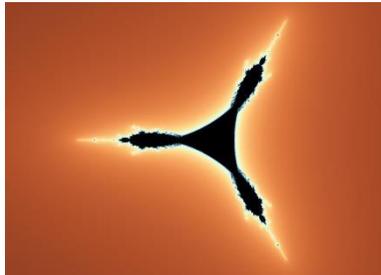


156 Mandelbrot set for third powers

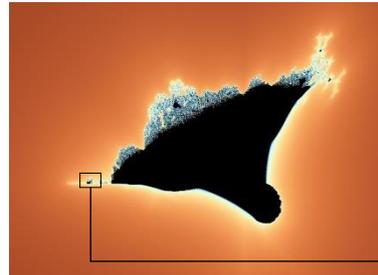


157 Mandelbrot set for fourth powers

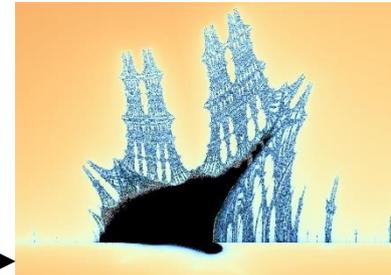
This revolution stimulated the investigation of chaotic formulas. Now there were not only formulas with squares, but also with higher powers for which you could make Mandelbrot sets (**Fig.156** and **Fig.157**). Several additions to the first formula brought other variants of the original Mandelbrot set (**Fig.158 - Fig.160**).



158 Conjugate Mandelbrot set



159 Burning ship Mandelbrot set



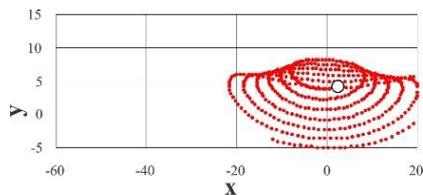
160 Enlargement of the extreme left part of Fig.159

This yields other images such as **Fig.159**. In the enlargements you may recognize the entire image in unexpected places in a different context.

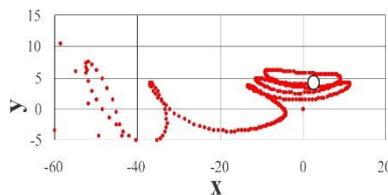
Still no one can explain how or why iteration creates such specific shapes and forms.

^a Mandelbrot(1977)
Mandelbrot(1982)

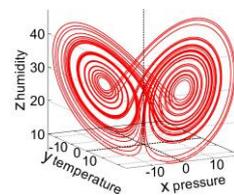
THREE VARIABLES PRODUCE A LORENZ SET



161 Lorenz $s=30, r=0, b=0$



162 $s=30, r=3, b=0$



163 $s=10, r=28, b=8/3$

Meteorologist Lorenz^a understood already in 1963 that, in order to simulate the connected fluctuations of atmospheric pressure (x), temperature (y) and humidity (z) requires a succession of phases obeying an fractal-like iteration of at least *three* operations.

He invented three mutually dependent formulas for x, y, and z, with three parameters s, r, b:

$$\begin{aligned} X_{n+1} &= X_n - s * (X_n - Y_n) \\ Y_{n+1} &= Y_n + X_n*(r - Z_n - Y_n) \\ Z_{n+1} &= Z_n + (X_n*Y_n - b*Z_n) \end{aligned}$$

Any phase of weather then can be plotted in a three-dimensional x-y-z graph, the 'phase space'. Any next phase is based to the previous one. A small difference in the initial values x_0, y_0 and z_0 causes an increasingly different result by the next steps in time x_n, y_n and z_n .

The resulting curve is the 'phase portrait' of this system of equations.

If you make the steps small enough and then only look at the first 500 steps in the x-y plane (**Fig.161 - Fig.162**), then you already may surmise what may happen by the next steps.

If you keep r and b at zero and only s varies (**Fig.161**), you will see a spiral that seems to revolve approaching a point called a 'Lorenz attractor'. Wherever you start ('initial value') in the phase space, you will end up with a spiral. Above $s=30$, those windings only become wider.

At $r=3$ (**Fig.162**) it looks like a sloppy spring with more or less regular windings.

If at $s=30$ you start increasing r from zero, then at $r=1$ almost nothing happens, but at $r = 2$, a winding loosens to form a second spiral at $r = 3$. That spiral revolves around a second attractor. Changing b then has little effect, the image only distorts a little.

Lorenz first examined the behavior of $r=28$ (the 'Rayleigh number'^b) at $s=10$ and $b=3/8$.

With 10000 steps (points in time) you then get **Fig.163**^c, the 'Lorenz butterfly'.

With the parameters s, r and b you can make infinitely many phase portraits that have little to do with the real weather, but it may help to understand why weather forecasting is so difficult.

These x, y and z are not the only dimensions that play a role in the weather forecast.

There are many more. The weather in the longer term only can be predicted if you could precisely measure or determine all parameters and initial values with an infinite number of digits after the decimal point. And that is not possible.

At most, you may repeat the phase portrait and calculate the probability of ending up in a certain phase (for example a whirlwind).

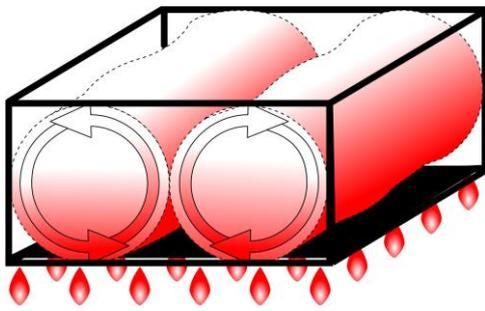
There is some regularity, but where on Earth that will probably arise, is not yet certain.

^a [Lorenz\(1963\)](#)

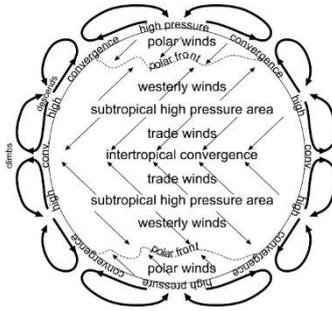
^b Rayleigh number is the property of a fluid that determines how heat is transferred throughout the fluid.

^c How that works is beautifully explained in <https://blogs.mathworks.com/cleve/2014/04/28/periodic-solutions-to-the-lorenz-equations/>

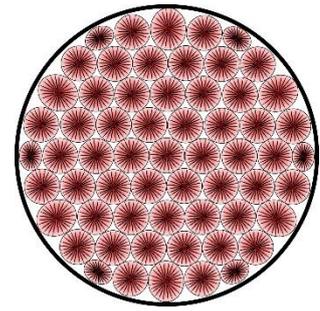
BÉNARD CELLS SHOW EMERGING ORDER IN CHAOS



164 Cylindric convection



165 The atmosphere



166 Bénard cells

Lorenz was inspired by a round bowl of water that Bénard^a in 1908 (*Fig.166*) heated slowly and very evenly. If you heat up a *rectangular* bowl of water (*Fig.164*), the temperature of the water will rise from hot below to cold upwards ('conduction').

The water sets in motion ('convection') because hot water is slightly lighter than cold water and therefore rises (especially in the middle).

That hot water flows off to the walls cooling off and thus creates a cycle that, if you are lucky, makes the water run in two cylinders (*Fig.164*).

Such cylinders can also be found on a much larger scale in the atmosphere (*Fig.165*).

However, that system is soon disturbed when further heating up.

The cylinders start to wave in the length and finally the water starts bubbling chaotically.

When these phase transitions take place depends exactly on the temperature difference between bottom and top, the height of the tray, the gravity, the expansion of the water, its viscosity and its willingness to mix. These influences are nicely summarized in a formula that results in the so-called Rayleigh number. And that was Lorenz's parameter r !

If r is less than 1 (*Fig.161p87*), then the water is not yet moving, there is only conduction of the heat upwards. Between $r=1$ and 24.06 you may see two cylinders running.

In terms of Lorenz, a second 'attractor' comes in (*Fig.162p87*). If r becomes greater than 24.74, then it becomes chaos. The spirals of Lorenz do not run to a center, but go to infinity, where somewhere a third strange attractor appears to have started operating.

Bénard, however, used a round tray, which, if you're lucky, gives a pattern of round, donut-like cells that fit in a hexagonal pattern (*Fig.166p88*).

GLOBAL ORDER COMBINES LOCAL CHAOS IN AIR CIRCULATION

If you look at the dominant global airflow in general, cooling air will drop down at the poles and heated air will rise at the equator, so that a constant air circulation is created.

The air rising the tropics, however, cools down earlier on the way to the poles and descends to the subtropics, in order to find its way to the north and south at the surface of the earth (for us observable as wind). As a result, three toroidal air circulations develop on each of the two hemispheres. They interlock as gears (*Fig.165p88*). You also need an odd number of gears to turn clockwise again.

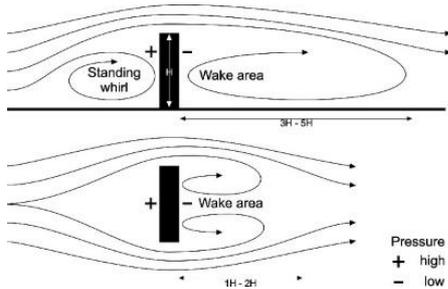
During that process, however, the entire atmosphere also moves with the earth from west to east. At the equator the earth's surface moves with 1600 km/hour, but in the temperate zone with 1000 km/hour.

^a [Bénard\(1900\)](#)

In a northern latitude the dominant wind towards the pole is deviated by its higher speed from the equator to the east. The wind then comes from southwest due to its eastward velocity impulse from the larger equator circle. South of the subtropics, on the other hand, it comes from the northeast.

Sailors on their way to America have been sailing south for years to visit the 'trade winds' (NE passates) and from America first to the north and from there back to Europe to use the westerly wind (**Fig.165**p88). The ocean water may also be pushed up by these winds, so that a large ocean swirl (the Gulf Stream) gives the ships a boost under water.

LOCAL WHIRLS EMERGE IN A REGULAR FLOW BEHIND OBSTACLES



167 Whirls behind obstacles



168 Kármán vortex street near California^a

At the boundary of the atmosphere and the earth's surface, all kinds of smaller whirls are created in the air behind mountains and buildings as counter-rotating smaller gears (**Fig.167**). There, the accumulated air seeks a way out in a corkscrew movement upwards or passes behind the obstacle in a series of vertical whirls (a von Kármán vortex street, **Fig.168**).

In fractals the ever recurring spirals are striking and we recognise them in many real movements as well. That is obvious, if similar processes *repeat* on an increasingly smaller scale. Nature's repetition, however, is not exact, and context-sensitive. As soon as semipermeable membranes develop in evolution, the context at both sides of the membrane will differ.

If membranes selectively close a cell, then other laws apply.

If membranes develop within a cell, numerous new environments may arise for processes with their own laws. The parameters for pressure, moisture content, temperature difference, size, the expansion of material, its viscosity and the willingness to mix^b, shift everywhere.

Predicting is doubtful by so many small differences in initial values and parameters with great impact.^c Wolfram (2002) did not give up hope.^d In more than 1250 pages, he explained little more than that we have to reverse the case, and compare all conceivable fractal and chaotic forms with what we find in reality. But that is only a formal similarity.

SIMILARITY IS NOT YET ORGANIZATION

Life phenomena tend to unmix by separation: different processes get their own environment. Organs and organisms get different functions, structures and shapes, far from self-conformity at different levels of scale. A tree and its leaves may look similar, but a tree does not have a compact form, and its structure and function are different from those of a leaf.

Propagation may be reminiscent of self-uniformity, but you are definitely different from your parents, even if you resemble them. Every species is different and within each species each specimen is different (perhaps except *exact* cloning). Moreover, each copy also ends up in a different context, which means also that its history and *learning experience* will be different.

^a From <http://fuckyeahfluidynamics.tumblr.com/post/1093448891/the-von-karman-vortex-street-isnt-just-found-in>

^b Entropy (a physical probability term for disorder) is decreased on a small scale, paid with increased disorder outside the separated space.

^c Tennekes(1990)

^d Wolfram(2002)

Counted in millions of years, your ancestors are even a different species. The formula for evolution is simple: procreate and die. That propagation must yield variants. What survives evolves further, the rest dies out. That formula does not work with exact uniformity, but only with variation, little changes in initial values and parameters.

Iteration sometimes produces astonishing self-similar patterns that remind of natural phenomena. It is, however, based on the *exact* repetition and should not surprise us. Repetition is common, but never exact in living nature, and repetition is something else than self-organization (developing organelles, organs, organisms, and organizations).

It is at most pattern formation. Self-uniformity on different levels of scale such as spirals and whirls are rare in living organisms. In the society of different organisms, studied in ecology, it sometimes *looks* like that. There is much repetition, but it is never *exactly* the same.

Between the scale levels with a nominal radius of 3000km to 30m, the human traffic network has a hierarchy that is sometimes roughly coincidental with a factor of 3 of self-similar hierarchy^a, but that is based on *human* optimization^b.

Ecological phenomena should be studied separately at different levels of scale.

Otherwise you may overlook the trap of a scale paradox (**Fig. 9p9**): the potential reversal of conclusions on a three times larger scale. The patterns on 1m radius may seem equal to those on 10m radius, but different on 3m radius. In that case you should be aware of substantially different phenomena falsifying your generalisation.

^a [Jong\(2012\)](#)
^b [Nes;Zijp\(2000\)](#)

§ 24 A NEURAL NETWORK CORRECTS ITS SUPPOSITIONS



169 Turing^a



170 Simon^b



171 Minsky^c



172 Rosenblatt^d

Leading designers of this paragraph

AN ARTIFICIAL NEURAL NETWORK (ANN) SIMULATES THE BRAIN

An 'Artificial Neural Network' is a mathematical simulation of nerve cells ('neurons') interconnected with conductors ('axons') in a living organism.

Every human contains an estimated 86 billion neurons, each with many incoming and outgoing connections with other neurons, senses, muscles or organs. These are able to *correct* their connections (suppositions) by *weight* and allow them to die or arise. In the artificial simulation they cannot die or arise, and the neurons got the weights from a changeable list instead of axons.

In a neuron, the incoming signals are combined, and the neuron determines to what extent this combination should be passed on as an outgoing signal (weakened or strengthened) to a next layer of neurons. A large artificial neural network (ANN) may contain hundreds of billions neurons, each, however, with a limited number of incoming and outgoing connections.

THE INPUT IS A SET OF PATTERNS, THE OUTPUT IS THEIR CATEGORIZATION

The input (from observations) of the ANN is a table with numbers 'normalized' between 0 and 1 ('scaling'). Let us take the S.O.S. morse code **••• — — — •••** noted as $\frac{1}{3}\frac{1}{3}\frac{1}{3}000111000\frac{1}{3}\frac{1}{3}\frac{1}{3}$ (a row of 15 numbers). Take 4 deviant variants, some meant as S.O.S., and some definitely not.

Each row of that 5*15 table is a *pattern* of values, the sequence of number codes, some with failures, but meant as S.O.S. and others definitely not. Each *row* contains a different pattern. The aim is now, to recognize which of them are probably *meant* as S.O.S. and which are not.

There are then 5*15=75 input neurons. They pass their code for each row in each column into a column of a smaller number of neurons (a column called 'hidden layer' of the ANN).

Each hidden neuron then receives 75 signals (numbers) of the 75 input neurons per input line, weight them, and combines them into one output signal to a next layer of neurons.

a Turing(1936) Alan Turing laid the theoretical foundation for AI and raised substantial questions about machine intelligence.
b Simon(1966) Herbert Simon has been an authority on the intersection of economics (Nobel prize 1978), psychology, cognitive science, statistics and organization theory. He defined 'intuition' as a set of context memories ('bounded rationality') and designed early AI models with cognitive approaches to problem solving.
c Minsky(1985) Marvin Minsky, one of the founders of AI had a major influence on the direction of AI research.
d Rosenblatt(1962) Frank Rosenblatt designed the first neural network (ANN). His ANN 'perceptron' remained underestimated for a long time after Minsky's criticism ('AI winter' 1974–1980), but regained interest at last.

EACH PART OF A PATTERN IS TAKEN MORE OR LESS SERIOUS FOR RECOGNITION

The neurons of a hidden layer, do not attach the same value or 'weight' to each incoming column signal. These weights are initially random, but later they are adjusted by an iterative feedback, a 'learning process'. Each neuron in the 'hidden layer' weighs the incoming signals with their own list of weights per column. These weights are adjusted in a next round of calculations.

How does such a hidden neuron combine all those signals into a single outgoing signal (number) for the next layer of hidden neurons? It multiplies each incoming signal with the corresponding weight, edited with a formula^a that gives them a value between 0 and 1 ('scaling') or 0 or 1. The sum of these products is passed to the neurons of a next layer.

RECOGNIZED ERRORS DETERMINE WHAT HAS TO BE TAKEN MORE SERIOUS AND WHAT LESS

The next layer may be a smaller number of neurons that do the same with the results of the previous layer, until it reaches a single neuron as the last layer.

This 'output neuron' then also has its own list of provisional weights, with which the output of the ANN is determined in the same way as the outcomes of the previous layer for each row.

If you want the ANN to recognize the character A in the entered patterns (for example 16x16 pixel icons), then give each row with a pattern that looks like an A the value 0 (or 1 if not). This creates a column ('wish') of ones and zeroes.

Subtract that from the output values that ANN found, in order to find a list of deviations. The positive square of each deviation is called 'error'. The sum of all those errors is the average error ('Mean Squared Error' or 'MSE'). MSE finally should become near to zero.

TRAINING SUPPOSES RECOGNIZING PATTERNS FROM KNOWN EXAMPLES

ANN adjusts all weights in order to decrease MSE.^b

MSE does not always reach (nearly) zero at once. After each adjustment you will see MSE (the percentage of errors) decrease. It adjusted all weights a bit.

If you are not satisfied (for example, if the MSE is not smaller than 0.01 or 1% chance of errors), you simply put it back to work. This process is called 'training the neural network'. The network that does not 'know' anything yet, starts with random weights.

As soon as the chance of errors is less than 1%, the network has 'learned' to recognize the pattern almost faultlessly. That knowledge is stored in the table weights that determine how seriously the neurons have to take their input in order to make no mistakes.

TESTING SUPPOSES APPLYING SERIOUS INDICATORS ON UNKNOWN EXAMPLES

You now can test ANN without giving the right answer. If you add a new pattern such as an arbitrary character as a test row to the input list, without telling if it is an A, then ANN says 0 ('this is an A!') or 1 ('this is not an A!'). You then have a 99% chance that she is right.

NEURAL NETWORKS ARE USED IN ORDER TO RECOGNIZE PATTERNS

For example, credit providers have many characteristics of their debtors such as age, home ownership, gender, and so on. From experience, they also know who will or will not pay back in time. The question is, whether a pattern for defaulters can be recognized in the row of features per person. It is better not to give a loan to that risk group.

For example, you may also recognize a pattern in:

- the course of stock prices of various funds in the past and respond to this;
- the sale of products in different seasons, holiday periods, and so on;

^a For example $f(x)=1/(1+e^{-x})$ produces a value of x between 0 en 1.

^b Excel, for example, has a 'solver' plug-in that adjusts the preliminary parameters (weights) used in any formula in order to minimize or maximize the end result. In this case, you want to make the average error (MSE) as small as possible. So you ask the solver 'minimize' MSE.

- the course of the weather in different weather conditions in previous days;
- properties of plant species to trace their name.

The last application is a classification problem. That is best served by more than one hidden layer. They sequester to a result successively. Different problems may therefore require different network configurations. Many different suitable configurations have been found in the human body for various tasks.

For example, 'circular configurations' are held responsible for our memory.

In addition, the neurons and axons may also be very different and their connections may change. Connections may degenerate or be newly created. Our neural system is differentiated and flexible in details, but the *number* of neurons is largely fixed from birth.

If our pattern recognition proceeds according to the scheme of artificial neural networks, it could for example explain how we combine the totally different information from different senses into the constant awareness of a variable object ('synaesthesia'). You may imagine how the actions of dozens of muscles are coordinated as a training-based pattern into one specific activity.

EVEN IF YOU KNOW HOW IT WORKS, YOU STILL MAY NOT UNDERSTAND HOW IT WORKS

Such a mathematical simulation of biological examples may lead to other suppositions about our functioning. It appears to be a barely comprehensible alternative to current mathematical optimization techniques or multivariate analysis (p80 note a).

ANN expresses the weights in numbers, but our own neural network uses chemical reactions. ANN adjusts these numbers in a round of mathematical feedback operations ('solver' in Excel). How does that feedback work chemically in a living organism? I don't know.

You may simulate a simple neural network in Excel^a

If you want to present to ANN the list of the shopkeeper of *Fig.128* p128, you first have to convert that list (*Fig.173* columns **B C D**) into numbers between 0 and 1 ('scaling' in **H I J**).

The shopkeeper must specify (**F**, 'wish') whether is satisfied (0) or not (1).

In this case he is satisfied when the turnover minus **advertising** (**E**) is larger than 9, but ANN is not aware of that motive. She only sees the scaled patterns of **H I J** and the wish-list.

ANN now becomes the student you should train and test.

	A	B	C	D	E	F	G	H	I	J
1	month	turnover	price	advertising	t-a	whish		turnover	price	advertising
2	1	18	4,00	10	8	1	too little profit	0,125	1,00	0,167
3	2	20	3,75	10	10	0	OK	0,375	0,80	0,167
4	3	24	3,25	12	12	0	OK	0,875	0,40	0,333
5	4	17	3,75	8	9	1	too little profit	0	0,80	0,000
6	5	22	3,00	12	10	0	OK	0,625	0,20	0,333
7	6	21	3,50	14	7	1	too little profit	0,5	0,60	0,500
8	7	25	2,75	20	5	1	too little profit	1	0,00	1,000
9	TEST	23	3,00	18	5	1	too little profit	0,75	0,20	0,833
10							ANSWER	(B9-B\$12)/(B\$11-B\$12)		
11	MAX	25,00	4,00	20,00	AFRONDEN.NAAR.BENEDEN(MAX(D\$2:D\$9);2)					
12	MIN	17,00	2,75	8,00	AFRONDEN.NAAR.BENEDEN(MIN(D\$2:D\$9);2)					

173 The wish list and the scaling into normalized values in Excel

You can teach ANN

You first teach ANN how she should *evaluate* the patterns from month 1 to 7 (the wish column). The last row you don't tell her as a test rule to see if she shares the judgment of the shopkeeper after training, with the experience of a pattern that is unknown to her. *You* can also deduce that

^a [Choong\(2009\)](#) provides a clear explanation for some operating ANN-applications in Excel.

from 'sales minus advertising' (t-a), but ANN has no idea of that motive. She sees only the patterns H I J, as evaluated with a one or a zero (1 means 'too little profit').

Fig.173 and **Fig.174**p94 together give a complete picture of this simple ANN in Excel.

It consists of 3x7 scaled Input neurons (the columns H I J of **Fig.173**).

Fig.174 p94 shows a list of random weights, two hidden layers (AC Hidden 1 and AD Hidden 2) and one Output column AK.

Hidden 1 and 2 (in **Fig.174**p94 distinguished by shades of green) will each receive the input of their own **three** weights.

The **Output** column in turn will produce the results from Hidden 1 and 2 with **two** weights. From that output, the wish list is subtracted, so that only the deviations remain.

The square of each deviation is called '**error**' and the mean of those squares is called '**MSE**'.

Excel generates random numbers between 1 and -1 in column V to be copied (their *values*, not their formulas!) as arbitrary weights in column W. (Excel immediately starts generating new random numbers, but that does no longer play a role.)

ANN has not yet learned anything with these random weights, and the number of errors coincides (**MSE = 25%**). The training can start in order to minimize the errors in **MSE**.

	V	W	XYZAA	AC	AD	AAAAAA	AK	AL	AM	AN	AO	AP	AQ	AR
1	copy as VALUES >	Weights		Hidden1	Hidden2		output	wish	error	MSE				
2	0,811543133	-0,102496637		0,4850087	0,6324399		0,59025	1	16,79%	24,16%	SOM(AM2:AM8)/AANTALARG(AM2:AM8)			
3	0,083267510	-0,132244341		0,4814689	0,5541936		0,58388	0	34,09%					
4	0,109100127	0,555437945		0,4975161	0,3962324		0,57285	0	32,82%					
5	-0,697747296	-0,795611919		0,4735758	0,6235547		0,58863	1	16,92%					
6	-0,755277800	0,630829761		0,5142804	0,4137580		0,57560	0	33,13%					
7	0,972097142	0,067920544		0,5292477	0,5036630		0,58384	1	17,32%					
8	-0,586328144	0,334740467		0,5969967	0,3257015		0,57547	1	18,02%					
9	-0,788884537	0,32041375												
10	ASELECTUSSEN(-1000000000;1000000000)/1000000000						1/(1+(EXP(-(AC9*\$W\$8+AD9*\$W\$9))))							
11		these weights should be adapted by the solver		1/(1+(EXP(-(H9*\$W\$2+I9*\$W\$3+J9*\$W\$4))))			1/(1+(EXP(-(H9*\$W\$5+I9*\$W\$6+J9*\$W\$7))))							

174 ANN does not know anything yet; she has still 25% chance to make mistakes

You can train ANN

Ask Excels solver to adjust ANN's weights in order to minimize **MSE** (mean chance on errors). On solvers menu you choose the possibility to minimize cell **MSE** by adjusting column W (the weights) with the 'evolutionary method'. Once you have given that assignment, you see **MSE** near 0%, eventually after several training rounds (**Fig.175**).

The solver stops with the announcement that he has found a solution. If **MSE** is not yet less than 1%, then let him do the same again. If the *training* is successful, then you may *test* ANN.

	V	W	XYZAA	AC	AD	AAAAAA	AK	AL	AM	AN	AO	AP	AQ	AR
1	copy as VALUES >	Weights		Hidden1	Hidden2		output	wish	error	MSE				
2	0,733207205	-28,945717411		0,8880656	0,0000036		1,00000	1	0,00%	0,00%	SOM(AM2:AM8)/AANTALARG(AM2:AM8)			
3	-0,938407444	-1,910457724		0,0006685	0,4350409		0,00000	0	0,00%					
4	-0,292882606	30,439334567		0,0000001	0,0000000		0,00000	0	0,00%					
5	-0,565324830	40,945397089		0,1782329	0,0002864		1,00000	1	0,00%					
6	-0,774106260	-10,197310578		0,0002419	0,9998223		0,00000	0	0,00%					
7	0,024406569	-44,747931419		0,4014406	0,0003288		1,00000	1	0,00%					
8	-0,267800830	90,90029908		0,8166206	0,0218271		1,00000	1	0,00%					
9	-0,103830249	-57,15271541												
10	ASELECTUSSEN(-1000000000;1000000000)/1000000000						1/(1+(EXP(-(AC9*\$W\$8+AD9*\$W\$9))))							
11		these weights give a good result		1/(1+(EXP(-(H9*\$W\$2+I9*\$W\$3+J9*\$W\$4))))			1/(1+(EXP(-(H9*\$W\$5+I9*\$W\$6+J9*\$W\$7))))							

175 ANN has adjusted her weights; now test her to recognize an unknown pattern

You can test ANN

Copy the *formulas* (not te values!) AC8 into AC9, AD8 into AD9 and AK8 into AK9 (**Fig.176**). Hidden 1, Hidden 2 and the Output column then should display the values of that row as a result of the data in **Fig.173**p93 (H9, I9, J9), produced by the new weights.

ANN now gives the correct opinion (1 : 'too little profit') about the unknown eighth pattern!

	V	W	XYZAA	AC	AD	AAAAA	AK	AL	AM	AN	AO	AP	AQ	AR
1	copy as VALUES >	Weights		Hidden1	Hidden2		output	whish	error	MSE				
2	-0,997260567	-28,945717411		0,3880658	0,0000036		1,000000	1	0,00%	0,00%				
3	-0,633160957	-1,910457724		0,0006685	0,4350409		0,000000	0	0,00%	0,00%				
4	-0,549880974	30,439334567		0,0000001	1,0000000		0,000000	0	0,00%	0,00%				
5	-0,695700167	40,945397089		0,1782329	0,0002864		1,000000	1	0,00%	0,00%				
6	0,616388051	-10,197310578		0,0002419	0,9998223		0,000000	0	0,00%	0,00%				
7	-0,039383606	-44,747931419		0,4014406	0,0003288		1,000000	1	0,00%	0,00%				
8	-0,075077620	90,90029908		0,8166206	0,0218271		1,000000	1	0,00%	0,00%				
9	0,272593607	-57,15271541		0,9635517	0,0001884		1,000000	1	0,00%	0,00%				
10	ASELECTUSSEN(-1000000000;1000000000)*1000000000						1/(1+(EXP(-(AC9*\$WS8+AD9*\$WS9))))							
11		these weights give		1/(1+(EXP(-(H9*\$WS2+H9*\$WS3+J9*\$WS4))))										
12		a good result!		1/(1+(EXP(-(H9*\$WS5+H9*\$WS6+J9*\$WS7))))										

176 The answer of ANN is right

The ANN detailed here is a simple example that you may expand with many more neurons: you may fill in the rows and columns of the input neurons with much more data.

The instrument is numeric, but non-numerical data may be differentiated by numerical coding or given a separate column. The 'wish' column may thus contain more values than 0 or 1 or be divided in more columns with more criteria ('this is an A', 'this is a B').

If the average error (MSE) is not small enough yet, you may extend the configuration with more hidden layers than Hidden1 and Hidden2 used here. For different problems you may design different (consecutive, side by side, branched or circular) network configurations.

USUAL STATISTICAL METHODS RECOGNIZE ONLY WELL-KNOWN PATTERNS

What is the difference with statistical 'multivariate analysis' methods?

According to some statisticians, ANN offers nothing more than 'non-linear multivariate analysis' and 'discriminant analysis' that may also be performed with conventional statistical software.^a

This is a one-sided vision from mainly numerical data analysis. It reveals an extensive background of unspoken pattern-recognizing mathematical suppositions (graphs) among statisticians.

The regression patterns are limited in statistical practice to known mathematical functions (linear, exponential, polynomial, etc.). It already has been difficult to invent a combination of known functions for the distribution of income in **Fig.127** p78.

Then try to invent a mathematical function that describes the character A.

An ANN does not have that restriction: any pattern can be recognized.

If you give an ANN thousand data sets (lines) of one hundred per line of data (columns), and you then tell her on each line whether the set is linear, exponential or polynomial (for example in the wish column coded as 1, ½, 0), then that ANN, after training, may recognize a mathematical function in this way, even though there is no question of 'understanding'.

You can also use this method to recognize formulas such as $ax + b$, $ax^2 + bx + c$ and so on. That goes with their operation in the software of Excel all by itself, but to *make* that software a human neural network has been necessary. In order to be able to make such curves in all their parametric variation and finally even make sense of them, another ability is needed.

This ability must not only be able to distinguish identifiable patterns that meet a 'wished' characteristic, but it may also dissect a pattern in detached properties (analysis and abstraction) that have not yet been named in columns (the input neurons).

We had pre-appointed the import categories and were then able to deduct the advertising (and all other costs) from the turnover to also name something as 'profit'.

This not only involves combining predetermined constituent data that makes a pattern recognizable, but also to analyze a given pattern and to make new patterns from those parts.

^a Sarle(1994)

'Judgment ability' in the classical sense is attributing characteristics to existing parts and wholes and their distinctive or summarizing naming.

The creative ability to invent patterns that do not yet exist as a whole or in parts (designs) goes even further. I do not know if such ANN configurations may be thought of. Perhaps the connections should be changeable. They are still stable in an ANN.

To make an ANN that knows and can do everything what a statistician or a normal person knows and can do, you will need innumerable neurons in different configurations for different tasks.

These are apparently spatially separated in the living neural networks. Then you have to train and test that network. The latter may require a training that is just as long-lasting as what people need to come to the 'years of discernment'.

This upbringing now mainly consists of pre-saying and checking whether it is 'understood' (in the limited sense of 'usable for other wishes, in other situations, with different patterns').

The corrections in relation to a precooked list of 'good answers' are, in principle, still external. In evolution, the outside world is basically merciless: wrong is dead. Imagination then is a benefit: first simulate, then do. Every success should be remembered and can be called up for repetition by an unblocking stimulus in order to survive.

That course of action repeated descends into another configuration in the neural network as a routine that makes time-consuming simulations in advance unnecessary. With a threat the reaction *speed* is competitive. For unknown circumstances, the ability of prior simulation remains.

In the described ANN, the import and its classification were precooked. That applies also for an explanatory statistician, but for the reliable and valid handling of existing formulas, in addition to this description, a long-term training in mathematical foundations and their convincing evidence is assumed.

Those bases include a series of steps that suppose each other in a strict order. All our actions (e.g. muscular movement), however, suppose (perhaps less strictly) such a series of preceding, learned, tacit, 'self-evident' routines, suppositions and representations.

Subsequently, if you detach all routine, ready to change usual suppositions then you keep the domain of designing: searching for possibilities that are not yet true or probable, and even not necessarily wanted by anyone.

§ 25 MATHEMATICS ARE BUILT ON SUPPOSITIONS^a

This chapter is entitled “Mathematics supposes *equality* and repetition”, where repetition supposes *equal* change. Indeed, equations suppose *equality* symbolised as ‘=’, and numbers suppose a repetition of *equal* units. However, equations without *different* expressions at both sides of ‘=’ have little sense, and 1, 2, 3 ... are definitely *different*.

If difference includes equality (§ 2p6), then even the suppositions of mathematics should start by difference. Each question about a quantity supposes an answer on ‘Which quantity?’ e.g. ‘Height, width or depth?’. Height, width, depth are *qualities* (properties) of an object, but imagining quality does not *suppose* an object. The reverse: qualities *enable* to imagine an object.

In § 7p15⁺ I propose that equal differences in any direction enable to imagine an object. The differences may concern *any* quality, e.g. form, colour, coherence or even movement. Difference of *any* quality is difference as such, but there are different differences (qualities). That enables to specify *Fig.15p14* as successive suppositions of mathematics.

A Mathematics \Downarrow ^b **different** internally *equal qualities* (homogeneous, without differences).
An environment of **changing** qualities \Uparrow a less changing **object** (coherence).
An object \Uparrow **separation** of different qualities a,b,c ... \Uparrow a **function** $f(a,b,c, \dots)$ of the object.

If a quality \Uparrow separation in equal parts (*units*), then quality \Uparrow **quantity** (\Downarrow unit).
A quantity of units \Uparrow a **variable**. So magnitude \Downarrow variable \Downarrow quantity \Downarrow unit \Downarrow function \Downarrow qualities.
Combination of different units \Uparrow new unit \Uparrow new variable.
Combination of different variables \Uparrow new coherence \Uparrow new function.

B **Function** \Uparrow **metabolism** of an input (x) into a different output (y).
Functions with a *different* input and an *equal* output \Uparrow **equation**.

Regulation \Downarrow changing the metabolism from input into output \Downarrow 'parameters'.
Coherent regulation \Uparrow **organization** in subsequent equations ('algorithm').
A selection of algorithms \Uparrow **specialisation** for a specific task ('application').
Reproduction of applications brings mathematics into the **Cultural** layer.

C Applications may be reproduced \Uparrow **understanding**^c \Uparrow **certainty** ... \Uparrow **publicity** \Uparrow **influence**.
A patent or a copyright connects that sequence to an *certain* creator. Groundbreaking results in mathematics still bear the name of *influential* mathematicians. Honor where honor is due.

Mathematics extends imagination beyond probability or even possibility and desirability.
It releases blocking suppositions. It attacks commonly shared suppositions.
It enables freedom of imagination without a context, except a context of ... *difference*.

GEOMETRY

Euclidean geometry \Downarrow **differences** of place \Uparrow difference as **distance**.
The smallest distance \Uparrow a **point**. A distance filled with points \Uparrow a **straight line** \Uparrow different lines \Uparrow **change** of lines \Uparrow **separation** (subtracting **line segments**), connection (adding) \Uparrow **moving** \Uparrow **combination** (**forms**)^d.

Moving at equal distance from a point \Uparrow a **circle** or **globe** \Uparrow different **directions** \Uparrow different lines \Uparrow **crossing** lines \Uparrow different **angles** \Uparrow equal angles at crossing lines \Uparrow **right angle** (\perp) \Uparrow 2D and

^a **A, B, C** and **bold** words refer to crucial steps in *Fig.15p16*, words in **bold italics** are added intermediate suppositions.

^b Read \Downarrow as ‘supposes’ and \Uparrow as ‘enabling to imagine’. If B *supposes* A, then A *enables* to imagine B; if $B \Downarrow A$ then $A \Uparrow B$.

^c ‘Understanding’ reproduces otherone’s imagination. Someone then under-stands (sup-poses) otherone’s sup-positions.

^d Forms combined by lines include outlines of surfaces and volumes. So geometry is no longer fully expressible in 1D linear language.
By the way, a different combination may serve as a proof (*Fig. 67p64*).

3D units \uparrow *quantities* \downarrow *surfaces and volumes*.

These suppositions \uparrow analytic geometry \downarrow adding different distances to any point.

Analytic geometry \downarrow 3 distances ('*coördinates*' e.g. x, y, z) from any point to 3 surfaces, mutually crossing at 3 lines ('*axes*' e.g. X, Y, Z)^a and all crossing in one point ('*origin*').^b

This enables to locate each point by 3 distances to these surfaces (or 2 if e.g. z=0).

Such a *coördinate system* enables an algebra of directions and transformations of forms.

The design of algebraic geometry started by **separating** a coördinate system from a form.

[Descartes\(1637\)](#) added the supposition that algebraic geometry requires a *reference frame*.

Vectors combine magnitude and direction.

[Euclides\(ca.-300\)](#) used lines with direction and length for geometric translations, the foundation for later vector-like thinking. [Archimedes\(ca.-250\)](#) used lines with direction and length to model mechanical effects. [Newton\(1687\)](#) used quantities with both direction and magnitude for velocity, acceleration, and force. [Euler\(1736I II and 1765\)](#) formalized Newtonian mechanics.

Operations on vectors and forms enable their **metabolism**.

[Lagrange\(1788\)](#) formalized components of force and motion, anticipating *adding vectors* and laid the foundation of the *dot product*. Grassmann(1840) in [Grassmann\(1844\)](#) formalized the operations of vector algebra. [Hamilton\(1843\)](#) constructed dot-cross products ('quaternions').

[Gibbs\(1901\)](#) separated the *cross product* from quaternions.

Matrices enable to **regulate** different operations.

[Sylvester\(1850\)](#) introduced the "*matrix*", separating qualities of variables in rows and columns.

Different matrices enable to **organise** their mutual operations.

[Sylvester\(1853\)](#) separated co- and contra-variant.

[Cayley\(1858\)](#) enabled *matrix multiplication*, and the inverse of a matrix.

CALCULUS

Calculus \downarrow coördinates of *adjacent points* still differ ('*differentials*' dx, dy, dz).

Dividing them (e.g. $\frac{dy}{dx}$) and summing a product with them (e.g. $\int y \cdot dx$)^c give real numbers.

From an 'Ordinary Differential Equation' ('ODE') such as $\frac{d}{dx}y = x^2$ \uparrow solve y as $y = \frac{x^3}{3} + c$.

Changes \uparrow **object**

[Newton\(1671\)](#) (unpublished during his lifetime) and [Leibniz\(1684\)](#) invented the method.

Newton found the foundation for solving ODEs in mechanics. Leibniz provided tools and notations that made solving ODEs more accessible and generalizable.

Separation \uparrow **combination**

[Bernoulli\(1695\)](#) found separable and homogeneous equations. [Alembert\(1743\)](#) applied ODE's to mechanics systematically. [Euler\(1744\)](#) and [Euler\(1755\)](#) greatly expanded the theory and solution techniques of ODE's. [Lagrange\(1788\)](#) unified differential equations and mechanics.

Napier(1614) discovered 'Euler's number'. [Euler\(1728\)](#), called it 'e'^d and described its useful properties for calculus (e.g. $\frac{d}{dx}e^x = \int e^x dx = e^x$) and trigonometry.

^a Descartes(1637) did not yet suppose perpendicular axes.

[Barrow\(1670\)](#) drew the axes perpendicular as I will suppose further, but [Oresme\(1360\)](#) made \perp 2D graphs earlier.

^b Note distance $x \perp$ surface YZ, $y \perp$ XZ, $z \perp$ XY in 3D. In 2D $z=0$, $x \perp$ Y and $y \perp$ X.

^c 'Differentiate' into a 'derivative' and 'Integrate' into an 'integral'.

^d Read a letter of Euler in English: [Smith\(1929\)](#) p95.

PROBABILITY ↑ COMBINATION

Probability **combines** (reduces) differences as distances into an *average*.

ITERATION ↑ REPRODUCTION

Iterations suppose operations repeatedly applied (**reproduced**) on their own output.

Fractal iterations are continuous but 'broken' (nowhere differentiable).

Riemann invented the first fractal iteration, and [Weierstrass\(1872\)](#) proved that his variant was fractal in any detail. [Koch\(1904\)](#) found another fractal function known as Koch's snowflake.

[Julia\(1918\)](#) based a set of fractals on iterative functions. Mandelbrot(1967) studied broken curves. Mandelbrot(1975) coined the term 'fractal', studied and plotted the Julia sets, and Mandelbrot(1982) introduced their Mandelbrot set .

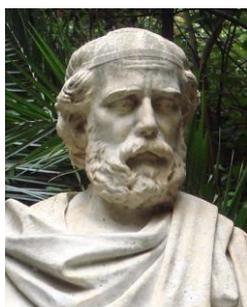
[Malthus\(1826\)](#) modelled population growth (an iterative process)

[Verhulst\(1845\)](#) and [Verhulst\(1847\)](#) modelled its environmental limits. [Lorenz\(1963\)](#) modelled three dimensional iterations for wheather forecasts. Smale(1974) and Feigenbaum(1978) brought some order in chaotic iterations showing repetition after a number of steps.

NEURAL NETWORK ↑ IMAGINATION

[Turing\(1936\)](#) laid the theoretical foundation for AI and raised substantial questions about machine intelligence. **Rosenblatt(1962)** designed the first neural network (ANN). His ANN 'perceptron' remained underestimated for a long time after Minsky's criticism ('AI winter' 1974–1980), but regained interest at last. **Simon(1966)** designed early AI models with cognitive approaches to problem solving. **Minsky(1985)**, one of the founders of AI had a major influence on the direction of AI research.

5. ABIOTIC CONDITIONS ARE PROBABLE



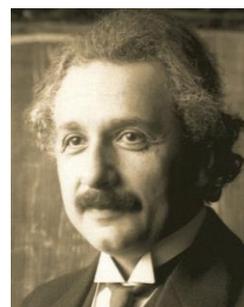
177 Archimedes^a



178 Galilei^b



179 Maxwell^c



180 Einstein^d

With Newton (*Fig.39p28*) leading designers of the contents of this chapter.

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^a Archimedes sculptured by Luciano Campisi (1885).

Archimedes introduced *rigorous mathematics* in physics, see [Heath\(1897\)](#)

^b Galilei(1635) painted by Sustermans [Galilei\(1632\)](#) Galilei improved the Dutch telescope and discovered the moons of Jupiter (1610), changing suppositions about the celestial system. He introduced precise experiments in physics such as falling (retarded on a slope to enable measuring time and distance). He partially refuted the physics of Aristoteles, but still supposed circular inertia. Galilei prepared the questions, finally solved by Newton(1687) *Fig.39p28*.

^c Maxwell(ca.1870). [Maxwell\(1865\)](#) incorporated all observations and theories on electricity, magnetism and light in 20 formulae, reduced to 4 by Heaviside(1885), inspiring Einstein.

^d Einstein(1921). [Einstein\(190506\)](#) and [Einstein\(1916\)](#) Einstein relativized Newtons absolute space and time.

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What is the designerly content of physics? Which discoveries are actually inventions, designs of a model? Does physics cover a broader field of possibility beyond probability?

This chapter explores some disciplines of physics at highschool level. I conclude:

Movement is the core of mechanics. It supposes a change of place. That supposes different places ('space') and different moments ('time'). My meters and seconds may be different from yours ('relativity'). At the smallest scale, you cannot determine the place and the moment of a quantum at the same time, otherwise than statistically.

Between both, thermodynamics studies many different movements of molecules statistically. A challenge has been, to force them into one direction, into one movement usable at our scale. A solution has been, the stable *form* of a cylinder, filled with gas at fluctuating temperature.

A stable shape is in-formed. Technology is the information about stable forms, enabling directed movements. Organisms store such information in their genes, but there, it informs not the shape, but the *development* of shapes functional and structured in mutual connection. This is the road ahead for information technology in order to approach the phenomenal complexity of life itself.

Physics does not only contain the design of math models, but also the design of instruments which may demonstrate the correspondence of these models to an actual reality.

That *demonstration* is not a design. It is the empirical activity of testing the design of a model. That design, however, is often preceded by an unexpected observation, asking for explanation.

There are different probabilities, expectations, conditioned at layers and levels (*Fig.14p13*). What is probable within a living cell may be not probable at the level of the universe.

A design should be a unique case, new until it is copied. The designed unique case cannot be probable by a lack of comparable cases. Physics may broaden our imagination into the smallest and largest levels of scale. That may unlock possibilities that no one had expected before.

A predominant task of physics, however, is to show the *limits* of possibility.

§ 26 MECHANICS RELATIVATE SPACE AND TIME

A vocabulary of classical mechanics since Newton^a (without derivatives) reads:

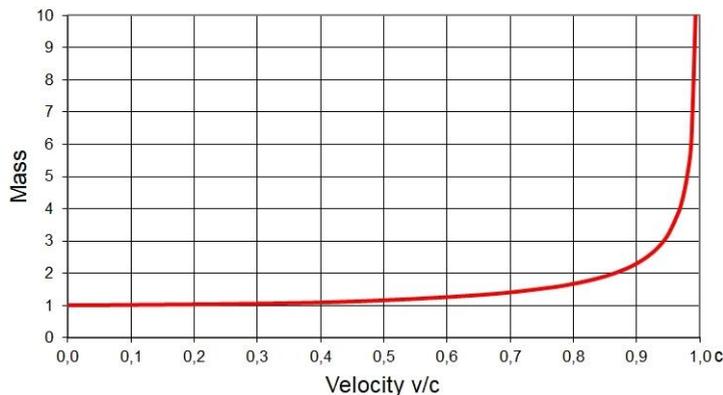
Velocity 'v' is a traveled distance 's' divided by the required time 't'(m/sec) ^b :	$v=s/t$
Acceleration 'a' is v, again divided by the time t, required to reach that speed (m/sec ²):	$a=s/t^2$
Momentum 'p' quantifies the movement of a mass 'm' (kg*m/sec):	$p=m*v$
Force 'F' is the acceleration a, times the accelerated mass m (kg*m/sec ² , newton, N):	$F=m*a$
Energy ^c 'E' is a force F exerted on a mass m over a distance s (joule, J): ^d	$E=m*v^2$
Power 'P'(watt, W) is energy 'E' per second (J/sec):	$P=E/t$

Mechanics creates a deterministic worldview. This makes the world *in principle* predictable as a calculable process from the Big Bang onwards, *if you would know exactly all of its initial values*. The mechanics of Newton seemed to be a complete whole until Einstein put them into a relativistic, but also deterministic perspective.^e

E=MC² IS THE SPECIAL CASE OF E=MV² AT THE MAXIMUM VELOCITY V=C OF MASSES

Masses appear to have a maximum mutual speed $c = 299\,792\,458$ m/sec (the velocity of light).^f At that maximum velocity c, more energy added in mv^2 cannot end up in a higher velocity v.^g

So it must result in increasing mass m, according to $E=mc^2$.



181 Lorentz' mass increase by velocity

Lorentz found that mass increases with its velocity by a factor $\lambda = (1-(v/c)^2)^{-1/2}$.^h

This mass building-up already starts from 0m/sec onwards by increasing speed.

At a low v compared to c (v/c), however, the mass increase is immeasurably small (**Fig.181**).

^a [Newton\(1687\)](#)

^b In this section I will use and add units in *italics*. E with its unit E(J) then is distinguished from a symbol for electric field strength E(N/C).

^c [Leibniz\(1686\)](#) added energy to the vocabulary as 'vis viva'.

^d Usually work $W = \int_0^{v_e} mv \cdot dv = \frac{1}{2}mv^2$, but that is half the required energy E. If you push a car to that speed v_e , then the ground surface also undergoes the same force in the opposite direction. This should bring about a very small movement of the very large mass of the earth.

That 'reacting mass' then receives the same kinetic energy in opposite direction, an unnoticed other half of your work, in total $E=mv^2$.

^e [Einstein\(190506\)](#) and [Einstein\(190509\)](#)

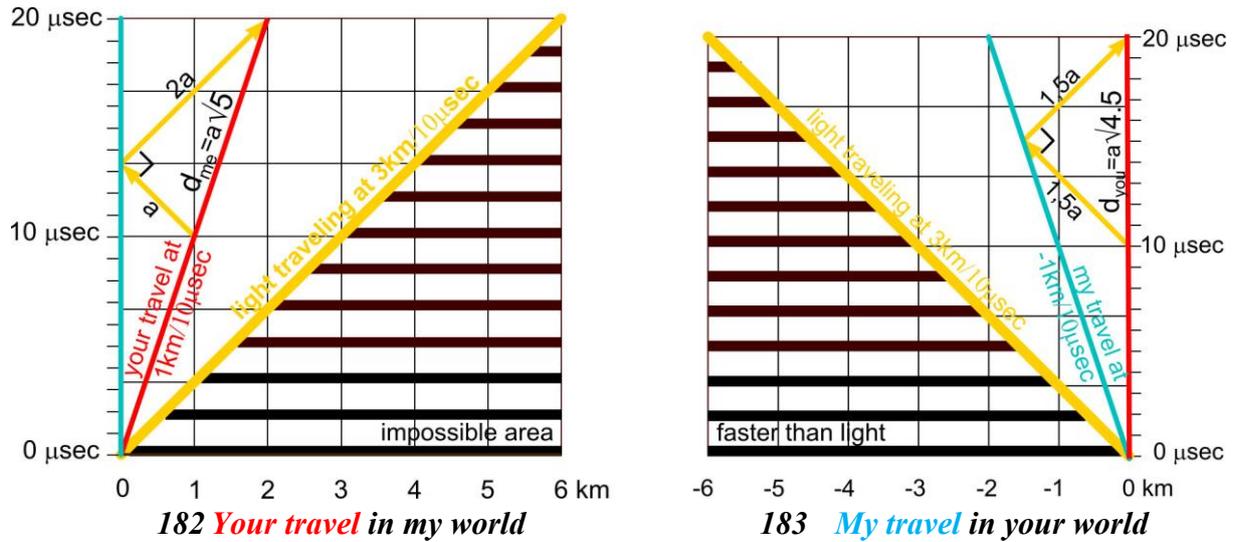
^f [Beeckman\(1634, Dutch\)](#) already invented a method to calculate c but [Rømer \(1676\)](#) actually calculated c from astronomical observations.

On the 15th Conférence Générale des Poids et Mesures (CGPM) in 1975, the speed of light c was finally set at 299 792 458 m/s.

^g Beyond c you would have to use more than an infinite amount of energy to speed up. As a thought experiment, however, it is a simple shortcut into the complicated mathematics of the special relativity theory of Einstein(190506).

^h [Lorentz\(1895\) English](#) This 'Lorentz factor' λ and therefore the moving mass, would become infinite approaching the speed of light c.

MASS INCREASES, BUT TIME AND SPACE SHRINK BY INCREASING VELOCITY



In both figures, the **diagonal** represents the **maximum speed** $c \approx 3\text{km}/10\mu\text{sec}^a$ as a constant. The grids show 1km and $3\frac{1}{3}\mu\text{sec}$ as interchangeable 'space-time' units in 4 dimensions.^b

In **Fig.182** I see **you moving** away from **me** with a velocity $\frac{1}{3}c \approx 1\text{km}/10\mu\text{sec}$. We both start at the origin $(0, 0)$, but I travel only in time (**vertical axis**), not in space (km).

In **Fig.183**, however, you see **me disappearing** behind you, supposing that **you** don't move. At $10\mu\text{sec}$, you send me a light signal (**yellow arrow**)^c, which I mirror 90° back to you. The light reaches you over the same distance ($3a$), but your **travel** in **Fig.183** seems shorter.

In **Fig.182** the **red route** after your **yellow signal** (with a rectangular detour reflected by me), is the slanted side d_{me} of a right triangle. According to Pythagoras $d_{me}^2 = a^2 + (2a)^2$, so $d_{me} = \sqrt{a^2 + (2a)^2} = a\sqrt{5}$.

In **Fig.183**, however, you are not moving (the **red line is vertical**), but **I move away** from **you**. Then, your **rectangular triangle** looks different. In both cases, the light travels the same distance in the same time ($a+2a=1.5a+1.5a$), but your slanted side d_{you} is $\sqrt{(1.5a)^2 + (1.5a)^2} = a\sqrt{4.5}$. So d_{you} is $\sqrt{4.5} / a\sqrt{5} \approx 95\%$ of mine (d_{me})^d. Your whole grid shrinks if you move!

If you ever come back, then I have grown old faster than you, but you are not as heavy as you were on the way. Moving keeps you younger.

^a A μsec is a second/million.

^b [Minkowski\(1908\)](#) p53–111 introduced time as a fourth dimension with equal units.

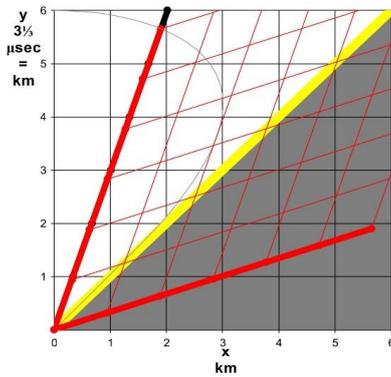
^c The **thick yellow** diagonals represent the speed of light c ($3\text{km}/10\mu\text{sec}$), also being the maximum velocity of masses.

Each slope parallel to that yellow line (or back perpendicular to it) equals that speed. It is the same for you and me. Even with a moving light source, c remains the same forwards and backwards, proven by the experiments of [Michelson;Morley\(1887\)](#) p333-345

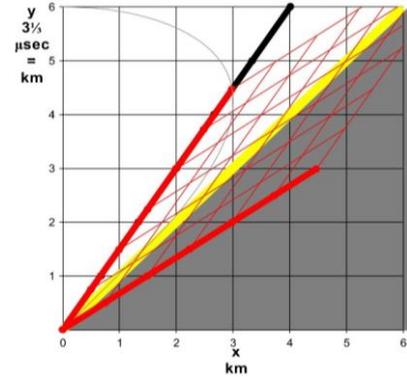
^d I chose convenient figures. For different speeds and more generally, a derivation applies with other triangles. Suppose you *pass* me at a shortest distance p . Exactly at that moment I send you a light signal. It travels a distance r at speed c in order to reach you while you have traveled a distance q at speed v . According to Pythagoras, $p^2 + q^2 = r^2$. Now divide everything by r^2 : $p^2/r^2 + q^2/r^2 = 1$ or $p^2/r^2 = 1 - q^2/r^2$. The ratio between p and r $p/r = \sqrt{1 - q^2/r^2}$. In the time r/c that the light is traveling along r , you traveled the distance $q = v(\text{your speed}) \cdot r/c$. Now $p/r = \sqrt{1 - v^2 r^2 / c^2} = \sqrt{1 - v^2 / c^2}$, or simply $p/r = \sqrt{1 - (v/c)^2}$. That is the *shrink* factor $1/\gamma$! In this, γ is the famous Lorentz factor, with which your mass *grows*.

ACCELERATION DRAWS YOUR SPACE-TIME CROOKED COMPARED TO MINE

In **Fig.184** I project **your world** (red) as warped in my grid (black). Your seconds and metres are smaller. The *time* is smaller *for those who move related to an observer*.



184 My projection of **your world**

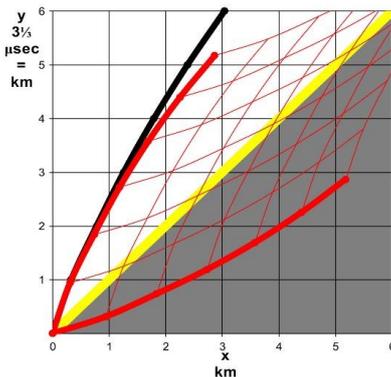


185 The same with double speed

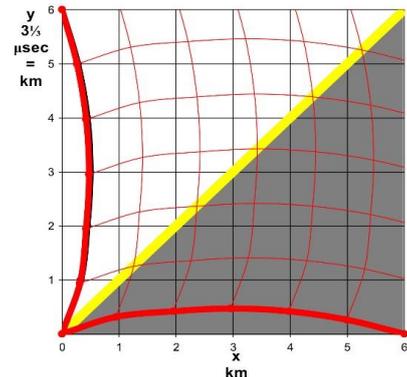
In 1905 Einstein had advanced so far with his *Special* Theory of Relativity, thanks to the concept of 'local time' by Lorentz (1895).

How could you understand *acceleration* now? After ten years, Einstein's *General* Theory of Relativity (1916)^a answered. The accelerations in **Fig.186** show curved lines (more and more kilometers are made per μsec). Time and space themselves are curved.

In **Fig.186** acceleration is positive, retardation is a 'negative acceleration' (**Fig.187**).



186 Acceleration



187 Retardation

A free floating mass *m* can be accelerated or deviated only by gravity or electromagnetic force. Gravity is only observable in the vicinity of a mass. Your grid curves in the vicinity of a mass. In fact, gravity *is* that curvature of space-time!

Many masses in a universe cause waves and swirls of accelerations in space-time.

There are countless masses moving away from you or coming towards you.

Lorentz' mass growth λ (**Fig.181** p102) then makes the gravitational landscape heterogeneous.

We have long assumed that light in vacuum follows a straight line. This is not true.

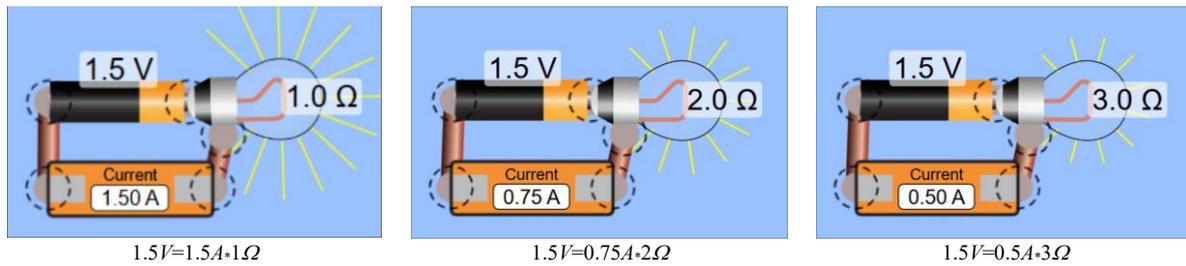
For an observer, a beam of light has to deflect in the vicinity of a mass if space itself is curving.

Then you should be able to see a galaxy behind the sun where you expect it to be hidden.

That is what Eddington^b demonstrated for the first time during the solar eclipse on 29 May 1919.

^a [Einstein\(1916\)](#)
^b [Eddington\(1920\)](#)

ELECTRIC CURRENT MEETS RESISTANCE



189 Ohm's law in the circuit of a flashlight^a

At the scale of our daily use of electric *current*, the number of coulombs flowing per second through an electric wire, is called ampere ($A=C/sec$).^b Current is caused by a different number of electrons present at both ends of a wire (a tension expressed in volts $V=J/C$).^c A wire obstructs the flow with a resistance (expressed in ohms Ω), for example, in the thin wire of a light bulb^d.

The *units* are related as $V=A \cdot \Omega$, their *quantity* provides Ohm's law^e $U=I \cdot R$ (the tension U in *volts* V , the current I in *amperes* A , and the resistance R in *ohms* Ω).

Fig.189 is an example of Ohm's law in a flashlight, with increasing resistance $R(\Omega)$ and different values for $I(A)$, all of which correspond to this law.

The current direction as shown traditionally in electrical circuit diagrams is opposite (different from initially supposed) to the direction in which the electrons actually flow (counterclockwise \cup in **Fig.189**). So, '+' indicates an electron *shortage* ('minus is more').

The resistance $R(\Omega)$ differs per material and temperature. For example, the 'resistivity' of copper at $20^\circ C$ is $1,7 \cdot 10^{-8} \Omega \cdot m^2/m$. So, a copper wire of $1m$ with an intersection of $10^{-6}m^2$ ($1mm^2$) has a resistance $R=resistivity \cdot length/diameter=1,7 \cdot 10^{-2}=0,017\Omega$.

My low-voltage light bulb with its very thin wire measures 2Ω .

In order to cut styrofoam, a wire has to become less hot, but hot enough over a longer distance. I then have to buy 'resistance wire' of 5.65Ω per *meter* at $20^\circ C$. That is 1.13Ω for $20cm$. But resistance is temperature-sensitive. At $1000^\circ C$, the resistance will rise into 1.5Ω .

ELECTRIC ENERGY CAN BE STORED

A light bulb radiates two kinds of energy: light and heat. Energy per second is called 'power' P (expressed in *watts*, W). In a circuit $P(watts)=U(volts) \cdot I(ampères)$. (Remember it as ' Wa is VA !')

A person at rest uses about $100watt$, but running $12km/hour$ takes $1000watt$ ($1kilowatt$, kW). in 1 hour you then have used $1 kilowatt-hour$ (kWh) or $1000 \cdot 60 \cdot 60$ 'wattseconds' (' J ') energy.

So, one wattsecond ($W_{sec=joule=J}$) is not power, but (*during a second*) energy, $E(J)$.

A $1watt$ LED, on during a year, takes a wattyear: $365 \cdot 24 \cdot 60 \cdot 60=31\ 536\ 000J$ or $31.536MJ$.

A wattyear happens to be almost equal to the energy content of a m^3 natural gas, a *kilogramme* of coal or a *litre* of petrol.

The flashlight uses energy from a battery. A battery produces and keeps its voltage by chemical means^f, but its performance can be compared to that of a 'capacitor'. A capacitor keeps a voltage between two separate, differently charged plates, because the plus charge of one plate attracts the minus charge of the other with the forementioned Coulomb force $F=k \cdot |Q_1| \cdot |Q_2|/s^2$.

^a From [phet](#).

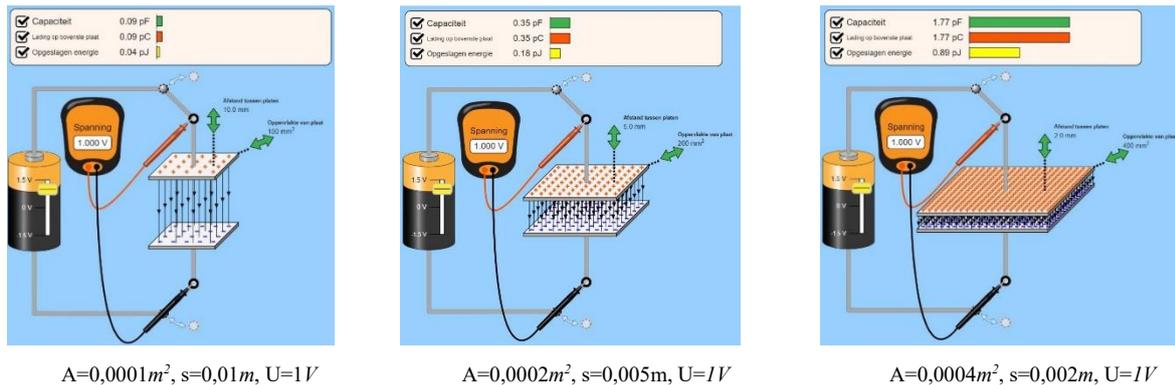
^b [Ampère\(1826\)](#).

^c [Volta\(1800\)](#).

^d After [De la Rue\(1820\)](#), [Swann\(1878\)](#) and others, [Edison\(1880\)](#) designed a commercially successful bulb.

^e [Ohm\(1827\)](#)p178

^f https://en.wikipedia.org/wiki/Electric_battery



190 A capacitor stores the applied voltage, depending on surface and distance^a

If you put two conductive plates of $1 \times 1 \text{ cm}$ (surface $A=0.0001 \text{ m}^2$) at 1 cm distance ($s=0.01 \text{ m}$) under 1 volt (**Fig.190**), then the 'capacitance' of the capacitor is: $\epsilon \cdot A/s=0.09 \text{ pF}$ ^b, where ϵ is the 'permittivity'^c of the medium between the plates. If you multiply that capacitance $\epsilon \cdot A/s$ by tension $U(V)$, then you know also the charge $Q=\epsilon \cdot A \cdot U/s=0.09 \cdot U(\text{pC})$.

With the charge Q and the voltage U , you know also the stored energy: $E=Q \cdot U/2=0.04 (\text{pJ})$ ^d. So, this *energy storage* of the capacitor $E=Q \cdot U/2=0.04 (\text{pJ})$ is something else than its *capacitance* $\epsilon \cdot A/s=0.09(\text{pF})$. This storage of electricity has been invented already in 1745.^e

With Q you may also calculate the attractive force between the plates: $F=Q^2/2 \epsilon s^2=0.73 (\text{pN})$. This force increases when the distance s in the denominator decreases (see the third **Fig.190**). More force attracts more electrons to a plate.

This also applies if the surface A of the plates increases. They can hold more electrons. In both cases, the capacity increases and so does the charge $Q(=\text{capacity} \cdot \text{voltage } U)$ and the energy storage $w(=Q \cdot U/2)$. So a capacitor serves as a battery.

A VACUUM STILL MAY CONTAIN AN ELECTRIC FIELD

If there would be a vacuum between the plates, then there would still be a 'force field' in between by which every free electron⁻ is pushed from plate⁻ and drawn to plate⁺. What pushes or pulls the electron? It cannot be the plates, because in vacuum there is no physical connection. It should be a vectorfield (compare **Fig.105p74**), and it is called **E**.

Such a field exists also around one or more *points* of charge. Their force has an electric component **E_E** and a magnetic component **E_M**. The strength of both can be visualized by a number of field lines (**Fig.191p108**). The density of lines (if they are well drawn) indicates the field strength in a volume around the charge or on a surface in the environment where they pass.

^a From [phet](#)

^b The unit of capacitance is farad ($F=C/V$), but 1F is a very large capacitance, so I will continue using picofarad= $pF=10^{-12}F$.

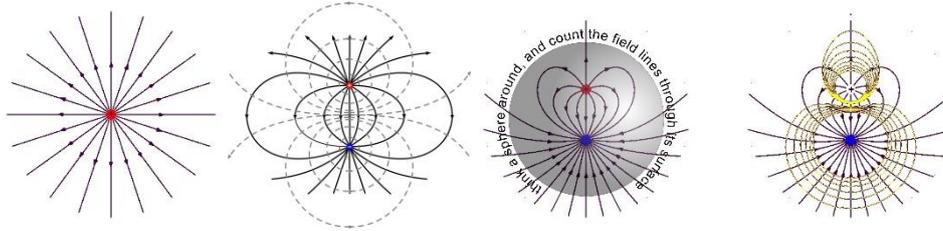
^c The "permittivity" $\epsilon=\epsilon_0 \cdot \epsilon_r$ determines the degree to which not the electric current, but electromagnetic force is transmitted.

In this, $\epsilon_0=8.854187818 \cdot 10^{-12} (C^2/N \cdot m^2)$, the 'electric field constant under vacuum' is a nature constant. If the space between the plates is filled with material ('dielectric' medium), for example air, then ϵ_0 must be multiplied by a factor ϵ_r ('relative electric field constant'). That is a factor specific to each material. For example, for air it is 1,00056, but for water 78.50.

We now can also calculate the "constant" of Coulomb k better as $1/(4 \cdot \pi \cdot \epsilon)=8.9876 \cdot 10^9 (N \cdot m^2/C^2)$, where π ('pi') = 3.141592654.

^d For the capacitance, except ϵ you only need to know surface/distance A/s . If you, however, already knew the charge Q and voltage U , then also capacitance =charge/voltage= Q/U . You can see this relationship in its own unit $F=coulomb/volt=C/V$. The charge Q is derived from the sum of each dq growth of a charge q counting from 0 to Q ($\int_0^Q q dq=Q^2/2$). Divide that by the capacitance Q/U and you get the work $W=E/2=Q \cdot U/2$.

^e **Kleist(1745)** did not publish his invention. **Musschenbroek(1746)** used a glass jar with metal foil on the inside and outside, filled with water and a conductor. This became the classic Leyden jar as reported by [Nollet\(1746\)](#)



A point charge, two equal opposite, a smaller +. The \perp magnetic field added
191 Electric force fields and perpendicular (\perp) to them a magnetic field ^a

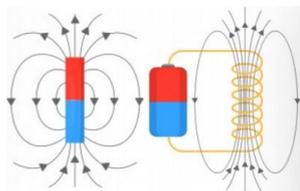
Q/volume is called 'charge density' ρ . Q/surface is reduced by the permittivity of the medium ϵ . It is called 'flux' $\Theta_E = Q/\epsilon$ (Gauss's law 1813).^b With more point charges you may think a sphere or any closed surface around it where the lines pass. The volume of a sphere is $\frac{4}{3}\pi r^3$, its surface $4\pi r^2$.

MOVEMENT OF CHARGE INDUCES MAGNETIC FIELDS AND THE REVERSE

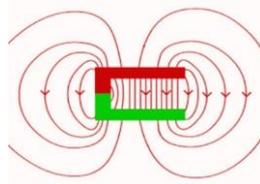
Without movement, a *stationary magnet* has a permanent magnetic field. An *electromagnet*, however, may change its polarity. A *moving charge* (for example within an electric wire) develops *electric* force field lines and \perp of these lines a *magnetic* field (the **Fig.191** right).

Ampère(1820) amplified magnetism around a current wire by winding it on a coil (**Fig192**). Faraday(1831) generated current moving a magnet (dynamo^c), and the reverse (motor)^d. This interchange of electromagnetic fields and currents is called 'electromagnetic induction'. The current in a wire causes a field. That field resists changes of the current ('self-induction').

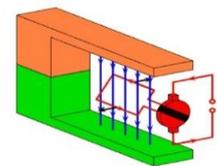
In the magnetic field within a horseshoe magnet, the current in a wire is pushed \perp to the field lines of the magnet and it is attracted when the current direction is reversed. An electric motor periodically reverses the electric flow direction with contacts on a spinning axis in order to change the push into pull and the reverse (**Fig192** right).^e



192 Stationary magnetic force



A horseshoe magnet



Principle of an electric motor^f

If a charge $Q=1$ C(coulomb) moves with velocity $v = 1$ m/sec \perp through a magnetic field, then it will experience a force $F=1$ N(newton), and the 'field strength' $B = F_B/(Q \cdot v) = 1 \text{ N} \cdot 1 \text{ sec} / (1 \text{ C} \cdot 1 \text{ m}) = 1 \text{ T (tesla)}$. Winding a wire n times on a bar (making a magnetic coil^g), increases B n times.

The smaller the length l of the bar, the larger appears its winding density and thus its magnetic field strength: $B=4000 \cdot n/l$. The factor 4000 ('relative permeability' μ_r)^h applies if the wire is wound around an iron core, enhancing the magnetic force significantly. Therefore, an electric motor should have as many winding turns n as possible at the shortest possible length l of the iron core.

^a Edited from [Brunning](#)

^b [Gauss\(1813\)](#)

^c The old name "dynamo" has been replaced by "direct current generator" or "communator", in order to distinguish it from an "alternator" that generates alternating current. Both are then "electric generators".

^d [Faraday\(1845\)](#)

^e This is beautifully explained in <https://www.youtube.com/watch?v=CWulQ1ZSE3c>

^f From [Brunning](#)

^g The induction capacity of an electric coil is expressed in henry $H = N \cdot m/A^2$.

^h See [https://en.wikipedia.org/wiki/Permeability_\(electromagnetism\)](https://en.wikipedia.org/wiki/Permeability_(electromagnetism))

Magnetic field lines *outside* the magnet spread out (**Fig. 192p108**) and then concentrate again at the opposite pole, becoming parallel between the poles.

The low density outside the poles has little effect.

Thus, an electric motor functions through changing internal and static external *magnetic* fields.

An electric field **E** exists around any stationary electric charge, and exerts a force on other charges $F_E=QE$. Magnetic field lines (perpendicular (\perp) to electric field lines) connect points with equal potential energy ('equipotential'). When you cross these field lines, you experience changes in electric potential (voltage), expressible as volts per meter ($V/m=N/C$).

WALKING THROUGH THE FIELDS CHARGES YOU

Crossing \perp magnetic field lines means following an electric field line **E** 'upwards' into the source charge or 'downwards'. The *voltage* you win upwards at each point is the local charge density ρ of the crossed line, divided by the permittivity of the medium ϵ .^a If you are charged yourself, then you will also experience the forementioned Coulomb's force $F_E=k\cdot|Q_1|\cdot|Q_2|/s^2$.

Crossing \perp the electric field lines means following a line of the equipotential magnetic field **B** without a change of voltage. Instead, if you are magnetic yourself, then you will experience a force $F_B=Q(B\times v)$, dependent on your *speed* v relative to that of the field **B**.^b

If you move with the same speed as field **B** is moving, then you will experience no force: $F_B=0$.

Electric forces $F_E=Q\cdot E_F$ can be deflected by magnetic forces $F_B=Q\cdot(v\times B)$, resulting^c in the Lorentz force: $F_L = Q(E+v\times B)$.^d The velocity v influences the magnetic component, not the electric force.

A SUMMARY OF ELECTROMAGNETISM TAKES 4 EQUATIONS

The mathematical representation of *curved* lines (as in **E** and **B**), requires partial derivatives (δ)^e with respect to three dimensions x,y,z : $E/\delta x+E/\delta y+E/\delta z$ and $B/\delta x+B/\delta y+B/\delta z$, briefly represented by the 'nabla-operator' ∇ as $\nabla\cdot E$ and $\nabla\cdot B$.

Maxwell (1865)^f originally formulated the fundamental laws of electromagnetism in 20 equations with his own addition. Heaviside (1884) later simplified them to 4 equations:^g

1 $\nabla\cdot E = \rho/\epsilon$ (Gauss, 1813). You will lose or gain ρ/ϵ voltage on each step.

2 $\nabla\cdot B = 0$ (Gauss, 1813). In the magnetic field you have equal velocities back and forth.

3 $\nabla\times E = -\partial B/\partial t$ (Faraday, 1831). **E** changes when **B** moves \perp E_F or $\times E_F$ ('induction').

4 $\nabla\times B = \mu\cdot\rho\cdot v + \mu\cdot\epsilon\cdot\partial E/\partial t$ (Ampère(1826) + Maxwell(1865)). **B** changes proportional to the permeability μ , the charge density ρ , and its own *velocity* v + Maxwell's addition: proportional to μ , the permittivity ϵ , and the *change* of **E**.

This, along with the Lorentz's force law, is the foundation of classical electromagnetism.

^a Gauss's law (1813) and Maxwell's first equation (1865).

^b This is simulated nicely in <https://bruningonline.nl/applets/inductie/inductie.htm>

^c The 'resultant' is a vector sum (a diagonal in the parallelogram of vectors). A vector is a number with a direction, further shown in bold.

For vectors, '+' means a "vectorial addition". The sign 'x' is the 'cross-product' between both direction-bearing vectors v and B .

It is the matrix operation that formulates the difference of perpendicular (\perp) direction between the two. See p108.

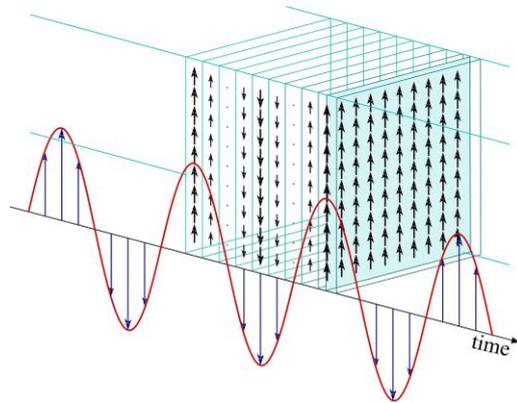
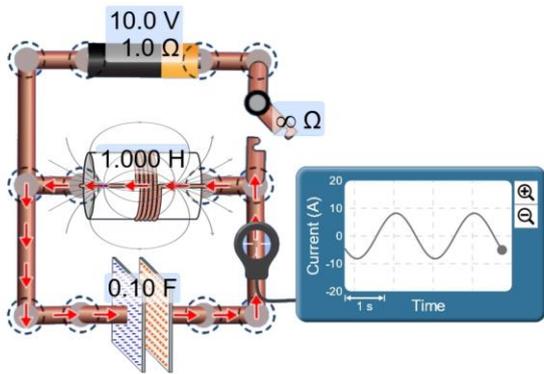
^d <https://nl.wikipedia.org/wiki/Lorentzkracht> This is simulated nicely in <https://bruningonline.nl/applets/lorentzkracht-afbuigen/lorentzkracht-afbuigen.htm>

^e $\partial B/\partial t$, would deduce all variables in $B=Fb/(Q\cdot v)$ into t , but $\partial B/\partial t$ is a 'partial derivative', keeping any variable constant except speed v .

^f Maxwell(1865) predicted the existence of electromagnetic fields and Hertz(1887) proved their existence at the speed of light.

^g See Wikipedia

RADIATION SUPPOSES *CHANGING* MAGNETIC FIELDS



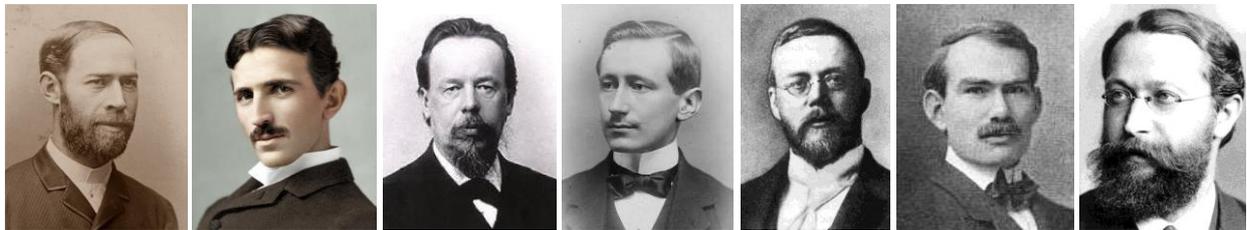
193 An electric oscillator^a causes ...

194 ... changing polarities of the field.

Fig. 193 shows an electric circuit with a battery, a coil^b and a capacitor. If you connect the battery for a moment, then a current goes trough the coil, producing a magnetic field. If the battery is disconnected, then the capacitor delivers current in opposite direction. The coil then unloads its magnetic field as current in the wire, and reverses its polarity.

That loads the capacitor again for the next cycle. The magnetic field varies as a sinus (**Fig. 194**). A change in the magnetic field travels with the velocity of light (c) as ‘radiation’. Its wavelength λ may vary from 10^8 to 10^{-16} m, or a ‘frequency’ ($f = c/\lambda$) from 1 to 10^{25} cycles per second (Hz).

A radio^c receives frequencies between 10^3 and 10^{11} Hz (**Fig. 196p111**). It transforms radiation again into a current for a speaker by a coil (**Fig. 193** without a battery fed by radiation^d).



Hertz
(waves)

Tesla
(signals)

Popov
(detecting)

Marconi
(telegraphy)

Fessenden
(broadcast)

Forest
(amplifying)

Braun
(tuning)

195 Founders of radio transmission

Higher frequencies may be obstructed by the atmosphere. From numerous frequencies a variable capacitor may select (tune) a proper one: the single frequency of the sender you want to receive.

^a From [phet](#)

^b Explanation by [Houten](#)

^c See for a general overview [Esaulov\(2019\)](#).

[Tesla\(>1891\)](#) developed systems for alternating current, wireless energy transmission and radio signals.

[Marconi\(1895\)](#) developed the first usable wireless telegraphy system and Founded the Wireless Telegraph and Signal Company in 1897. He was the first to send a radio signal across the Atlantic Ocean in 1901. ([Nobel Prize 1909](#))

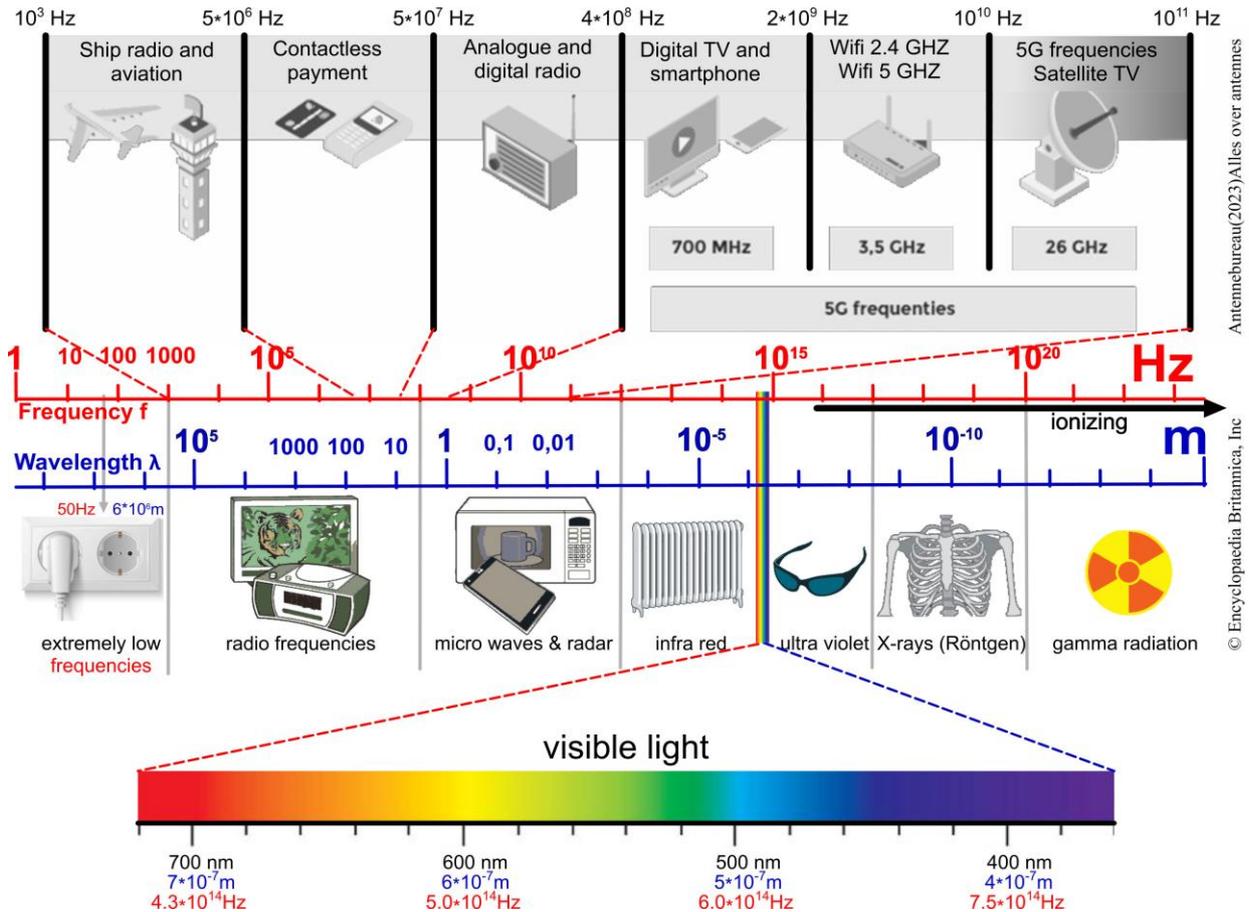
[Popov\(1895\)](#) demonstrated a working radio machine in Russia.

[Fessenden\(1900\)](#) realized the first wireless transmission of speech and, in 1906, the first music radio broadcast. This marked the transition from Morse code telegraphy to audio broadcasting.

[Forest\(1906\)](#) invented the audio tube (an early electron tube). This enabled the amplification of radio signals, essential for radio receivers and later for broadcasting.

[Braun\(1909\)](#) improved transmitting equipment with tuned circuits and oscillators. ([Nobel Prize 1909](#))

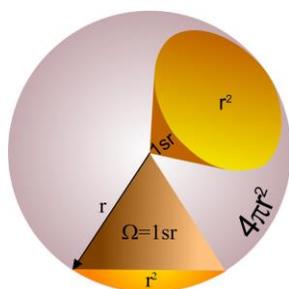
^d A crystal receiver, a radio in its simplest form without battery.



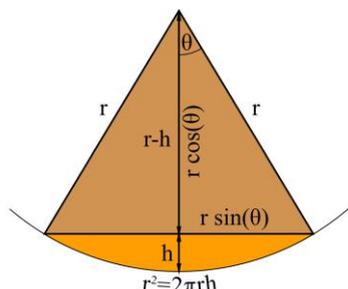
196 Frequences and wave lengths of radiation ^a

Fig. 196 shows the available **frequencies f**, their corresponding **wave lengths λ=c/f** and their use. The energy of waves is roughly proportional to their frequency until 10^{14} Hz. Beyond 10^{16} Hz they may damage living tissues. A small part is the spectrum of visible light.

LIGHT ON A SURROUNDING SPHERE WEAKENS BY INCREASING DISTANCE OF ITS RADIUS²
 The surface of a sphere is $4\pi r^2$. If $r = 1\text{m}$, then the surface of the sphere = $4\pi = 12.6\text{m}^2$.
 A *curved surface* $r^2 = 1\text{m}^2$ on the sphere determines an angle θ . Rotated 3D, θ becomes a 'solid angle' $\Omega = 2\pi(1-\cos(\theta)) = 1\text{sr}$, a unit called 'steradian'^b. A total sphere counts $4\pi\text{sr} \approx 12.6\text{sr}$.



197 A sphere divided in solid angles of 1sr ^d



198 A cross section (Ω) of 1sr

The unit *surface* $r^2 = 2\pi rh$ ^c. So you may solve $h = \frac{r}{2\pi} = 0.159\text{m}$ and $r-h = 0.841\text{m}$.

Now you may calculate $\theta = \arccos \frac{r-h}{r} = 0.572$ radians = 32.75° , and $(\otimes \text{sr}) 2\theta = 1.14$ radians = 65.5° .

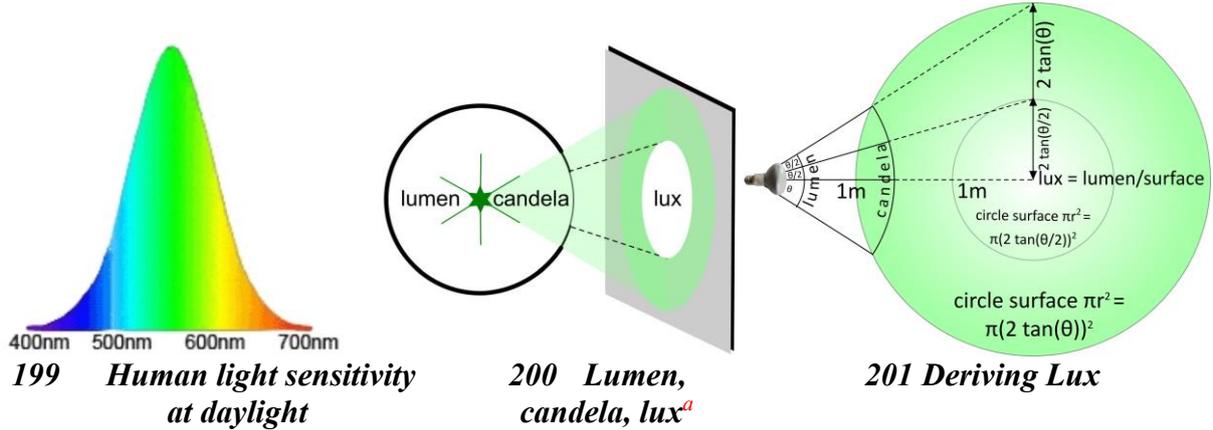
Note that the brown triangle is not equilateral. Its basis is not $r = 1\text{m}$, but $2r \sin(\theta) = 2 * 0.541\text{m} = 1.08\text{m}$.

^a From [Antennebureau\(2023\)](https://www.britannica.com/science/electromagnetic-spectrum); <https://www.britannica.com/science/electromagnetic-spectrum>

^b <https://en.wikipedia.org/wiki/Steradian>

^c [Gieck\(1969\)](#) pC3

^d Edited after [Steradian](https://en.m.wikipedia.org/wiki/File:Steradian_cone_and_cap.svg) By Andy Anderson - Own work, CC BY-SA 4.0, https://en.m.wikipedia.org/wiki/File:Steradian_cone_and_cap.svg



The surface 12.6m^2 of sphere with a radius $r=1\text{m}$ is $4\pi r^2$. A green^b (Fig. 199) lamp, emitting 12.6 'lumen' in all directions emits 1 lumen per sr ($2\theta = 65.5^\circ$) or 1 'candela' (\approx a candle light). If 1 lumen in a $2\theta = 32.75^\circ$ beam is projected on a flat screen at $r \approx 2\text{m}$ distance of the lamp, then the illuminated flat surface will be 1m^2 , and its 'illuminance' is 1 lumen/m² ('lux').

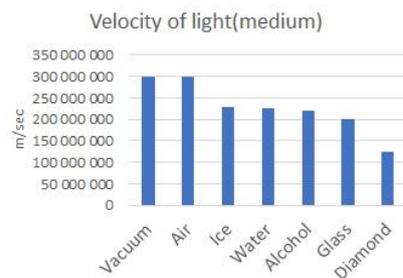
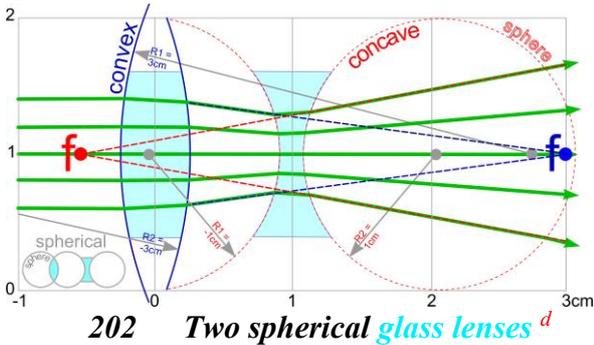
Delivering 500 lux (lumen/m²) at $r = 2$ meter distance from a bulb (internally illuminating a sphere of $4\pi r^2 \approx 50\text{m}^2$ in all directions) requires $500\text{lux} \times 50\text{m}^2 = 25000$ lumen. Concentrating light on a desk in a beam reduces that number.

A 1sr beam ($2\theta = 65.5^\circ$) illuminates at 2m from the lamp a flat surface of $\pi(2\tan(\theta))^2 = 5.21\text{m}^2$. In order to get 500 lux on 5.21m^2 , then requires $500 \times 5.21 = 2610$ lumen.

A $\frac{1}{2}\text{sr}$ beam ($2\theta = 32.75^\circ$) illuminates at 2m from the lamp a flat surface of 1.09m^2 . In order to get 500 lux on 1.09m^2 , then requires $500 \times 1.09 = 543$ lumen.

One lumen has a power of $1/683 = 0.00146$ watt. So, 683 lumen requires at least^c 1 watt. A light bulb produces only approximately 15 lumen per watt, a halogen lamp 20, an energy saving lamp 60, and a light emitting diode (LED) 90–210.

CONVEX LENSES CONCENTRATE LIGHT RAYS; CONCAVE LENSES DISPERSE THEM



In Fig. 202 a convex lens concentrates light rays directed to its focal point f at 3cm. These rays are, however, intercepted by a concave lens dispersing them as if they stem from a virtual focal point f before the lens. The light rays entering and exiting a medium such as glass, change direction by a reduction of their velocity (wave length) in the medium (Fig. 203).

The velocity of light in vacuum c , divided by v in the medium, c/v , is the 'refractive index' n . Each lens has two sides with their own radius R_1 and R_2 . In Fig. 202 any $R_2 = -R_1$ and $n=1.5$.

^a [https://en.wikipedia.org/wiki/Lumen_\(unit\)](https://en.wikipedia.org/wiki/Lumen_(unit)) <https://en.wikipedia.org/wiki/Candela> <https://ledgloeilamp.nl/lumen-lux-candela/> <https://www.suslight.nl/candela-lumen-en-lux/>

^b The most visible green light has a wavelength $\lambda = 555$ nanometer, implying a frequency $f = 540$ terahertz: $f = c/\lambda$ and $\lambda = c/f$, where $c = 299792458\text{m/sec}$, the velocity of light in vacuum.

^c 'At least', because a lamp also produces heat.

^d The figure is constructed with the optical simulator <https://phydemo.app/ray-optics/simulator/>.



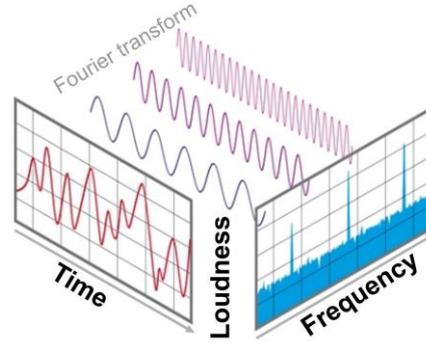
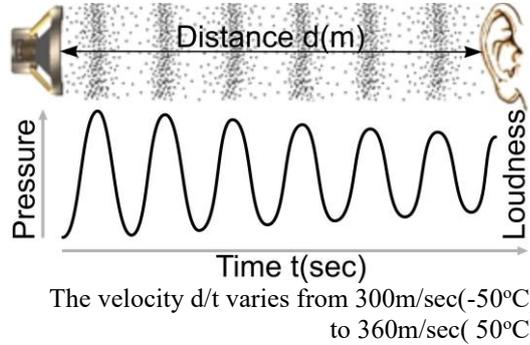
R1 and R2 are related to **f** by a ‘lens makers formula’ (Snellius’ law): $\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$.

For the **convex lens** $R_1 = 3\text{cm}$ and $R_2 = -3\text{cm}$, so $f_1 = 3$ in **Fig. 202**p112.

For the **concave lens** $R_1 = -1\text{cm}$ and $R_2 = 1\text{cm}$, so $f_2 = -1$.

But together $\frac{1}{f_{total}} = \frac{1}{f_1} + \frac{1}{f_2} = -\frac{2}{3}\text{cm}$. So, in **Fig. 202**p112 f_{total} is at **-1.5cm** from the **second lens**.

SOUNDS DISPERSE AS WAVES



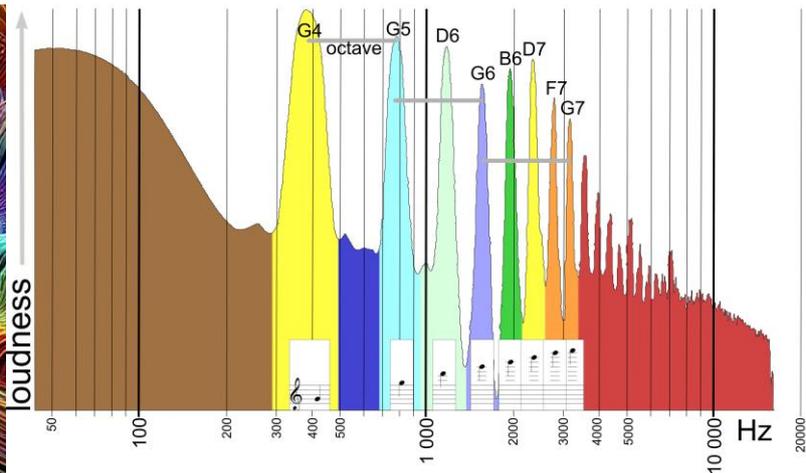
204 Sound(pressure)^a

205 Mixed and untangled wavelengths^b

Sounds reach our ear by changing loudness(air pressure) propagated like waves(**Fig. 204**).

Loudness decreases by the distance **d** between the source and the receiver as loudness/**d**².

The velocity of sound **d/t** varies by temperature.^c Different waves are added into one irregular pattern (**Fig. 205**), untangled by our mind or mathematically (‘Fourier transform’).



206 Sounds of a violin^d

207 Such peaks of a Stradivarius violin^e

In **Fig. 206** many **undertones** and **overtones** surround the loudest ground tone of a violin.

In **Fig. 207** such loudness peaks accompany the played **G4** of 387Hz on a Stradivarius (1677).

The violin adds the higher octaves **G5**, **G6**, **G7** and many other overtones at lesser loudness.

That gives a ‘warm’ sound and it makes a violin or a specific voice recognizable.

The **low frequencies** have a high pressure^f, but ears **registrate** a lower loudness (**Fig. 209**p114).

The least Δ pressure registrated by ears is approximately 0.00002Pa = 0 ‘decibel’ (dBA^g).

A decibel (see **Fig. 208**p114) is more convenient measure of loudness:

20dBA = 0.0002Pa, 40dBA = 0.002Pa, 60dBA = 0.02Pa and so on.

^a <https://www.geluidsmeting.nl/c-3280391/informatie-over-geluidsgolven/>

^b <https://www.nti-audio.com/en/support/know-how/fast-fourier-transform-fft>

^c Velocity(sound) = 0,59*temp(air)+331.

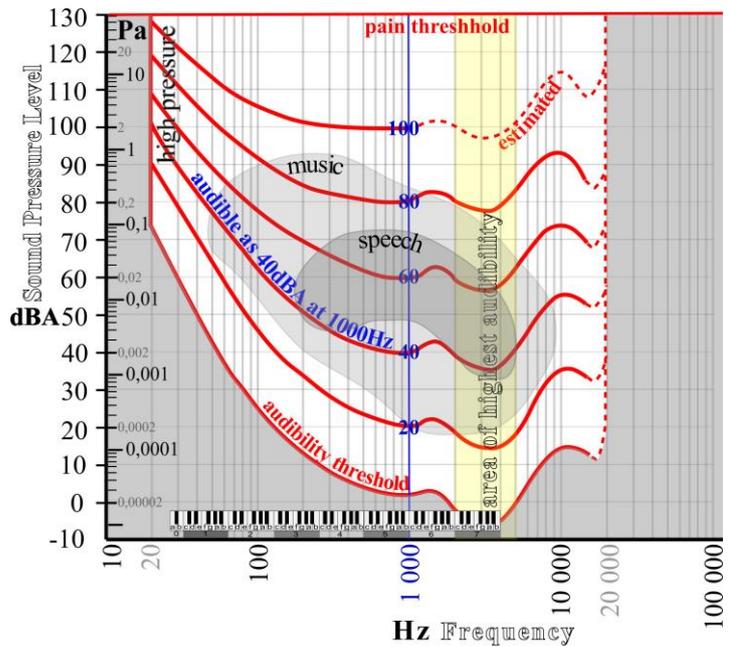
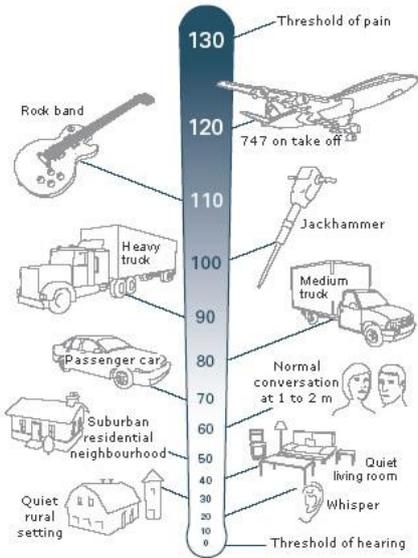
^d ChatGTP

^e Haar(2014)

<https://www.robvanderhaar.nl/wp-content/uploads/2019/06/Klankanalyse-vioolbouw-deel-1-eindversie-dd140614.pdf>

^f A pressure change (Δ) is measured by pascals Pa = N/m², where N(newton) \approx 0.1 kg weight.

^g The ‘A’ (auditory) is added because ‘dB’ is also used in other scientific disciplines, where variables are represented by exponents (log₁₀ or log_e).



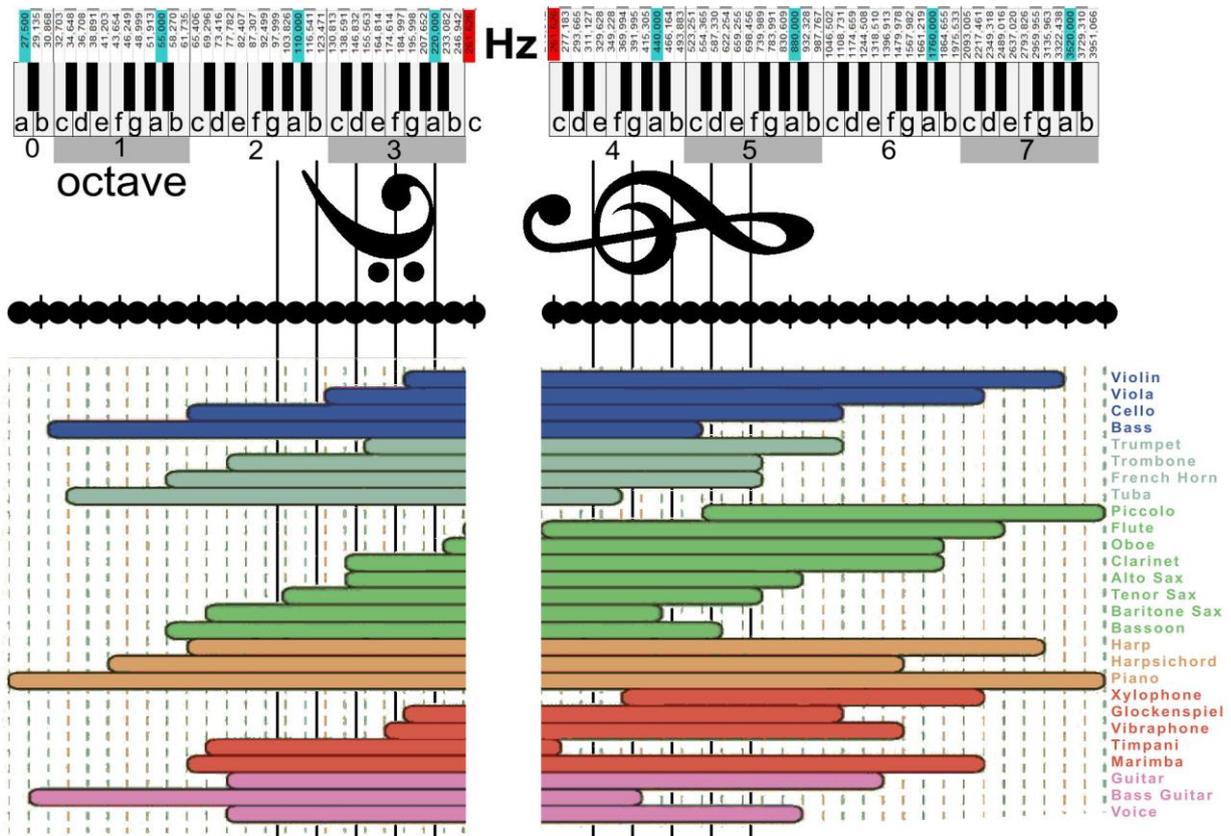
$$dBA = 0,00002 * e^{(0,11512926 * Pa)}$$

$$Pa = 8,6859 \ln(dBA) + 93,979$$

208 dBA loudness^a

209 Audible frequencies^b

Low frequencies are tempered by our ear (Fig. 209, with the piano inserted as a reference). Compare the piano with the audible range of other musical instruments (Fig. 210).



210 Musical names of notes and the available range in different instruments^c

^a <https://www.flickr.com/photos/maroulisnick/14905796177>

^b ISO 226:2003 revision https://en.wikipedia.org/wiki/Hearing_range

^c <https://www.researchgate.net/profile/Tuna-Torun/publication/339313593/figure/fig27/AS:1002647008059404@1616061083332/Frequency-ranges-of-orchestral-instruments.ppm>

TRAFFIC IS A LINE SOURCE OF NOISE

The noise of a highway (**Fig. 211**) stems from a large number of moving points in a line. Their individual noise weakens by a distance r^2 , but together the reduction is less.

The horizontal distance and the altitude where the noise is heard are important suppositions of any specified ‘dBA’. In the example of **Fig. 211** the maximum noise is heard at the 7th floor, 20m altitude (**73dBA**, **Fig. 212**).

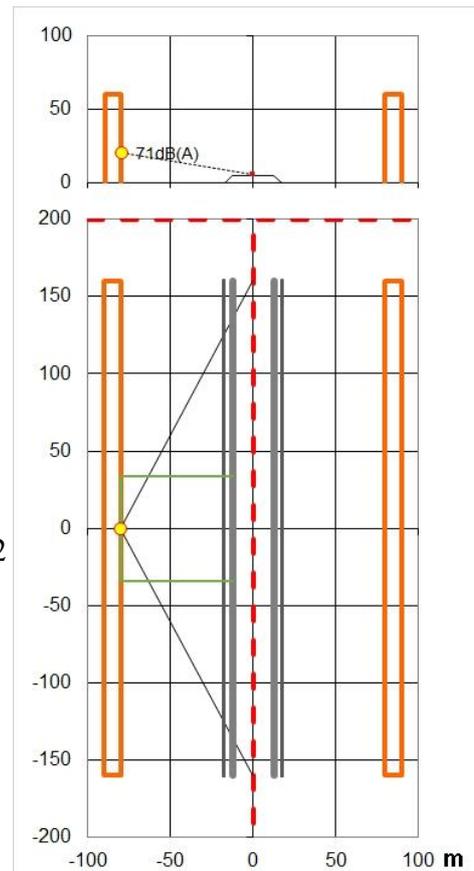
... *If nothing is done to reduce it.*

A proper asphalt surface^a (**Fig. 212**) may reduce that noise by 3dBA to 70dBA. If the surface in between is **not paved** (**Fig. 211** the **square**), then the noise is again reduced by **1 dBA** (**Fig. 212**), due to less noise reflection from the floor.

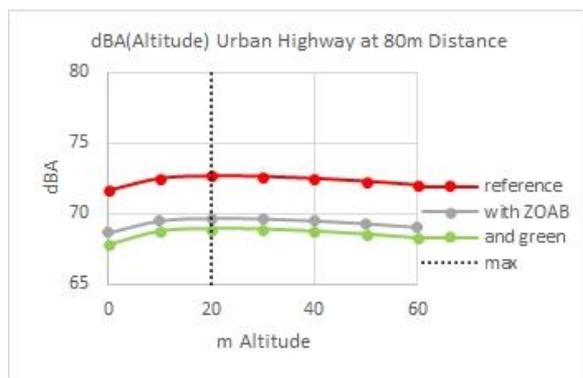
Supposing these conditions, a 30km/hr *increase* of the velocity of vehicles (classes light and medium) may cause **2 dBA more noise** (**Fig. 213**). For heavy vehicles a velocity of 80km/hr is supposed in both cases.

A still hidden supposition in these calculations is the number of vehicles of this urban highway: 5000 Light Vehicles/hr, 2000 Medium Vehicles/hr, 2000 Heavy Vehicles/hr. This requires 4 lanes on the road.

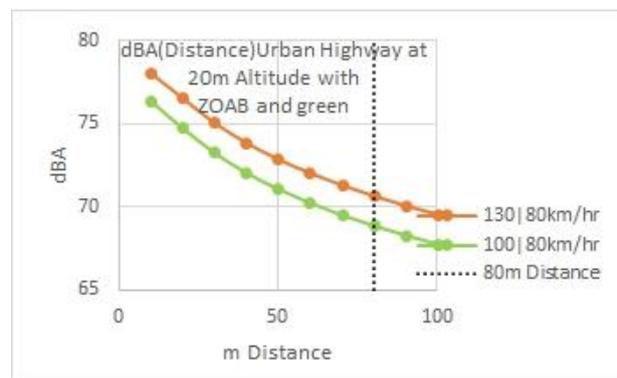
There are, however, more suppositions not mentioned here: the distance, altitude and width of the opposite noise reflecting surface, the distance to eventual obstacles, a nearest crossing and a number of reduction factors.



211 An urban highway between high buildings



212 Some reductions of traffic noise



213 The impact of velocity

The wind may temporarily disrupt these figures significantly and over great distances.

^a Here 1L ZOAB replaces a reference, but there are many more alternatives.

§ 28 THERMODYNAMICS CONNECTS TWO LEVELS OF SCALE



214 Boyle^a



215 Watt^b



216 Carnot^c



217 Boltzmann^d

Leading designers of the contents of this paragraph

WORK AND HEAT SUPPOSE ENERGY AT DIFFERENT LEVELS OF SCALE

The hose of a cycle pump becomes warm as soon as you start pumping.
 You lost some work (directed movement) as heat (molecule movement in all directions).
 The rest is stored as the 'potential energy' of the compressed air.

That remainder can be reclaimed as work, lifting a weight if you release the pump.
 As a whole, no energy has been lost (the First Law of Thermodynamics), but you lost the
 'energy quality' of useful directed movement as heat (Second Law of Thermodynamics).

If you close the end of the hose (so that no air can escape) and you push the piston $s_{max} = 20cm$
 downwards, then you feel an counterforce increasing from $s = 0m$ into $0.2m$. If your final force
 f_{max} matches $1kg$ weight, then your force f increases from 0 to $1kgforce (= 9.8newton = 9.8N)$.

The *energy* you delivered (your work W) is force times distance, $f \cdot s Nm (= joule = J)$, but f and s
 both increase stepwise (**Fig.94p70**), from zero to $98N$ and to $0.2m$, and not in the same rate.
 You loose heat and counterforce: the temperature and pressure in the pump change pumping.

DECREASING VOLUME INCREASES FORCE, PRESSURE AND TEMPERATURE

Temperature T is a measure of the average kinetic energy per molecule.
 If there is no longer any molecule moving, then T is $0 K$ ('kelvin'). That zero *kelvin* = $-273,15^{\circ}C$.
 The units of *celcius* and *kelvin* are the same, but their zero-point differs.

Now take $6.022141 \cdot 10^{23}$ equal molecules of gas (a '*mole*' see page 134), at temperature T .
 Then the number of *moles* $n = 1$. Their heat energy pV appears to be $n \cdot R \cdot T$ joule, where $R =$
 $8,314\ 462\ 618\ J/(K \cdot mole)$ (the 'gas constant' valid for any gas). So, $pV = nRT (J, joule)$.
 Written as $pV/T = nR$ (a constant) it is known as the 'Law of Boyle-Gay-Lussac'.^e

The atmosphere presses with $c.1kgf$ on $1cm^2$, or approximately $10N/cm^2 = 100\ 000N/m^2 (Pa) = 1bar^f$.
 Suppose your bicycle pump has a working length of $54\ cm$ and an inside diameter ('bore') of
 $3.57\ cm$. So, it contains $54 \cdot \pi \cdot 1.78^2 = 540\ cm^3$ of air (that is $0.7\ gram$ or $0.024046\ mole$ at $25^{\circ}C$).

^a [Boyle\(1660,1662\)](#) Robert Boyle invented the model $P \cdot V = k$: in gasses pressure times volume is constant. In 1802 Joseph Louis Gay-Lussac published that the volume increases in proportion to its absolute temperature.

^b [Watt\(1769\)](#)
 James Watt improved the steam engines of Savery and Newcomen, clearing the way for the Industrial Revolution.

^c [Carnot\(1824\)](#)
 Sadi Carnot clarified the efficiency of steam engines. This has been the foundation of thermodynamics as a science

^d [Boltzmann\(1877\)](#)
 Ludwig Boltzmann made probability theory the basis of thermodynamics. Until then, probability hardly played a role in physics, but it proved to be necessary in order to predict the behaviour of small particles. In thermodynamics it became necessary because of their large number, and later in quantum mechanics because of their individual unpredictability.

^e Boyle(1660) proved that pV is constant at the same temperature, Gay-Lussac did that in 1802 for V/T at equal pressure and Clapeyron in 1834 for $pV/T = nR$ at $n = 1mole$.

^f Our air pressure is approximately $100\ 000N/m^2$, $100\ 000\ pascal$, ' Pa ', $1000\ hectopascal$ ' hPa ' or ' $1bar$ '.

Now push the piston down 20cm (your 'stroke') very fast in order to loose little heat. The pressure was 1bar and you added the same, pressing $1\text{kgf}/1\text{cm}^2$. So, you have doubled the air pressure in the tube. The number of molecules (*moles*) does not change, but the volume becomes $540-200=340\text{cm}^3$ ($540/340$ is called the 'compression ratio').

You have *increased* pressure from the atmosphere $p_1=100\,000\text{N}/\text{m}^2$ into $p_2=200\,000\text{N}/\text{m}^2$. You have *decreased* the original volume from $V_1=0.00054\text{m}^3$ into $V_2=0.00034\text{m}^3$. The increase of energy in the pump is $V_2p_2-V_1p_1=14\text{J}$, but 'stepwise' (\int) 7J .

Let us for the time being forget stepwise integration (\int). According to Boyle-Gay-Lussac pV/T is constant, so $p_1V_1/T_1=p_2V_2/T_2$. The initial temperature T_1 was $298.15\text{K} = 25^\circ\text{C}$. Then the new temperature must be $T_2=T_1 \cdot p_2V_2/p_1V_1=298.15 \cdot (200000 \cdot 0.00034)/(100000 \cdot 0.00054) = 375\text{K}$. That is $375-273,15=102^\circ\text{C}$.^a **Your cycle pump is a heater!**

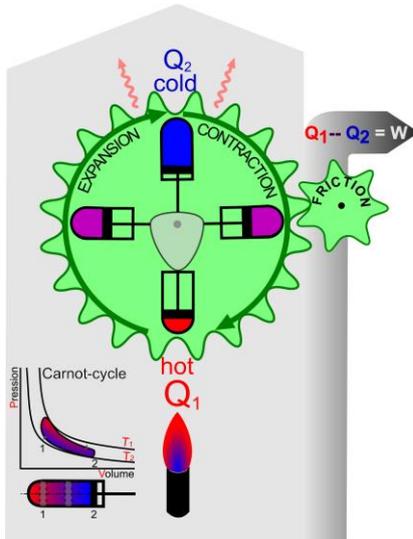
If you release the cycle pump, the piston will shoot up again, but not completely. The cylinder has lost some heat in the mean time. Lacking that heat, the temperature inside the tube becomes *lower* than T_1 . Pull the piston higher. T decreases again. **Your cycle pump has become a refrigerator!**

Let the corresponding volume of air escape, until the piston has dropped 20cm. Then close the hose again. Now put the cycle pump in boiling water. The pressure will rise, so that the piston will rise. There is less air to expand (you have let it escape), so it will not reach 20cm, but it still can lift a weight over some distance. The supplied heat ΔQ is then partly converted into work W .

Your cycle pump has become a motor!

A CARNOT ENGINE EXTRACTS WORK FROM A DIFFERENCE OF TEMPERATURE

Carnot(1824)^b clarified how a steam engine extracts work (directed movement) from heat (molecules moving in all directions). Imagine four cycle pumps on a wheel in a cold environment with a hot flame below (**Fig.218**).



218 A Carnot-engine

Q_1 heat enters a cylinder, its **volume V expands**, then Q_2 escapes by cooling, and **V contracts**.

The difference ΔQ equals the work W delivered: $W = Q_1 - Q_2 = \Delta Q$ (minus a part lost by friction). Work or heat is Boyle's pV in $pV/T = nR = \text{constant}$ ^c.

The absolute temperature T_{hot} cooles $-\Delta T$ into T_{cold} , delivering W and then the reverse heats again $+\Delta T$. That does not happen at once, but gradually, stepwise.

W is the stepwise integral sum of pressures $p = nRT/V$ times each stepwise change of volume dV :

$$W = \int_{V_{\min}}^{V_{\max}} p \, dV = \int_{V_{\min}}^{V_{\max}} nRT/V \, dV = nRT \cdot \int_{V_{\min}}^{V_{\max}} 1/V \, dV.$$

In the cycle as a whole R , n , and $T (=T+\Delta T-\Delta T)$ are constants. So, they can be put outside the integration.

One '*mole*' of gas contains $6,022 \cdot 10^{23}$ molecules (Avogadro's number N_A). If $n=1\text{mole}$, $R=8.31$ (gas constant), overall T is also constant, and V_{\max} is $2V_{\min}$, then $\Delta Q = W = nRT \cdot \int_{V_{\min}}^{V_{\max}} 1/V \, dV = 1 \cdot 8.31 \cdot T \cdot \int_1^2 \frac{1}{V} \, dV = 8.31 \cdot T \cdot \ln(2/1) = 8.31 \cdot T \cdot 0.693 = 5.76T$. $\Delta Q/T (=5.76)$ is called entropy.

^a If you take a more realistic normal air pressure of $1011,3\text{hPa}$, then it is 94°C .

^b [Carnot\(1824\)](#)

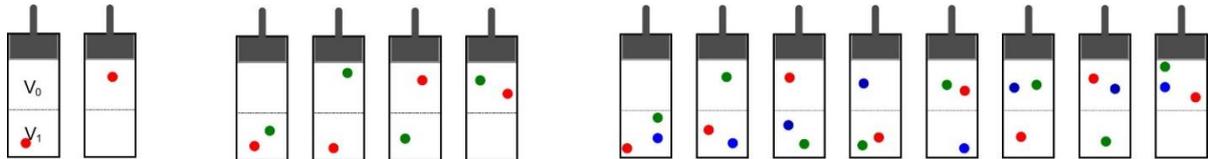
^c Law Boyle-[Gay-Lussac\(1802\)](#) See [Magie\(1935\)p165](#)

ENTROPY SUPPOSES A PROBABILITY OF DISTRIBUTION

Clausius(1854)^a studied Carnot. He interpreted entropy as a probability of distribution. Molecules hurrying in random directions, always concentrate and disperse locally.

Imagine a cylinder with a gas filling its largest volume V . The chance that the gas incidentally concentrates in one half V_1 leaving the other half V_0 empty, may be extremely small, *but not impossible*.

You may *calculate* that extraordinary little *probability* as an imaginary *possibility*. With one molecule, that probability is yet $\frac{1}{2}$ (50%). With two molecules that probability is $\frac{1}{2}^2 = \frac{1}{4}$, with three molecules $\frac{1}{2}^3$ (**Fig.219**).



219 All possible distributions of 1, 2 or 3 molecules over two equal halves of a cylinder

With m molecules that probability then is $\frac{1}{2}^m$. The chance that all molecules of one *mole* ($m=6,022 \cdot 10^{23}$) happen to be in V_1 of **Fig.219**, is one to 2^m ($1/2^m \approx 1/2^{602\ 200\ 000\ 000\ 000\ 000\ 000\ 000}$). If you do not choose a compression up to $\frac{1}{2}V$, but up to $\frac{1}{3}V$ or even $1/22V$ (as in some diesel engines), then that probability is even smaller (not $\frac{1}{2}^m$, but $\frac{1}{3}^m$, $1/22^m$ etc.). With such unimaginable small chances, it is better to take the *exponent* at 10, the 'logarithm' $\log(m)$, or the *exponent* at 'e', the 'natural logarithm' $\ln(m)$, see p.71

Entropy S based on probabilities, compares two chances: $S=R/m \cdot \ln(\text{chance}_{\text{all in } V_0+V_1} / \text{chance}_{\text{all in } V_1}) = R/m \cdot \ln(2^m / 1^m) = mR/m \cdot \ln(2/1) = R \cdot \ln(2) = 8.31 \cdot 0.693 = 5.76$ (in fact ΔS , but the second chance is practically zero).

So, the *chance theoretic* $S = R/m \cdot \ln(\text{chance}_1 / \text{chance}_0)$, equals the *gas theoretic* $S = \Delta Q/T = 5.76$.

A crystal, ice, or a system of motionless molecules near the absolute zero point of temperature ($T=0K$) have a lower entropy S (a greater 'order') than liquid or gas with higher temperatures, but their absolute values are difficult to determine.

Their *differences* Δ , however, can be calculated based on measurements.

The real zero point of disorder (the highest degree of 'order') is never reached, because a temperature $T=0 K$ is unattainable, although experiments are close to it nowadays. Something similar applies to the highest degree of 'disorder'.

If you take the piston out of a cylinder, then the system boundary shifts, and V_0 suddenly encompasses the entire atmosphere. So, V_1 is an even smaller part of it. A total dispersion of matter in the universe would represent the highest entropy. Spreading seems inevitable, even though we see local and temporary concentrations.

Two mutually approaching particles may pass each other or collide. In both cases the convergent (concentrating) movement $\rightarrow \leftarrow$ changes necessarily into a divergent $\leftarrow \rightarrow$ (dispersing) movement. This mechanical process increases entropy. It is not reversible without an *enclosure* of concentrated matter. The arrow of time cannot be reversed.

If you do not want to wait until the gas accidentally concentrates in one half of the cylinder (with a probability of 1 in $2^{602\ 200\ 000\ 000\ 000\ 000\ 000\ 000}$ cases), then you should deliver an amount of pumping work W for compression.

^a [Clausius\(1854\)](#).

WORK OUT OF HEAT SUPPOSES LOSS OF ENERGY

A steam engine brings water to a boil in a closed boiler.

The saturated steam can reach a temperature of 190°C and a pressure of 12bar.

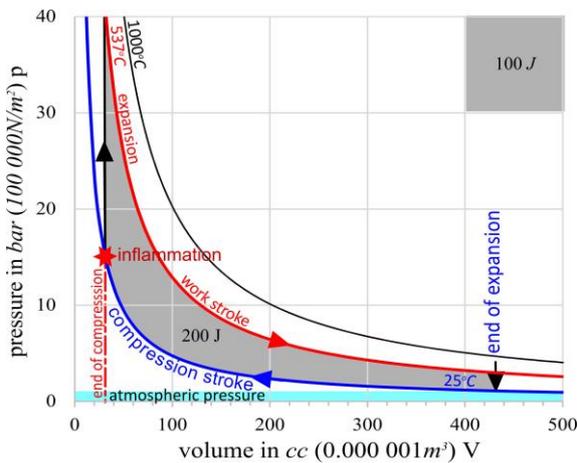
That pressure moves a piston in a cylinder on one side (or alternately on both sides).

If after that first stroke, the expanded and cooled steam is discharged by the receding piston, then the process can be repeated. Various constructions have been developed for the timely opening and closing of fuel supply and discharge, for example the 'camshaft' used in cars, which opens and closes at least two 'valves' per cylinder.

Since the invention of the 'ottomotor'^a, the fuel is hardly used anymore to generate steam pressure, but the fuel itself has been ignited, exploding in the cylinder.

A gas mixture (for example 1 part of petrol on 15 parts of air) explodes, provides the necessary pressure, and the burnt gas is emitted via the exhaust.

Normally two expansion and two compression strokes are required: an *expansion* stroke to collect the fuel, a *compression* stroke (10-18 bar 300-400 °C) to ignite it with an electric spark (generated by a 'spark plug'), so that the subsequent *expansion* stroke provides work and finally a *compression* stroke brings the burnt fuel outwards.



220 pV graph (Boyle-Gay-Lussac) in a passenger car

Fig.220 (the cycle of a passenger car), shows a pV-graph for two temperatures T from the formula of Boyle-Gay-Lussac: $pV=nRT$.

You can see how much work such a cycle can yield: $p \cdot V$ (energy) equals the grey surface.^b

So, one cycle in one cylinder yields 200J of work, and 6000 rotations per *minute* (rpm) or 100 per *second*, yields

$$100 \cdot 200J = 20\,000J/sec = 20\, watt.$$

With 3 cylinders that is a power (energy per second) of 60 000J/sec. = 60kW or 82hp (the old fashioned horse power).

The surface *under* the '*compression stroke*' represents the work needed to compress the air at that stroke. Up to 1bar, the atmosphere has a share in it.

Without the help of that pressure, compressing would cost more energy.

One stroke of 0.0004m³ takes about 6% petrol mixed with the necessary air.

It has a calorific value (heat production) of Q₁ = 872J, but only 200J is used for work.

The return (efficiency) $\eta = W/\Delta Q$ then is 200/872=23%.

The remainder, Q₂ = 672J, is lost as heat (see also **Fig.218** p117).

The left vertical arrow in **Fig.220** represents the moment after ignition where suddenly 872J of heat (Q₁) is released in the cylinder. The pressure immediately rises. In reality, however, the arrow will not be vertical, but during the ignition it will take a moment to the left (less volume) and then take a smooth bend to the right towards the *work stroke* (increasing volume).

^a The first combustion engine has been invented by Isaac de Rivaz in 1804, improved by Jean Joseph Etienne Lenoir in 1860 and at last successfully improved by Nikolaus August [Otto\(1877\)](#)

^b $\int nRT_{max}/V \delta V - \int nRT_{min}/V \delta V$, both determined between V_{min} en V_{max}, that is $nRT_{max}(\ln(V_{max})-\ln(V_{min})) - nRT_{min}(\ln(V_{max})-\ln(V_{min})) = 200J$. Where n=0,02005mole; R=8,314J/Kmole; T_{max}=525,965+273,15=799,115K; T_{min}=25+273,15=198,15K; V_{max}=0,034m³; V_{min}=0,0031m³.

If the volume would not change ('isochore'), the temperature should rise to 537 °C. That is unlikely to happen, if the volume increases immediately thereafter (**expansion** in **Fig.220**p119).

Since 1892, gas mixtures have been used that spontaneously ignite in a 'diesel engine' at 256°C without a spark plug.^a In order not to ignite too early ('pinging' or 'knocking'), the fuel should be injected fast under high pressure during compression (25-50bar). Then there is an even faster explosion than with the ottomotor, so that more cycles (revolutions) can be made per second.

For the wider application of the diesel engine after 1920, it was therefore waiting for a more effective execution of the at the time underperforming fast injection pump^b.

A Stirling engine has no inlet or outlet. It heats the same gas and cools it down on the other side of the piston again.

Fig.220p119 shows that a passenger car requires a temperature difference ΔT of 527-25 \approx 500°C to yield enough work and power. A racing car may require more than 1000°C.

The greater that difference, the more lost heat you could still re-use (yielding a higher total energy use, 'exergy').

For example, you could still run a small steam engine or Stirling engine using the very hot exhaust fumes of a racing car. The same amount of heat Q at high temperature has apparently more 'energy quality' (less entropy) than at a lower temperature.

If the entropy $\Delta Q/T$ increases, then the ability to produce work reduces.

This process goes by itself and is 'irreversible', if you do not add external energy (work W) in order to get a higher temperature T by compression.

IT IS EASIER TO MEASURE A DIFFERENCE THAN AN ABSOLUTE VALUE

Any heat or work entering or exiting a system, changes its internal energy U .

That U itself is difficult to measure or to calculate.

If you would have to include the mass according to $E=mc^2$ (p102) as potential energy, the potential decomposition energy of all molecules (bondings represent potential energy, see p136), the kinetic energy of their spinning, and other contributions, then you may better measure or calculate the difference (' ΔU ') between two states only.

You can determine ΔU from the incoming and outgoing energies $\Delta Q+\Delta W$.

A difference Δ then is a difference between two 'states' of a system or between two systems in a different state. Do not forget Δ is bridged in indivisible small steps d .

Their sum, integrating Δ into $\int d$ can still produce higher or lower values (**Fig.94** p70).

THE HEAT REQUIRED TO RAISE THE TEMPERATURE OF 1 KG BY 1 °C MAY BE DIFFERENT.

If you heat 1kg of air (34.5mol or 1.2m³) at 20°C (293.15K) into 21°C, without a change of *pressure* ('**isobar**') you have added 1003J of heat Q . That 1003J per °C or °K and kg is the 'specific heat at equal pressure' ('**c_p**') of air. At the same pressure, however, the air has acquired a larger volume.

If you keep the *volume* the same ('**isochore**') in a closed vessel, then you need less heat: 715J.

That 715J/(°K*kg) is called 'specific heat at equal *volume*' ('**c_v**') of air.

At the same volume, however, the air has acquired a greater pressure.

Suppose the atmospheric pressure to be 1 *bar* at ground level, neglecting the small variations.

In **Fig.220**p119 I used c_p to add up the **work** the engine had to do first: 'lifting the atmosphere'.

Before **delivering work**, it had to overcome the atmospheric pressure of the surroundings first.

The engines of an aeroplane may have to overcome a lower atmospheric pressure.

^a The first Diesel engine has been invented by [Diesel\(1886\)](#) He constructed the first operating Diesel engine in 1892.

^b The long road to an commercially valid fuel injection device is described in [DeLuca\(\)History of fuel injection\(WWW\)](#). Bosch succeeded at last in 1927.

Every different gas, or more generally any kind of material, has another specific heat.

Because liquid or solid material hardly expands, there is no difference between c_p and c_v .

Heating water costs for example $4187J$ per *degree* and *kilogram*, dry brick only $880J/(K*kg)$.

Heating up a brick of $1.75kg$ ($5*10*15cm$) one degree costs $1470J$. It is the 'heat capacity' of that brick as an object with a given mass. When you heat your home, all the stones, furniture and other materials contribute their share, depending on their specific heat capacity.

§ 29 QUANTUM MECHANICS SUPPOSES UNCERTAINTY

Quantum mechanics is already briefly introduced on page 36.

AT THE LOWEST OBSERVABLE LEVEL OF SCALE, SPACE HIDES TIME OR THE REVERSE

At the level of molecules, atoms, their parts (electrons, neutrons and protons) and even smaller particles^a, there are other field forces than gravity^b. They keep such particles together at a much shorter distance.

These forces are not immediately measurable, because the smaller size and mass, the less you can determine other properties without disturbing them by your observation (for example with light particles, photons).

If you are certain about its trace in a medium, then you cannot be sure *when* it reached a point.^c You can only calculate the *probability* when it was where.

Einstein and many others did not believe that probability was the end of the story ('Copenhagen interpretation'): 'God does not play dice' ('determinism').

Half a century before Einstein, however, a more statistical approach in thermodynamics had already proven to be necessary. It worked reasonably well to bring both approaches into line with each other at different levels of scale.^d With the rise of quantum physics, this again became a problem at an even smaller level of scale.

PARTICLES DISPERSE AS WAVES DO

If you send electrons through a narrow slit, then they seem to spread behind that slit in wave circles as it is known in a water surface. With two slits, these wave circles also alternately extinguish and strengthen each other ('interference'). They meet like the waves around two stones you throw into the water at the same time (**Fig.50**p36).

Conversely, a light wave cannot be infinitely divided into even smaller light pulses.

So you must conclude that light consists of particles ('quanta') called 'photons'.

If each wave field also has a particle character, gravity must also have a force-transmitting particle, although this has not yet been observed. For the time being it is called 'graviton'.

LIGHT SUPPOSES ENERGY WITHOUT MASS

Photons move at $c=299\,792\,458$ m/s, so according to Lorentz (**Fig.181**p102) they should have an infinitely large mass. Then you have to conclude that they have no mass, but that is again in contradiction to the fact that they *do* have an energy $E=mc^2$, even if $m=0$.

You can generate electrical energy from sunlight with photocells, after all.

The beginning of quantum theory (in 1900 see p36) has been Planck's constant h predicting the observed energy of light $E = h \cdot \text{frequency} = h \cdot c / \text{wavelength}$ as the smallest transferable quantum. The energy of light is only observable if it hits a mass transforming its 'momentum' into energy. For photons, momentum $p = \text{mass} \cdot \text{velocity}$ (p102) then has to be redefined as $p = h / \text{wavelength}$.

GRAVITY IS NOT YET OBSERVED AS A PARTICLE

In the meantime, the physicists have already splitted many known particles with their particle accelerators. This resulted in a large number of smaller particles with different properties.

Physicists distinguished them into groups, and have given them all a name.

But most of them live so short that you never meet them outside of those accelerators.

^a Quarks (from which protons and neutrons are composed), leptomes (like the electron) and bosons (like the photon).

^b Electromagnetic forces (transferred by photons), strong nuclear forces (gluons), weak nuclear forces and other (bosons).

^c [Heisenberg\(1927\)](#)

^d See for example [Young\(1964\)](#)

There are various mathematical constructions to find some regularity in the properties of those particles (for example, the 'Standard Model'). In a list with combinations of such properties, there are particles missing that have not yet been observed.

It is then the challenge to demonstrate a missing combination as an 'existing' particle.

Most particles have an antiparticle, which shoots in the other direction than the particle after some splitting. Their traces are then symmetrical. So, they both have the same properties of mass and lifespan, but their charge is opposite. The antiparticle of an electron is a 'positron'.

If a particle hits its anti-particle, then they both disappear leaving energy (or photons) behind. Then I think *adding* energy you can split 'the nothing' into a something and an anti-something. The majorana particle, however, turns out to be its own anti-particle, without immediately disappearing. At last, however, the graviton still remains untraceable.

QUANTUM ENTANGLEMENT SUPPOSES MORE DIMENSIONS THAN SPACE AND TIME

There is also a ghostly phenomenon called 'quantum entanglement'.

Quantum particles have measurable properties such as a direction of rotation (\cup 'upward spin' or \cap 'downward spin'). That direction can reverse, and usually that twofold state is divided randomly between different particles.

If two identical particles are created by splitting a larger particle, then they keep an opposite spin. That spin gets a value as soon as you measure it.

Now it is ghostly, that if you measure one spinning particle with the one quantum, the other one also changes immediately, no matter how far apart they are.

This has been proven over a distance of 1.3 km by Hanson and Hensen (2015) ^a.

According to Einstein, this seems impossible. Information from one particle can never be transmitted to the other particle faster than light. If it is a mysterious information transfer, it should go faster than light.

Maybe they stay connected in a 'fifth dimension' to take up an opposite charge.

In order to reconstruct something like this mathematically, however, you have to suppose more than 4 dimensions ('string theory').

THEORIES OF EVERYTHING REMAIN INCOMPLETE

Both relativity theory and quantum theory are good predictors. They are used everywhere.

The mathematical simulations work excellently, but to *imagine* quantum behaviour is almost impossible. It remains also insufferable that two so different theories (deterministic and mainly statistical) cannot be united.

Quantum theory cannot get a grip on gravity and determinists cannot determine entanglement or accept statistical uncertainty. Thermodynamics, however, is already since long accepted as a sound branche of physics, based on statistics.

^a Hanson c.s.(2015); Wayenburg(2015) and a comic strip that gives an exciting account of that evidence: Kriek(2015)

§ 30 INFORMATION SUPPOSES FORMATION

INFORMATION SUPPOSES PHYSICS

0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111	1000	1001	1010	1011	1100	1101	1110	1111	1000	1001	1010	1011	1100	1101	1110	1111
010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010	010
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_

221 Binary ASCII codes for 26 capitals and 6 other signs out of 256 possible codes

Information can be stored physically, and it can control physical processes. A footstep is very literally in-formation, an in-pression of physical differences that can be labelled with signs.

One bivalent sign [0 or 1], called '**bit**', may distinguish 2^1 cases [0 1]. Two bits $2^2=4$ may distinguish 4 cases [00 01 10 11], three bits $2^3=8$ cases and n bits 2^n . In order to distinguish $256=2^8$ characters ('alphabet') or colors (in a 'legend') requires 8 bits (**Fig. 221**).

The exponent of 2^n , 'the binary logarithm', 'lb' (instead of log or ln)^b is the number of bits. In order to distinguish only the numbers 0-9, requires $\text{lb}(10)=3.321928$ bits, but a digital computer only processes whole bits and it thus requires 4 bits to do so.

In 1963 The American Standard Code for Information Interchange (ASCII)^c used 7 bits (128 codes), later 8 bits, including even more signs (256) such as computer control codes. After 1992 The Unicode Transformation Format (UTF-8) also used 8 bits. The second row of **Fig.221** includes: 010 capitals, 011 lowercase, 001 numbers and 000 control codes.

A set of 8 bits with $2^8=256$ combination options available, is called a 'byte'.

A computer then 'knows' without a stop sign that a new character starts after 8 bits. The information 'I' per character is then $I=\text{lb}(256)=8$ bits or 1byte (B).

Human reading takes at average 240 words per minute. With an average word length of 10 characters that is $2400/60=40$ characters per second (40 'baud').

If a character requires 8 bits, you may read at a speed of 320 bits/second ('bit rate').

In order to digitize *spoken* text, you need 7 bits at least 6000 times per second.

You have to distribute the sound wave ('amplitude') in at least $2^7=128$ classes and give each a binary code. A call then takes 42 000bits/second.

A television image with 500 000 points ('pixels') in 16 colors, or $\text{lb}(16)= 4$ bits/pixel, and that 25 times per second, yields $500\ 000*4*25=50\ 000\ 000$ bits/sec or 50megabits/sec.

Nowadays it is already 256^3 RGB colors (3bytes/pixel), with more than 8 million pixels, 50 times per second (1200 megabytes/sec), but you can 'compress' that.

^a <https://www.rapidtables.com/code/text/ascii-table.html>

^b $\log_{10}(256) = 2.41$ $\ln(256) = 5.55$ $\text{lb}(256) = 8.0$

^c <https://en.wikipedia.org/wiki/ASCII>

REPETITION REDUCES INFORMATION VALUE

The information of moving images contains much repetition without new information ('redundancy'). It can be 'compressed' by passing on only the *differences* of each subsequent image keeping much of the previous picture the same (applied in the 'MPEG' compression). Something similar applies to sound and text. A text such as OOOOOOOOOO^a takes 80 bits (10 bytes), but it has little or no information value.

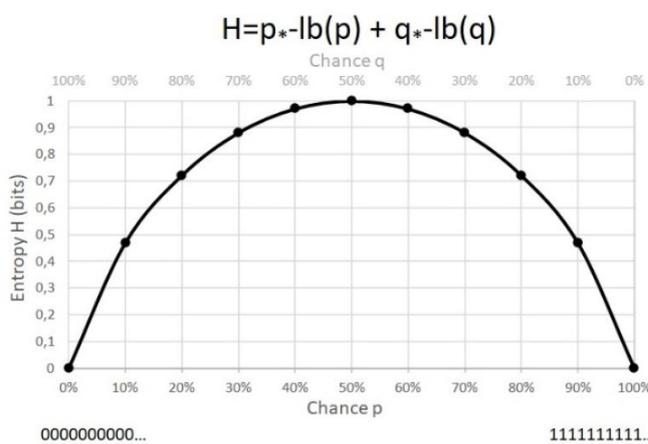
A small difference NOOOOOOOOO suddenly has much more information value. The repetition of O's can be understood as an emphasis like NO NO NO..., but for *numbers*, every next 0 has a different meaning by its *position*. In the information '1000' every repeating 0 is even more 'informative'.

So, the 'meaning' may be different for different users. How could you then quantify an 'information value' without having to include the meaning ('semantics') itself?

In **Fig.219**p118 all possible distributions of 1, 2 or 3 molecules are represented on two equal halves of a cylinder. You can call those halves 0 and 1 and n molecules can be located in a list of 2ⁿ locations.

The position of one molecule (n=1) in volume V₀ or V₁ can then be reported by 0 or 1, the position of two molecules (n = 2) with 00, 01, 10 or 11, the position of 3 molecules in 1 of the 2 volumes with 000, 001, 010, 011, 100, 101, 110 or 111, and so on.

The more molecules (the larger n), the smaller is the chance to find them all in one half of V, V₁ or V₂ (ordered, low entropy). On p118 entropy has been defined as S=k*ln(chance_{V or V₁}), a measure for disorder, the opposite of 'value' or 'quality'.



222 Shannon-function

Shannon^b proposed a concept of 'information entropy' (H) in order to quantify an information *value* without having to include the *meaning* of the message. It has been based on the *chance* p that '1' will be the next sign in a binary code (otherwise '0').

If that chance p is each time 100%, then the code will be 1111111111....

If p=0%, then you get 0000000000....

Both cases are easy to compress.

You are sure about what follows, but the *value* of the transferred information is 0.

If there is, however, p=50% chance to get a '1', then there is also 100%-p=50% (write 1-p=0.5) chance to get '0'. So you are completely uncertain about the outcome.

'Certainty' means, that the outcome will have 100% information *value* for you ('self-information'^c, let me call it 'SI'). But what about SI inbetween these extremes? If you already can guess what it will be, then the amount of information I=ln(2) is one bit, but its SI is less.

You may reduce I by the chance p: p*I (p*ln(2)bits), but then, if p=1 (100% certainty) it would also be 1bit (p*ln(2)=1*1) while it has not any SI, and if p=0.5 (50% certainty) the SI would also be 0.5 bit, while it must be 100%.

^a A text to be analyzed is written here in capital characters, but the analysis does not distinguish between small characters.

^b Shannon(1948)

^c <https://en.wikipedia.org/wiki/Self-information>

This should be the point that Shannon remembered entropy $S=k \cdot \ln(\text{chance})$ as an energy-value. It does, however, not concern gas. Use $k=1.443$ to change the kind of logarithm $\text{lb}(x)=1.443 \cdot \ln(x)$.

If you take $SI=\text{lb}(p)$, then $p \cdot \text{lb}(p)$ is the chance you may receive *relevant* information (SI). Since $\text{lb}(\text{chance})$ is a logarithm of something between 1 and 0 (100% and 0%), it produces a negative number. In order to make it a positive value Shannon used $\text{lb}(1/p)=-\text{lb}(p)$ make his final formula for information-entropy (**Fig.222**p125) where q is the complementary chance of p ($q=1-p$).

The information entropy H (uncertainty, relevance) should include the complementary chance q . That is simply adding $q \cdot \text{lb}(q)$, and q is nothing else than $1-p$.

So, the information entropy H is a function of only p : $H(p)$.

According to this function the texts '000 ...' and '111 ...' do have an information entropy $H=0$, and a random text such as '110100111000' may have offered total uncertainty and thus the highest relevance $H=1$.

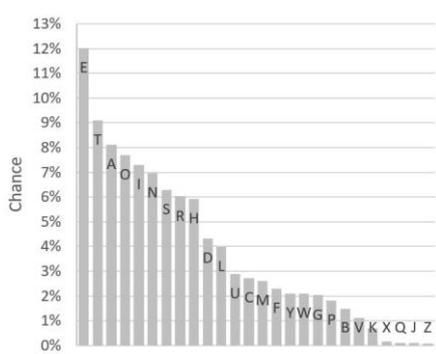
The chance to get '1' equals the chance to get '0'. Instead of '1' and '0', you may also choose 'E' and 'any other character' ('not E'). You can even split 'not E' into 'M' and 'not E or M', adding terms with p_E , p_M and $p_{\text{not E or M}}$.

An unweighted probability p that one of the characters from our alphabet appears at any location in a text would be $1/26$ (3,85%), taking $I=\text{lb}(26)=4.7$ bits.

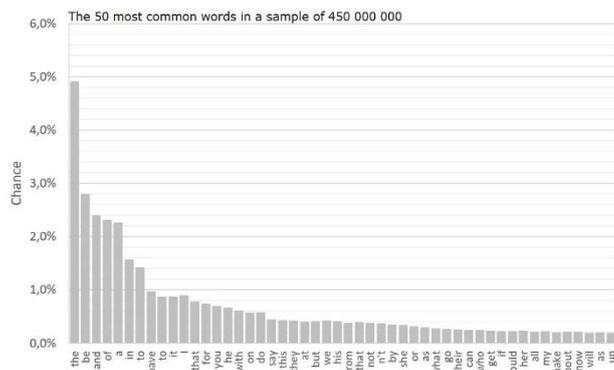
Any character, however, has its own probability to appear in a text.

Fig.223 shows that not every character is equally common. For example, the character E in the English language has a probability $p_E=12\%$ to appear in a text and the character M a probability $p_M=2.6\%$. So you can expect 'E' rather than 'M'.

The character E then has $SI_E=-\text{lb}(p_E)=3.06$ bits self-information, and M has $SI_M=-\text{lb}(p_M)= 5.27$ bits. The chance that you will actually *receive* this self-information is again p_E or p_M , producing $p_E \cdot \text{lb}(p_E)$, $p_M \cdot \text{lb}(p_M)$ and $p_{\text{not E or M}} \cdot \text{lb}(p_{\text{not E or M}})$. Add all, and you have Shannons entropy of the signal. Note that the *sequence* (ME or EM) does not yet play a role.



223 Characterfrequency ^a



224 Wordfrequency

If our alphabet consisted of the characters M and E only, and the 50% probability of M and E in a text would be the same, then the entropy H_E is 1bit, the Shannon maximum. (In this case the entropy H_M also, by the way.) Then the probability of ME (p_{ME}) would be 50% of 50%, that is 25% or 1 in 4, because EM, MM and EE are equally possible.

However, the four *combinations* are an 'alphabet' with 4 characters. So, you can no longer just use the binary Shannon function. With 26 characters, the unweighted chance of these combinations is $1/26 \cdot 1/26 = 3.8\% \cdot 3.8\% = 0.15\%$. That is much less predictable.

^a <http://pi.math.cornell.edu/~mec/2003-2004/cryptography/subs/frequencies.html> Broecke(1988)

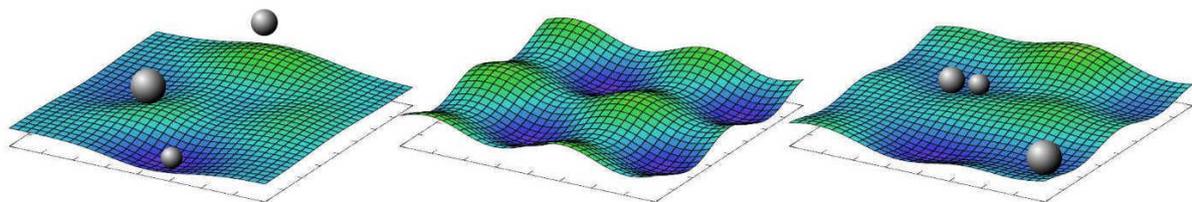
Based on the character frequency in English (**Fig.223**p126), however, the probability of ME is $3\%*12\%=0.4\%$. **Fig.224**p126 is based on a word list of 60 000 words in a sample of more than 450 million words. In an alphabet with 60 000 'characters' the probability of ME would be $1/60\ 000=0.0017\%$, but weighted to the word frequency in English it is 0.16%.

In order to supplement the expected characters for a computer when you have typed the first characters, the word frequency per language offers the highest chance of these methods. However, more methods have been devised. After a consonant often comes a vowel, in a sentence usually a verb must be present, preceded and followed by a noun, and so on.

MEANING SUPPOSES REPEATED IMPACT

In all this the *meaning* (studied as 'semantics') has not been taken into consideration. Haken^a assumes that the recipient, on the basis of previous information, attaches different importance or weight and thus significance to incoming messages. That weight can change again after following messages.

He imagines that as an undulating landscape in which information ends up as rain, or rather as heavy bullets. That landscape has flexible mountains and valleys (**Fig.225**). Of course, these bullets roll straight to the nearest valley, which has already been dented by bullets. That valley is then an 'attractor' for incoming information.



Landscape $N(q,\alpha)$ + Fluctuation $F(t) = N(q,\alpha) + F(t) = dq/dt$
225 *Attractors in the recipient's landscape, shaken by fluctuations*

The whole landscape 'N', however, also vibrates under the influence of external fluctuations 'F', so that bullets can roll to another, deeper or sometimes shallower valley, whereby that in turn becomes deeper, and gains more weight (**Fig.225**). The elevation 'q' of each point in the landscape thus changes with time t so that you can write q(t) and also F as F(t).

The whole landscape N, by the way, changes with q, in short: N(q). Each height q changes per second: q/t. That change is recorded as height per time. Every infinitely small change of q (dq) is accompanied by an infinitely small change in time t (dt).

So you write dq/dt. There are formulas to give a 'differential quotient' a fair value.

In order to calculate the change of the landscape N(q) apart from its external fluctuations F(t), you limit N(q) with all properties α ('parameters') that would have that landscape N without those fluctuations F. You then note N(q, α).

Each landscape point $N(q(t),\alpha)+F(t)$ now equals the change dq/dt.

As soon as you wake up, you will be flooded with information. It rains bullets with different weight and if they are heavy enough, they end up in your landscape.

Your senses are already a filter 'M' that determines their weight and stops light bullets, so that your landscape is hit by impulses with different weight.

With every message from outside, your landscape changes shape, but you already have your own priorities (attractors), and they do not change easily. However, you are a living organism with mood swings, and other fluctuations, so that these messages can conform to other priorities.

^a Haken(2006) p19. In addition to precursor in this quantitative semantics, Hermann Haken is mainly a laser expert and a pioneer in physical 'synergetics', the complexity theory that is discussed in the next section.

Haken^a quantifies that as follows (**Fig.226**). To keep it simple: take 3 mail messages p_0, p_1, p_2 .

relative importance p_j		attractors k	0	1	2		
j	messages	sent	recieved	normalized hor. k	$\sum_k M_{jk} = 1$		
0	p_0	→	M_{jk}	-	0,80	0,20	1,00
1	p_1	→		-	0,50	0,50	1,00
2	p_2	→		-	0,20	0,80	1,00
				-	1,50	1,50	

relative importance p'_j		normalized vert. j	0	1	2	
j'		$L_{jk} = \frac{M_{jk}}{\sum_j M_{jk} + \epsilon}$	L_{jk}			
0	p'_0		-	0,53	0,13	
1	p'_1		-	0,33	0,33	
2	p'_2		-	0,13	0,53	
	$\epsilon = 0,0001$	$\left(\sum_j \sum_k M_{jk} \right)$	-	1,00	1,00	$\sum_j p'_j = 1$

226 Weight of messages received

227 Matrix M normalized (relative weight)

They do not arrive at first, because you are still asleep, or your computer is switched off (q_0). Then you read them quickly with decreasing interest, but those impulses together have no more priority for you than to start drinking coffee (q_1). Then you read them again (q_2). They now have more weight and together they now have enough *priority* for you to send messages yourself.

Haken summarized this in a list (a matrix M_{jk} **Fig226**). The columns k (M_k) contain the relative weights, in percent (100% per row j), each having message p in the row j (M_j). So matrix M is the weight filter so that you receive the different messages p_j , but you do not have given *priority* p'_k to them per column.

They will only receive this priority if they land as bullets with different weights and then roll to a valley (attractor). 'The coin falls' so to speak.

These priorities p'_k stand in a separate list with one row (a 'vector') under the matrix M, also in percentages with a total of 100%. It is the *chance* of the information that you could forward.

From that probability p'_k (with $-p'_k \cdot \ln p'_k$) you can easily calculate the information content that you have added with those priorities: 0.64bit.

If you compare that with the information you have received, then you have added information with your priorities. Haken then says that you have created 'meaning'.

In order to calculate the amount of information *received*, you must 'normalize' the weights per column to 100% and add them per row.

That happens in the help matrix L_{jk} (**Fig.227**). You run the risk that the denominator becomes 0. This is prevented by adding a very small number ϵ to the denominator.

You can fill in all that is yellow as you wish, the rest will follow automatically according to the Hakens attached formulas. Often you also send less information, but you combine messages and give them different weights.

This model starts to look like a neuron that receives information of different weight with dendrites and transmits it to other neurons via an axon with a different weight (see **Fig.175** p94 and onwards).

^a Haken(2006) p21

§ 31 COMPLEXITY IS NOT PROPERLY DEFINED

A chaotic set of light waves (emitted by atoms in all directions: each time another electron is thrown out of its orbit delivering a photon), caught between mirrors, may suddenly create coherent highly focused coherent light in the same phase and with the same frequency. In a laser this light escapes as a high energy beam through a hole in the mirror.^a

Open systems are usually in a chaotic (high entropy) equilibrium. However, with steady or fluctuating external supply and dissipation of mass, energy or information, far from that equilibrium a sudden order may 'emerge' (a 'phase transition' similar to freezing or lasers), called 'complexity' or 'self organization'.^b

The hexagonal Bénard cells emerging in a slowly and evenly heated fluid (*Fig.166*p88), the swivels in chaotic gases (cyclones) and liquids (*Fig.168*p89), the 'invisible hand' supposed in economics^c or suddenly directed social movements ('hypes' or 'waves'), show 'enslaved' particles in a whole with apparently reduced entropy that can be described in less bits.

There is no unambiguous definition of this 'complexity' or 'self-organization', but it is apparently agreed that complexity ought to lie Between Order And total Randomness ('BOAR'), difficult to describe, to develop, to design, and to predict ('DEEP').^d Without a better definition than this, it is an embarrassing concept representing something you cannot understand.

I propose 'levels of complexity'. Complex systems:

- (1) differ from the environment in all directions ('difference'),
- (2) have some internal equality ('order'),
- (3) remain the same, despite changes in that environment ('self-ordering'),
- (4) adapt to such external changes ('adaptation'), or even
- (5) adapt that environment to itself ('accommodation'),
- (6) may be separated in connected subsystems with different functions ('specialization').

Freezing, swirls, Bénard cells and lasers do not go beyond *self-ordering* (3). Its emergence may be explained by iteration. I would speak of *self-organization* only at (6).

'ORDER' IS SCALE-DEPENDENT

For example, a city as a complex system^e, differs from its surroundings (1) for a long time (3). It is a layered difference of content, form, structure, function and intention (6).

Within the city (at a lower level of scale) the neighborhoods, industrial areas and parks differ in the same layers. *Within* these areas, the facilities or buildings differ again, but differently.

This 'complexity' (6) goes far beyond Bénard cells and lasers (3). The same counts for organizations, devices, living organisms, organs, cells and organelles within cells. Differences play a role at many levels of scale. *Separated* differences are again selectively *connected* by networks, this time in a repeating pattern through the subsequent levels of scale (note **b** p90).

There are many more levels of scale between 'microscopic' and 'macroscopic', than to which physics (mechanics, thermodynamics, and quantum mechanics) is limited per discipline. Ecology should distinguish at least 15 levels of scale e.g. in order to define biodiversity.

^a Haken(1978) claims to capture 'synergy' in complex mathematics.

^b Prigogine cs(1984), Gleick(1987), Kaufmann(1993).

^c Supposed in [Smith\(1776\)](#)

^d [Page\(2011\)](#) p32

^e [Portugali\(1999\)](#); [Batty\(2007\)](#)

§ 32 ABIOTICS ARE BUILT ON SUPPOSITIONS^a

The suppositions of physics largely correspond to those of mathematics (§ 25 p97).
I add some *intermediate suppositions*, and focus on **designers** changing suppositions.

MECHANICS

[Galilei\(1638\)](#) ↑ a **difference** between *velocity* $v=s/t$ and *acceleration* $a=s/t^2$.
[Newton\(1687\)](#)p1 ↑ a **difference** between *mass* m and *weight* ↑ *force* $m*a$ ↓ **change**.
[N.p197](#) Force as **object** ↑ **separating gravity** in subjects (m_1, m_2, s) ↑ **combination** ($G*m_1*m_2/s^2$).
[Leibniz\(1686\)](#)p161 ↑ a **difference** between *momentum* $m*v$ and *energy* $m*v^2$ ↑ object energy.
[Lorentz\(1895\)](#) ↑ **metabolisation** of mass by velocity ($m(v) = m_0/\sqrt{1 - (v/c)^2}$).
[Einstein\(190506, 190509\)](#) ↑ metabolisation of mass into energy ($m_0 = E/c^2$).
[Minkowski\(1908\)](#) combined space and time in equal units.
[Einstein\(1916\)](#) ↑ gravity ↓ change of space-time units by mass (proven by [Eddington\(1920\)](#)).

QUANTUM MECHANICS

[Planck\(1900\)](#) **separated** energy exchange in discrete quanta ↑ to fit measurements.
[Einstein\(190503,1907,190901,190910\)](#) ↑ quanta as a physical reality.
[Bohr\(1913\)](#) ↓ quanta in his atomic model, exposing deep tensions with classical mechanics.
These tensions were resolved in two equivalent reconstructions of mechanics:
[Heisenberg\(1925\)](#) ↓ particles and [Schrödinger\(1926\)](#) ↓ waves.
[Heisenberg\(1927\)](#) pointed their fundamental uncertainty.

ELECTRICITY

[Franklin\(1751\)](#) ↑ **equality** of **different** phenomena such as lightning and electrical sparks, positive and negative charge ↓ their conservation (neither created nor destroyed).
[Kleist\(1745\)](#) ↑ **stabelize** (store) electricity, but did not publish it.
[Musschenbroek\(1746\)](#) ↑ the same by the classic Leyden jar as reported by [Nollet\(1746\)](#).
[Coulomb\(1785\)](#) ↑ quantity of electric charge and force.
[Volta\(1800\)](#) ↑ electric potential (voltage).
[Gauss\(1813\)](#) ↑ electric flux through a surface proportional to a charge enclosed by that surface.
[Ampère\(1826\)](#) ↑ the force between current-carrying conductors, its law ↓ magnetism as an effect of electric currents. [Ohm\(1827\)](#)p178 ↑ his law **separating** resistance from voltage.
In 1831 [Faraday\(1845\)](#) ↑ electromagnetic induction, the field concept, dielectric polarization, electrolysis laws, electro-magnetic effects ↑ a motor transforming current into movement.
[Maxwell\(1865\)](#) ↑ electromagnetic fields. [Hertz\(1887\)](#) proved them to be at the speed of light.
After De la Rue(1820), Swann(1878) and others, [Edison\(1880\)](#) ↑ a successful bulb.
[Tesla\(>1891\)](#)) ↑ systems for alternating current, wireless energy transmission and radio signals.
[Marconi\(1895\)](#) ↑ the first usable wireless telegraphy system ([Nobel Prize 1909](#)).
[Popov\(1895\)](#) ↑ a working radio machine in Russia.
[Fessenden\(1900\)](#) ↑ the first wireless transmission of speech, (1906) the first radio broadcast.
[Forest\(1906\)](#) ↑ the audio tube (an early electron tube) ↑ the amplification of radio signals ↑ radio receivers and broadcasting.
[Braun\(1909\)](#) ↑ transmitting with tuned circuits and oscillators. ([Nobel Prize 1909](#))

^a A, B, C and bold words refer to *Fig.15*p15. Newly added intermediate suppositions are written in *bold italics*.

THERMODYNAMICS

[Boyle\(1660,1662\)](#) ↑ pressure times volume is constant in gasses ($P \cdot V = k$).

[Gay-Lussac\(1802\)](#) (English:[Magie\(1935\)p165](#)) added the expansion of gases by heat in proportion to its absolute temperature and Clapeyron(1834) ↑ $pV/T = nR$ at n moles.

After Savery, Newcomen, [Watt\(1769\)](#) ↑ the steam engine ↑ the industrial revolution.

[Carnot\(1824\)](#) ↑ the efficiency of steam engines ↑ [Clausius\(1854\)](#) ↑ thermodynamics.

[Boltzmann\(1877\)](#) ↑ probability theory to be the basis of thermodynamics.

After Rivaz(1804), Lenoir(1860), [Otto\(1877\)](#) ↑ the combustion machine.

[Diesel\(1886\)](#) ↑ the Diesel engine, constructed in 1892.

Bosch(1927) ↑ a valid fuel injection device.

INFORMATION

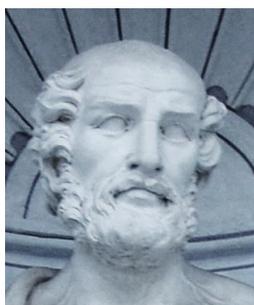
[Shannon\(1948\)](#) ↑ quantity of information regardless of its meaning.

Haken(2006)p19 ↑ meaning in the perspective of complexity.

COMPLEXITY

All sided difference ↑ self-ordering ↑ adaptation ↑ specialization.

6. BIOTIC CONDITIONS ARE IMPROBABLE^a



228 Theophrastos^b



229 Leeuwenhoek^c



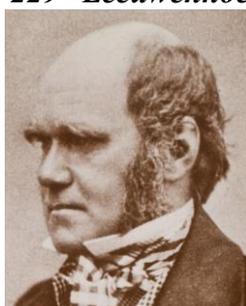
230 Linnaeus^d



231 Lavoisier^e



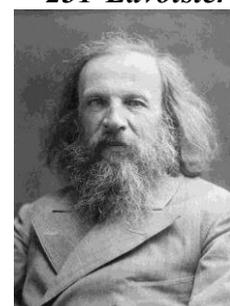
232 von Humboldt^f



233 Darwin^g



234 Mendel^h



235 Mendeleevⁱ

Leading designers of the contents of this chapter.

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^a 'Improbable' here is meant as 'with very little probability' or 'rare'.

^b Theophrastus statue by Tuccio in Palermo Botanical Garden [Theophrastos\(-300\)Inquiry into plants](#) completed the zoological work of Aristoteles(-350)[Historia animalium, De partibus animalium and Generation of animals](#).

^c Leeuwenhoek portret by Verkolje Van Leeuwenhoek founded the science of microbiology..See [Dobell\(1932\)](#) and [Delft\(2022\)](#)

^d Linnaeus portret by Roslin [Linnaeus\(1753\)](#) designed the current naming of plants.

^e Lavoisier portret by David [Lavoisier\(1789\) 1, 2](#) is the original basis of current chemistry.

Lavoisier invented the model of burning by oxygen, its cycle, named 30 elements based on experiments carefully measuring the quantities.

^f Humboldt portret by Stieler. Alexander von Humboldt described in many volumes the scientific discoveries of his extended travels as a professional in many disciplines. He already warned for climate change by deforestation and agriculture, laid the foundation for climatology, geology, ecology, anthropology, and inspired Darwin in his quest. His final magnum opus has been: [Humboldt\(1845\)](#) translated in English as [Humboldt\(1845\)](#).

^g [Darwin\(1859\)](#) established evolutionary biology with the concept of selection by survival of the fittest.

^h [Mendel\(1865\)](#) long unnoticed but rediscovered around 1900, translated as [Mendel\(1865\)](#), founding the current science of genetics.

ⁱ [Mendeleev\(1870\)](#) Mendeleev published the periodic table of elements in 1869 shortly before simultaneous inventor Lothar Meyer. It became the standard of current chemistry. The table predicted 4 elements not yet discovered.

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What is the designerly content of biology? Which discoveries are actually inventions, designs of a model? Do they cover a broader field of possibility beyond probability?

This chapter explores some disciplines of biology at highschool level. I conclude:

The improbability of life appears at many levels of scale: from atoms until the universe. At the lowest level, biodiversity starts with a few elements, combined in many connections. These are often improbably large molecules, produced and stable in physically rare conditions. Each reproduction supposes *repetition*, but there is a great *diversity* of productions and sites.

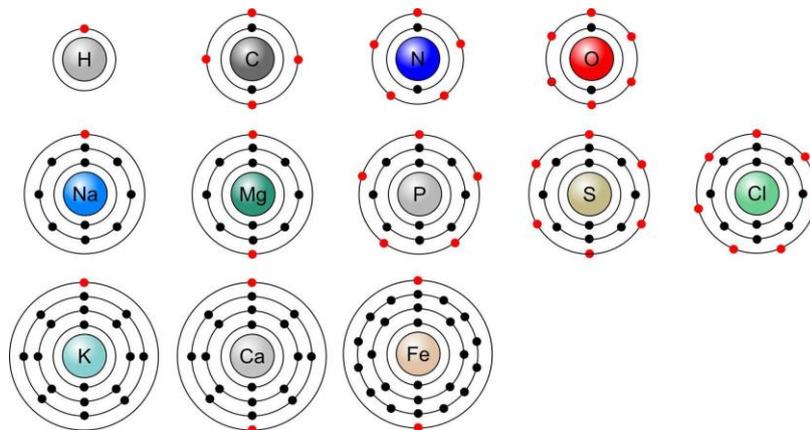
The diversity multiplies on each higher level: organelles, organs, organisms, organisations. The rare conditions are ensured by selectively enclosing membranes. Separations in the shape of a tube may develop a *gradient* of rare conditions, where a rare reaction may find its niche. Your intestinal tract is such a tube. Microbial mats may house a stepwise metabolism in layers.

The same goes for *fluctuations* as 'gradients in time'. Bats find their niche in the evening. In gradually changing conditions, rare reactions may wait for the right time. Phase transitions from chaos into order in complex systems are often observed by fluctuations. Gradients in space and time create numerous rare environments where life could have begun.

Biology is still the domain of improbable, rare or even unique observations. Science cannot deal with uniqueness by generalising at any level of scale. It would then have to split into as many specialties as there are specimens.^a At the lowest level, however, you may find exact repetitions.

^a Some 30 medical specialisms are in action studying one species: humans. A species, however, is a heterogeneous set. Statistics applied on heterogeneous sets raise doubt. The same medicine may cure *me*, but make *you* sick.

§ 33 LIFE USES PREDOMINANTLY 12 OF THE 118 KNOWN ELEMENTS



236 Elements in living organisms with their electrons per shell ^a

The elements once discovered^b are numbered in a 'periodic system'^c from 1 to 118. Living organisms mainly use the numbers 1 (H), 6 (C), 7 (N), 8 (O), 11 (Na), 12 (Mg), 15 (P), 16 (S), 17 (Cl), 19 (K), 20 (Ca), 26 (Fe). Iron (Fe) is the largest one with 26 electrons, in 4 shells: 2,8,14,**2**. There are still 92 other atoms, mainly not welcome in living organisms (often 'poisonous').

The 'atomic numbers' represent the number of 'positively charged' (+) nuclear particles ('protons') in the core ('nucleus'). These may be neutralized by an equal number of 'negatively charged' electrons (-), rotating around the core^d. If not, the atom as a whole is charged ('ion')

Electrons^e are separated and locked up in different 'shells' at different distances from the core.^f The first four shells have a maximum of 2, 8, 18 and 32 electrons from the inside to the outside. The electrons of **the outer shell** are attracted the least through the core. These are relatively loose and may join to another atomic nucleus in the neighborhood. That makes chemical connections between atoms into molecules possible, sharing electrons otherwise lacking in the outer shells.

If an electron falls back into an energy-poorer layer where is still space ('unsaturated shell'), the lost energy is emitted as a radio wave with a characteristic wavelength in an atom-specific spectrum.^g The reverse, radio waves may push up electrons into a higher shell or break a bond.

Electrons repel each other by their same negative charge. In pairs, however, electrons tolerate each other by turning around their axes opposite to each other as gearwheels (with opposite 'spin' ↻). Their number per shell is therefore preferably even.

The same element may contain a number of neutral core particles without charge ('neutrons')^h. An atom may have variants ('isotopes') with a different number of neutrons. So, the mass of an atom (the sum of the masses of its protons + neutrons + electrons) is not exactly related to the atomic number, but you may conclude that living organisms only use light atoms.

If you have atoms or molecules with the same mass **m** (* times the 'unified atomic mass unit'), then **m** grams of them make up one 'mole', which always contains $6.02214076 \times 10^{23}$ particles (Avogadro's constant).

^a https://en.wikipedia.org/wiki/File:Periodic_Table_of_Elements_showing_Electron_Shells.svg

^b [Lavoisier\(1789\)](#) **1**, **2** founded modern chemistry separating 30 elements in molecules.

^c [Mendeleev\(1870\)](#) predicted undiscovered elements in his periodic system.

^d [Bohr\(1913\)](#) supposed orbits of electrons, [Schrödinger\(1926\)](#) probability fields.

^e Electrons behave on the one hand as particles and on the other hand as diffuse waves ('quanta').

^f A further classification of these peels ('quantum paths') is left out of consideration.

^g [Balmer\(1885\)](#), explained by [Bohr\(1913\)](#)

^h [Chadwick\(1932\)](#)

CONNECTIONS (BONDS) COMPENSATE SHORTAGES IN THE OUTER ELECTRON SHELLS**Unsaturated atoms attract electrons**

'Noble gases' such as helium He (2 electrons) neon Ne (2, 8), argon Ar (2, 8, 8) and krypton Kr (2, 8, 18, 8) hardly react with other atoms. Their outer shell is 'saturated'.

Every other atom unsaturated in the outer shell, is inclined to supplement it into such a 'noble gas formation'. Hydrogen H needs one more electron to become saturated, and oxygen O a pair. Their connection H_2O saturates both by *sharing* two electrons. The number of electron *pairs* that an atom may share with another atom to a noble gas formation for both, is called its 'valence'.^a

Covalent bonds are strong; hydrogen bonds are weak

Two elements may complement their outer shell by sharing an electron *pair* together ('covalent bonding'). So, unsaturated O 's prefer to exist in a saturated state O_2 . Such a bond emerges when atoms are pressed together close enough to bring electrons from one atom under the attraction of the other. At a shorter distance 'Van der Waals forces' add another bonding effect.

During that 'falling upon each other', mainly energy is *released* ('free energy' or 'enthalpy'). *Breaking* a connection (increasing distance) then *costs* an equal amount of 'bonding energy'.

Between two molecules such as two long strings of DNA, hydrogen atoms may also share their electron with both, weakly connecting them, and easily to be separated. Such 'hydrogen bridges' *within* a molecule such as a long folded protein (e.g. **Fig.263**p148) keep its folding in form.

Ions are charged, attracting oppositely charged ions into a bipolar ion bonding

An atom or molecule with an electron too much or too little to be neutral as a whole (a 'ion')^b, has a negative (-) or a positive (+) 'charge'. Two oppositely charged particles attract each other. For example, a salt connects an acid⁺ ion with a basic⁻ ion ('ionic bond').

The different position ('locus') of the negative and positive ion in the resulting molecule gives the molecule a negative and a positive pole ('bipole'). These therefore tend to seek contact with opposing loci in the environment with a similar head (-) and tail (+).

Water molecules (H_2O) with their H^+H^+ and O^- poles are bipolar in a strong covalent bond. They may detach (crawling in between) the weaker ionic bond of bipolar molecules, 'dissolving' them into separate ions within a 'solution'.

THE ACIDITY pH REPRESENTS THE NUMBER OF H^+ -IONS ('PROTONS')

Hydrogen ions (H^+ -ions without electron, in fact protons) make a solution acidic. More hydroxide ions (OH^-) make it alkaline (basic).

The 'acidity' is a measure ('pH value') for the number of H^+ ion moles per litre in a solution.^c This number can vary from 1 mole H^+ per litre (e.g. the extremely acid hydrochloric acid H^+Cl^-) to 0.000 000 000 000 01 mole per litre (e.g. the extremely basic sodium hydroxide Na^+OH^-).

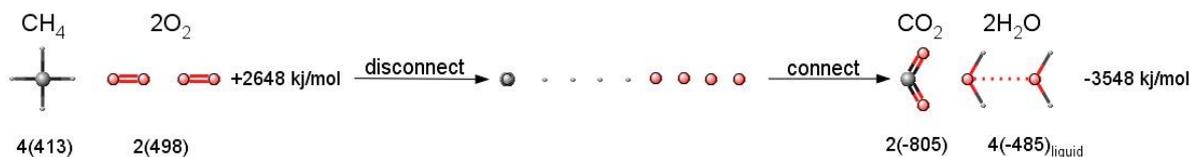
The Ph value only shows the 'number of zeros' (negative logarithm), in a scale of 0 to 14 (from 10^{-0} to 10^{-14} mol/l H^+). Up to 7 you may call the solution 'acid'.

With a majority of OH^- -ions or electrons (pH greater than 7) the solution is called 'basic'. Differences in pH, the availability of H^+ , charge or potential, play a major role in biology.

^a [Frankland\(1852\)](#), [Lewis\(1916\)](#), [Pauling\(1927-1954\)](#) [Pauling\(1954\)Nobelprize](#)

^b [Faraday\(1834\)](#)

^c Proposed by [Sørensen\(1909\)](#)

SEPARATING USUALLY *COSTS* ENERGY; CONNECTING *DELIVERS* ENERGY**237 A chemical reaction separates and connects**

If you light methane CH_4 with 2648 kJ/mole 'ignition energy', then you break its connections and those of the surrounding oxygen. The by separation unsaturated oxygen atoms (o) are hungry to connect with ('oxidize') the carbon and hydrogen of the broken CH_4 into the stronger bound ('more stable') carbon dioxide (CO_2) and water $2(\text{H}_2\text{O})$.

The required energy is written as positive input (+2648) and the released energy as negative output (-3548). So, you may write $\text{CH}_4 + 2\text{O}_2 + 2648 \text{ kJ/mole} \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} - 3548 \text{ kJ/mole}$, but the loss of one is gain for the other, and outgoing 3548 kJ/mole is sufficient to ignite (OXidize) the next methane molecule ('chain reaction'). The oxygen then is REDuced, together called a 'REDOX reaction'.

There are lists of (un)bonding energies for each compound under 'normal' atmospheric conditions (25°C and 1 bar pressure)^a, for example: disconnecting C-H costs 413, O=O 498, one C=O in carbon dioxide 805, O-H in liquid water 485 kJ/mole. That is the 'bond energy'^b required to separate, but also the energy released by connection (**Fig.237**).

Pressure from outside brings the atoms closer together and strengthens their bonds. So, at higher pressure increases the required (un)bonding energies (lost mass according to $E=mc^2$). Higher temperature, however, also increases their potential energy, and their collisions forcing a bond.

When all methane is burned, then $4(413) + 2(498) - 2(805) - 4(485) = 2648 - 3550 = -908 \text{ kJ/mole}$ of heat is extracted from the reaction.^c Living organisms prevent such an explosive chain reaction in order not to burn themselves by excessive heat. They realize the reaction step by step.

Separation usually *costs* energy, but separating a phosphate from Adenosine **Tri**Phosphate, ('ATP' **Fig.250**p141) *delivers* energy! This gave multicellular life the opportunity of energy transport and delivery with neglectible heat loss. The remaining Adenosine **Di**Phosphate 'ADP' is reloaded elsewhere into ATP from stored fat, sugars or directly by photosynthesis.

These molecules serve as batteries. They are able to be loaded, transport and easily release a small package of energy again and again, in order to deliver ('exotherm' or 'exergonic') the energy required for all other organic reactions using it ('endotherm' or 'endergonic').

Their loading station is the organelle 'mitochondrion' (p141, **Fig.300**p161), present in any eukaryotic cell, using energetic bonds once enabled by photosynthesis elsewhere. In step by step reactions, the released energy ('enthalpy') is directly energising other reactions, with little heat.

LIFE IS BASED ON A SIMPLE ENERGY CYCLE

Plants separate C with solar energy from CO_2 ($\text{CO}_2 + 2\text{H}_2\text{O} + \text{solar energy} \rightarrow \text{C} + 4\text{H} + 2\text{O}_2$). Disconnected C then enables to produce numerous organic bonds. Animals use the potential energy of these bonds reconnecting C and O_2 back into CO_2 (compare **Fig.237**). This 'carbon cycle' can be described simply in general, but in detail the chemical pathway is complicated by many intermediate steps.

^a http://www.wiredchemist.com/chemistry/data/bond_energies_lengths.html , <https://labs.chem.ucsb.edu/zakarian/armen/11---bonddissociationenergy.pdf>

^b Pauling (1932) calculated bond energies based on the quantum mechanics.

^c The calculation can be more complicated than it is important here for global understanding, see Ellison(2002)

§ 34 CARBON (C) CONNECTS

CARBON^a CONNECTS WITH HYDROGEN (H)^b

alkane	-alkyl	alkene	alkyne
C ₁ methane	-methyl		
C ₂ ethane	-ethyl	ethene	ethyne
C ₃ propane	-propyl	propene	propyne
C ₄ butane	-butyl	butene	butyne
C ₅ pentane	-pentyl	pentene	pentyne
C ₆ hexane	-hexyl	hexene	hexyne
			
cyclohexane		benzene	cyclohexyne

238 With hydrogen

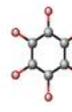
A ring with 3 'double' bonds is a member of the 'alkenes' in the third column. The fourth column with a triple bond are 'alkynes'. Molecules with double or even triple bonds are 'unsaturated'.

Carbon (c) plays a central role in living organisms^c. A carbon atom may connect with 4 other atoms (4 'valences')^d. A *chain* of carbon atoms has 3 free valencies left at the ends, the others 2.

If all remaining valencies are occupied by H, then you call such strings 'hydrocarbons'. In **Fig.238**, the chains of 1, 2, ... carbon atoms are summarised as C₁, C₂, etc..

The first column contains the 'alkanes': 'methane' (CH₄) to 'hexane' (C₆H₁₄). A hydrocarbon *rest* is called 'alkyl group'. At C₆ the chain may also form a hexagonal ring.

CARBON CONNECTS WITH OXYGEN (O)

alcohol C-OH	polyhydric alcohol	aldehyde -C=O	ketone >C=O	ether C-O-C
C ₁ methanol CH ₃ OH		C ₁ methanal (formaldehyde)		
C ₂ ethanol CH ₃ CH ₂ OH	glycol (ethanediol) HOH ₂ C-CH ₂ O	C ₂ ethanal (acetaldehyde)		dimethylether H ₃ C-O-CH ₃
C ₃ propanol	glycerol (propanetriol)	C ₃ propanal (propionaldehyde)	acetone	diethylether
		C ₄ butanal		
C ₆ cyclohexanol (phenol)	inositol	C ₅ pentanal	diethylketone	dipropylether
		C ₆ cyclopentanal	cyclohexanone	oxepan
		C ₇ cyclohexanal		

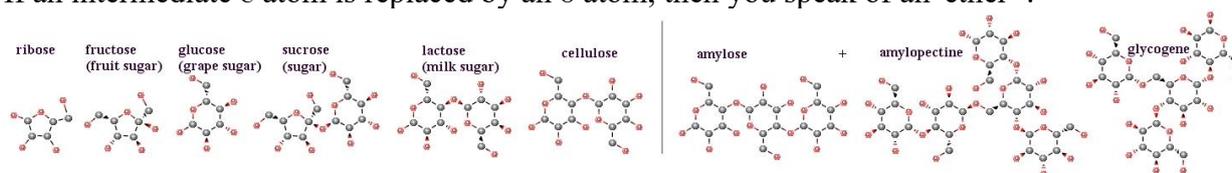
239 With oxygen

In methane and other hydrocarbons, 2H can be replaced by a 'hungry' Oxygen.

Their names (**Fig.239**), end with -ol (alcohol^e, single bond) or '-al' ('aldehyde'^f, double bond).

If an intermediate C atom has a double bond =O appendix, then it is a 'ketone'^g.

If an intermediate C atom is replaced by an O atom, then you speak of an 'ether'^h.



240 Sugars (saccharoses)

'Sugars'ⁱ (**Fig.240**) are composed of alcohols (**Fig.239**). Some sugars have the same formula, but a different spatial structure with a different behaviour ('isomers').

Lactose is a human nutrient, but the very similar cellulose is not digestible by humans.

Sugars are stored for energy as 'starch'^j in plants, or as 'glycogene' in animals **Fig.241**p137).

241 Starch and glycogen

^a Lavoisier(1789) 1, 2 separated carbon and many other particles as indivisible elements.



^b In the drawings the H-atoms are usually omitted to keep overview ('implicit hydrogens').

The molecular figures are mainly drawn with the freely downloadable computer program ChemAxon's Marvin sketch.

^c Justus Liebig(1837) founded modern biochemistry and important applications, inventing many of the necessary instruments.

See his text in English: [Liebig;Playfair ed\(1842\)](#).

^d The valences of C were found by [Kekulé\(1858\)](#)

^e Lavoisier(1789) p139... la fermentation vineuse

^f Liebig(1835)

^g Gmelin(1848)

^h Frobenius(1730) Dumas;Péligot(1834)

ⁱ Lippmann(1895)

^j Paven;Persoz(1833)

Fatty acids have a -COOH group

with -COOH a fatty acid		ester
C ₁	methanoic acid = formic acid	
C ₂	ethanoic acid = acetic acid	
C ₃	propanoic acid = propionic acid	
C ₄	butanoic acid = butyric acid	
C ₅	pentanoic acid = valeric acid	
C ₆	hexanoic acid = caproic acid	
C ₈	octanoic acid = caprylic acid	
C ₁₆	hexadecanoic acid = palmitic acid	
C ₁₈	octadecanoic acid = stearic acid	

242 Fatty acids and their esters^a

If two oxygen atoms claim all 3 valences from a C-end (-COOH), then the molecule becomes an acid. An alkyl group (**Fig.238**p137) with -COOH is a 'fatty acid' (**Fig.242**).

Three of them connected by a glycerol molecule (**Fig.239**p137) is a 'fat' or an 'oil'. From a fatty acid you can also make an 'ester' with at least one carbon atom at both sides.

A sodium⁺ (Na⁺) 'cat-ion', binds a fatty acid 'an-ion' into a soluble salt ('soap').

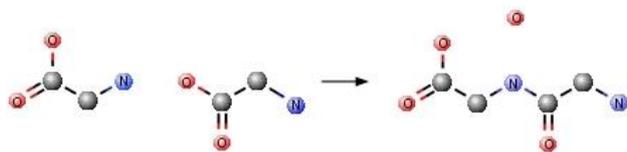
CARBON CONNECTS WITH NITROGEN (N)

with-NH ₂ : amine N-C	di-amine C-N-C	tri-amine	amide	amino acid	(hetero)cyclic
C ₁ methylamin CH ₃ NH ₂			methylamid		
C ₂ ethylamin CH ₃ CH ₂ NH ₂	dimethylamin (CH ₃) ₂ NH		ethylamid	glycine	
C ₃		trimethylamin (CH ₃) ₃ N	propylamid	diglycine	pyrimidin
C ₄	diethylamin (CH ₃ CH ₂) ₂ NH			triglycine	purin
C ₅					
C ₆ anilin					
C ₁₂		thiamine			

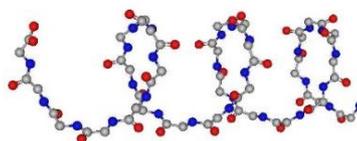
243 Amins, amids, amino acids and cyclics with N

If you replace a c by N (**Fig.243**), then you get 'amines'^b (such as vitamin B1 = thiamine) reacting as a base or almost neutral 'amides'^c.

If you replace the last c-atom of a hydrocarbon by N, and the first by a carboxyl group (-COOH), then you get an acid with a basic N-tail ('amino acid'^d). The smallest amino acid is 'glycine'^e. Two amino acids can be joined with head and tail to form a 'peptide' e.g. diglycine (**Fig.244**)^f.



244 Two glycine molecules → a peptide

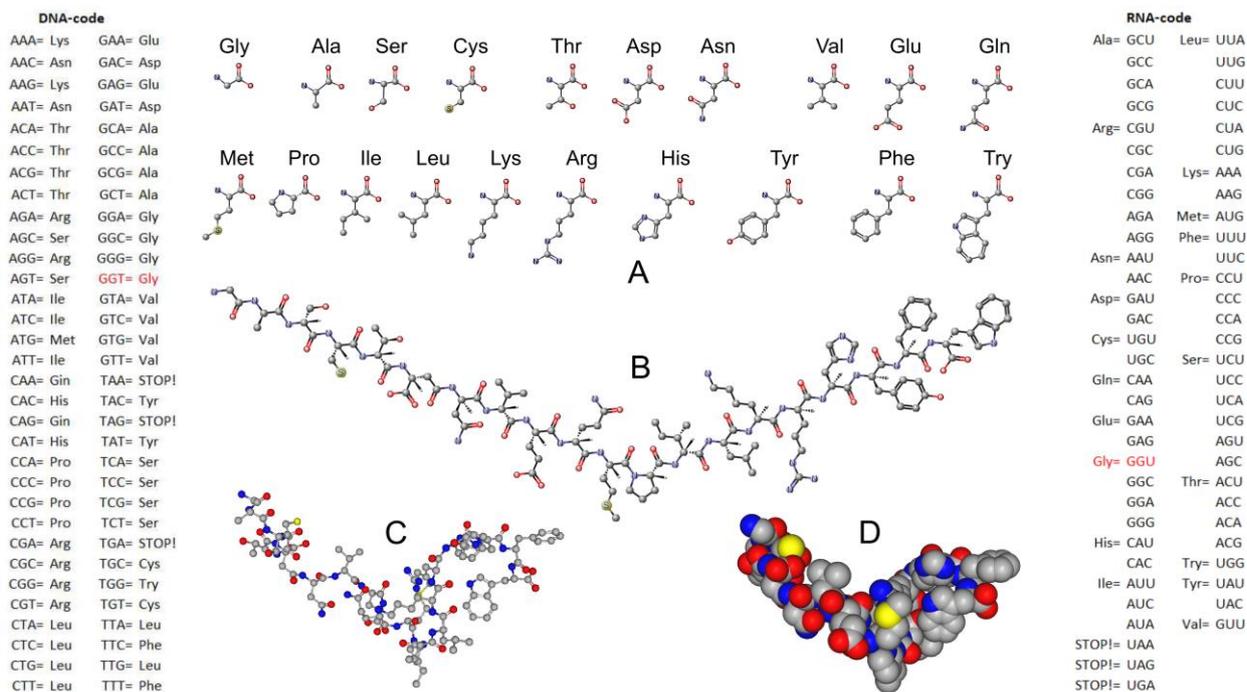


245 Polyglycine polymer as a spiral

Bonds have a preferred angle. If the angle of the bond between two glycines always has the same turning direction (∩ or ∪), then the polymer gets a spiral shape (**Fig.245**).

There are many larger amino acids than glycine. Amino acids are the building stones of protein. About 100 000 different proteins are known in the human body, each with its own form, structure and function. On the internet you may find a huge database.^g

^a [Chevreul \(1823\)](#). Structure by [Liebig\(1837\)](#).
^b [Wurtz\(1847\)](#) [Hofmann\(1865\)](#)
^c [Gerhardt\(1844\)](#)
^d [Vauquelin;Robiquet\(1806\)](#) found asparagine.
^e [Braconnot\(1820\)](#)
^f [Fischer\(1899-1906\)](#)
^g <http://www.rcsb.org/pdb/home/home.do>



246 Twenty amino acids in order of size (A), strung together (B, C, D) to an imaginary protein. On the sides the DNA and RNA codes (codons) with which they are made.

A 'protein'^a is a chain ('polymer') of about 50 to 3000 amino acids.^b

Fig.246A shows 20 types of amino acids present in living organisms in the order of their size.^c

Their names are usually limited to abbreviations with 3 characters, e.g. Gly for glycine.

In **Fig.246B** an imaginary protein is constructed from those 20 amino acids in order of size.

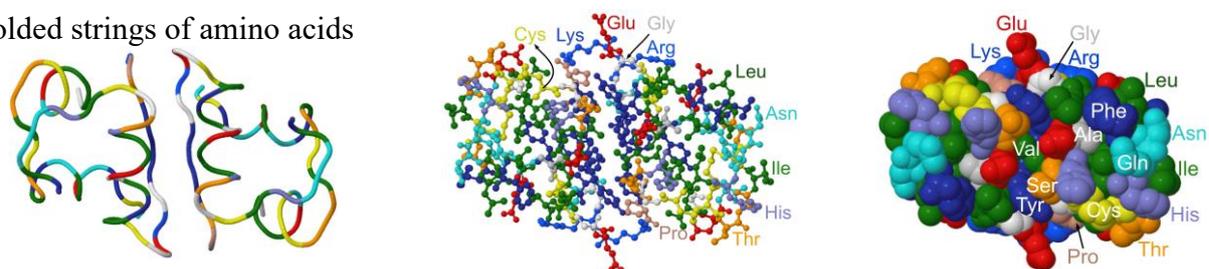
With different angles between the connections and due to internal mutual attraction, such a long chain never remains stretched, but it folds in all kinds of bends into always the same tangle.

Such a shape is characteristic for each protein (**Fig.246C**). **Fig.246D** shows the size of the atoms with their electron clouds and the shape of the folded molecule more realistic.

This *form* is crucial for mutually fitting interactions with other proteins or compounds.

Each protein is built by amino acids in a unique order of sequence (e.g. insuline **Fig.247**).

Folded strings of amino acids



247 An existing protein (insuline) composed of 17 different amino acids (colours)^d

^a **Berzelius (1838)** coined the Term "Protein" in his letters to Mulder:

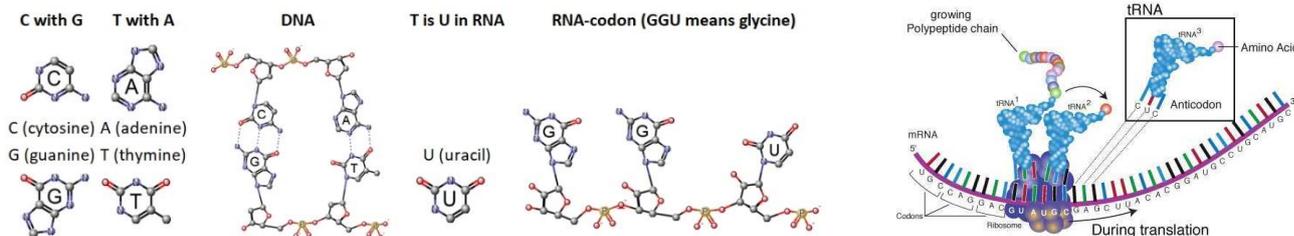
Mulder (1838);Fischer(1899-1906)an overview until 1906.

^b http://proteopedia.org/wiki/index.php/Proteopedia:Table_of_Contents is a wonderful educational program that explains in 3D moving images which connections exist within proteins and how they work.

^c With a few newly found rare amino acids, there are 22.

^d <https://www.rcsb.org/3d-view/jsmol/2C8Q/1> <https://www.biotopics.co.uk/jsmol/insulin.html>

DNA names each amino acid by three characters



248 The alphabet of DNA and RNA^a

249 The production of a protein^b

The recipes how to build different proteins are stored in huge DNA molecules (chromosomes).^c Every human cell nucleus has 23 pairs of chromosomes (from mother and father, in total 46). So, for any protein there are two recipes. Both may be active or (one or both) switched off.

DNA has an alphabet of 4 characters named C, A, G, and T (the bases Cytosine, Adenine, Guanine, and Thymine). Any amino acid is coded by *three* of these bases (a 'codon' or 'triplet'). For example, 'GGT' in DNA language means 'codon for Glycine' (**Fig.246**p139). The sequence of amino acids for a substance is coded in a part of DNA between stops ('gene').

DNA keeps its codes connected in sequence by a backbone of sugar and phosphate. It forms a long molecule of two strings that mirror each other (T as A, and G as C **Fig.248**). DNA reproduces easily by separating these strings (loosely linked by hydrogen). Each will attract its own new counterparts ('anticodons') completing itself with a second string.

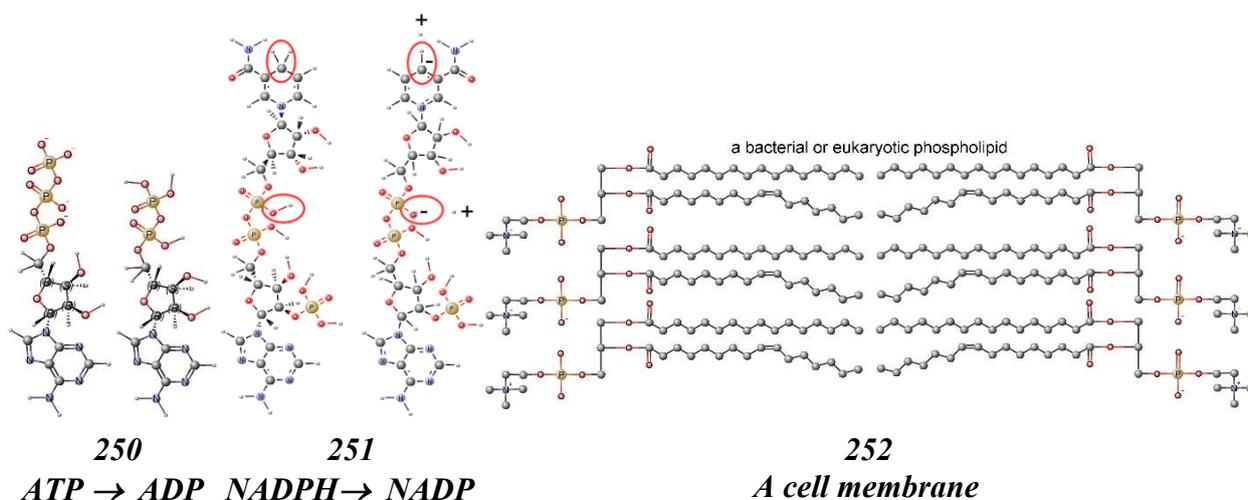
If somewhere a protein is needed, then a book in the DNA-library is triggered to make a copy (a 'messenger RNA' **Fig.285**p155)^d. That copy has the same alphabet as DNA, but in RNA language (C, A, G and U), 'Uracil (U)' replaces Thymine (T). The DNA code for a complete protein is flanked by stops (front and back cover of the book), for example 'TAA'.

After copying, the mRNA leaves the nucleus of the cell via gates in the core membrane into a protein factory ('ribosome'^e **Fig.249**, see also **Fig.284**p155), located in a business park around the nucleus (a labyrinth of membranes, called 'endoplasmic reticulum' see **Fig.300**p161).

A ribosome is a large molecule where a mRNA runs through with its codon(**Fig.249**). The ribosome assembles the right sequence of amino acids into the required protein. The protein is sent to its destination by the distribution centre of the cell ('golgi apparatus' **Fig.300** p161).

The energy for biotic processes is mainly delivered by a carbon bond with phosphorus.

^a **Miescher(1871)** isolated 'nuclein' (later identified as DNA) in pus cells. **History by Byrne;Dahm(2019)** **Kossel** isolated Guanine(1881), Adenine(1885), Cytosine(1894), Thymine, Uracil(early 1900s) in *Zeitschrift für Physiologische Chemie*. **Levene; Jacobs(1919)** supposed a string of them. **History by Hargittai(2009)**. **Chargaff** cs(1950) and **Chargaff (1952)** discovered that in DNA, the amount of A = T and C = G, hinting at base-pairing rules. **Chargaff's legacy**
^b **Watson;Crick(1953)** finally found the double helix structure and base pairing of DNA.
^c <http://aprendendogenetica.blogspot.nl/2011/03/genetica-molecular-aula-3-transcricao.html>
^d **Wall(2016)** describes the quest of 88 years to translate the foundational laws of **Mendel(1865)**into a chemical model.
^e **Brenner;Meselson (1961);Jacob;Monod(1961)**
^e **Palade(1955)** related the ribosome to protein synthesis. Nobel prize(1974). **Zamecnik;Hoagland(1956)** found RNA and amino acids involved. **Siekevitz;Palade (1958)** found biochemical evidence.

CARBON CONNECTS WITH PHOSPHORUS (P)^a**Phosphorus is required for energy supply**

Phosphorus has a crucial function in the energy supply for life. **Fig.250** shows the negatively charged AT('tri')P molecule, the 'battery' of a cell.^b If you take off a phosphate group, then the neutral AD('di')P remains (see note d p141). That separation delivers 30kJ/mole of energy.^c The battery is recharged elsewhere in a charging factory ('mitochondrium' **Fig.300**p161)^d.

Something similar happens in **Fig.251**, when NADPH offers two free hydrogen⁺ atoms. In **Fig.250** and **Fig.251**, the H-atoms are also depicted (explicit) in order to see the difference. It also shows that H has one valence, while O, N, C and P have 2, 3, 4 and 5 valences (electron pair shortage). The bonds dotted and bold mean 'backward' and 'forward' in 3D.

Phosphorus is present in the cell membrane^e

Fig.252 shows the role of phosphate (PO₄) in a cell membrane. Membranes are composed of molecules ('phospholipids') each with a tail of two long fatty acids. These are held together by glycerol (**Fig.242**p138), but the third branch of the glycerol contains a PO₄-containing head.

The fatty tail avoids water ('hydrophobic'), while the head searches for water ('hydrophilic'). In an aqueous environment, the heads may enclose the water-avoiding 'fatty' tails inside.

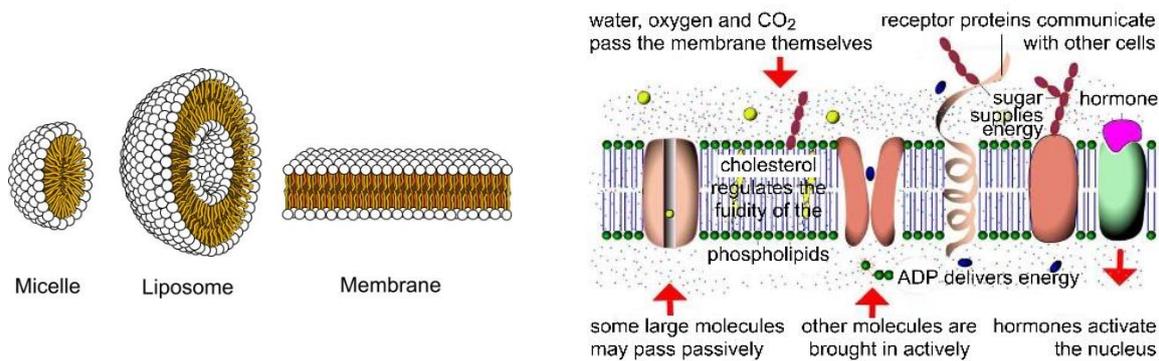
^a Hennig **Brand(1669)** produced light giving phosphor from urine, Johann Daniel **Krafft** dispersed his discovery in Europe, Robert **Boyle(1677)** repeated and confirmed the experiment. He published it in English: [Boyle\(1780\)](#) p11.

^b **Lohmann(1929)** found ATP and three phosphate groups involved in energy transfer. **Lipmann(1941)** linked ATP/ADP to metabolic energy transfer. **Kalckar(1941)** created a unified theory of biological energy metabolism.

^c https://en.wikipedia.org/wiki/Adenosine_triphosphate

^d **Köliker(1857)** separated mitochondria from a cell structure. **Altmann(1890)** observed 'bioblasts' (later identified as mitochondria). **Benda(1898)** coined the name mitochondrium, but supposed individual cells within cells. **Claude(1946)** studied the chemical composition. **Palade(1952)** visualised it. **Mitchell(1961)** modelled ATP synthesis. Nobelprize(1978)

^e **Overton(1896)** suspected lipidoid cell walls. **Gorter;Grendel (1925)** proposed the lipid bilayer model. By extracting lipids from red blood cells and measuring surface area, they proposed that the membrane consists of a bilayer of lipids. **Danielli;Davson(1935)** proposed the protein-lipid-protein sandwich model, and suggested proteins coat both sides of the lipid bilayer, forming a stable structure. **Singer;Nicolson (1972)** described the membrane as a dynamic structure with proteins embedded in or attached to a bilayer of lipids.



253 Arrangements of polar phospholipids^a

254 Active proteins in a membrane^b

In the simplest case, the phospholipids enclose a sphere with a fatty interior ('micelle'). A 'liposome' has a second layer of inversely directed phospholipids separating an aqueous space inside with reaction conditions different than elsewhere in the cell. With such a membrane, any cell is shielded from the unpredictable outside world.

Membranes may contain protein components (**Fig.254**), devices that selectively regulate transport to both sides, transmit signals, connect itself to a stabilizing structure (an internal 'cytoskeleton' or external 'matrix'), or accelerate reactions on either side of the membrane (hormones and 'enzymes', see further p148).

Phosphorus connects codons in DNA

Phosphor is a crucial component of DNA and RNA. Phosphate (PO_4), in a chain alternating with sugar ('ribose' from **Fig.240**p137), keeps the amino acids of DNA and RNA strings in the right sequence as a 'backbone' (**Fig.248**).

Phosphorus, not connected with carbon, is a major component of bones and teeth

Hydroxyapatite^c is a crystalline complex of ions *outside* the cells of an organism, making up 50% of the volume of bones and teeth (**Fig.277**p151).^d It is not connected to carbon, not organic, and in a sense not 'living'. The ions are directly obtained from the environment and separately transported to the location within the organism where a hard substance is required.^e

Dental plaque (tartar)^f is 70–90% composed of calcium phosphate salts (hydroxyapatite, brushite, octacalcium phosphate, whitlockite), and 10–30% inorganic material including proteins, lipids, and bacterial remnants.

^a https://commons.wikimedia.org/wiki/category:liposomes?uselang=fr#/media/File:Phospholipide_in_Wasser.svg

^b https://www.bioplek.org/sheets/sheet_celmembraan.html

^c <https://www.chemtube3d.com/sshydroxyapatite/>

^d **Lavoisier(1789) 1, 2** refers to the presence of calcium phosphate in bones. **Berzelius (1808–1818) 9** p540... confirmed the presence of calcium phosphate and carbonate in bones and teeth. **Liebig (1842)** contributed to the understanding of organic components in bones (e.g., collagen). **Astbury (1898–1961)** Applied X-ray diffraction to biological materials. **Posner;Perloff(1954)** characterized the mineral phase of bone as hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$).

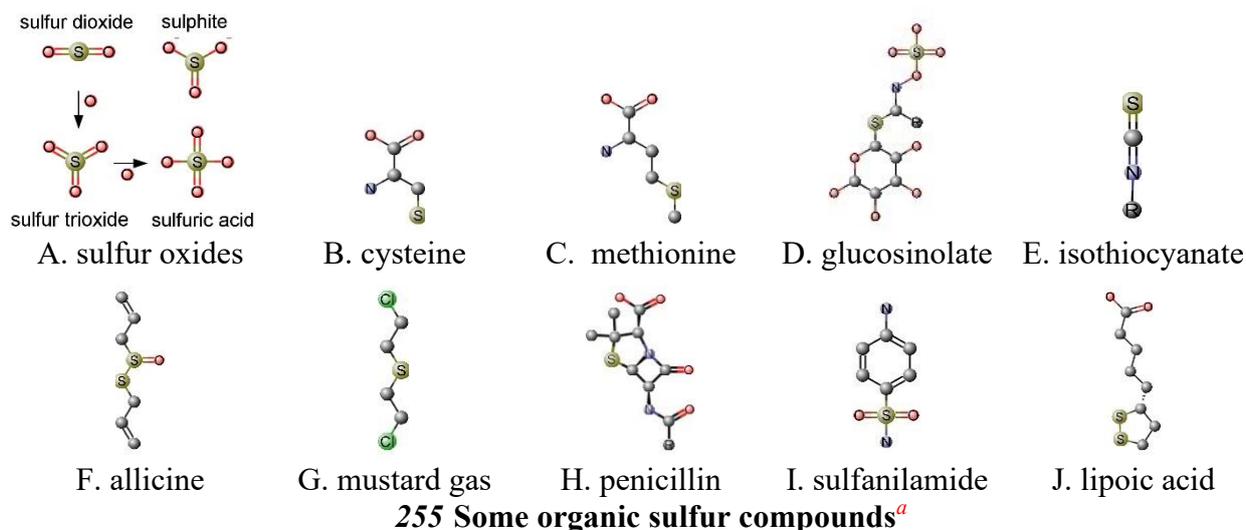
^e <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8704196/>

^f **Leeuwenhoek (1683)** described "animalcules" (microorganisms) from tartar scrapings.

Fauchard (1728) made early references to tartar and its effects on teeth.

Fox(1803) described tartar in more detail. **Berzelius es(Early to Mid 19th Century)** identified phosphate and carbonate salts in biological samples, including those from the mouth. **Fields(1840–1850)** identified tartar as composed largely of calcium phosphate, calcium carbonate, and organic matter, published in dental journals like The American Journal of Dental Science and Dental Cosmos

CARBON CONNECTS WITH SULFUR (S)



Sulfur dioxide (SO_2)^b is a well-known industrial pollutant of the atmosphere.

Fig.255A shows that sulfur (s) in connection with oxygen ('sulfur oxides') can handle different valences (not only 4 in sulphur dioxide, but also 6 in sulphur trioxide. In water, SO_2 changes into sulfuric acid (H_2SO_4) via the unstable sulfur trioxide, resulting in smog and acid rain.^c

Sulfur trioxide^d (SO_3 , used in smoke bombs) should not be confused with the negatively charged sulphite ion (SO_3^- , **Fig.255A**)^e. SO_3^- , for example, forms a stable 'salt' with calcium Ca^{++} (the ion connected 'calcium sulphite' CaSO_3). Calcium sulphite is to a limited extent allowed as a preservative (E226, for example to prevent fermentation and oxidation of wine).

Sulfur may serve as a bridge between atoms and molecules^f

Sulfur has already been recognizable in **Fig.246**p139 as an element in the amino acids (with nitrogen N) Cys and Met (cysteine and methionine, **Fig.255B** and C). There it appears with a hydrogen atom as -SH (a 'thiol') or as -SCH₃ (a 'thioether') at the end of the tail.

It may therefore form a covalent 'sulfur bridge' with another -s or -sc group between or within molecules. As a result, for example, large proteins remain more solid 'in shape' than with hydrogen bonds alone. 'Vulcanisation' of rubber^g is based on the application of sulfur bridges.

The outer layer of our skin ('epidermis') and hair, consist of a strong fiber protein ('[keratin](#)', with lots of cysteine and sulfur bridges). If you burn hair then you may smell the sulfur.

Sulfur is present in cabbage and other vegetables

Glucosinolate (**Fig.255D**) gives characteristic taste to cabbage varieties with different rest groups (R). Eating too much cabbage is not healthy, because glucosinolate is not entirely harmless. Isothiocyanate (**Fig.255E**) gives taste to mustard, radish, Brussels sprouts, watercress, East Indian cherry and capers. Alliinine does so to garlic (**Fig.255F**).

^a Zie https://en.wikipedia.org/wiki/Organosulfur_compounds

^b **Priestley(1777)** discovered sulfur dioxide in 1755. **Lavoisier(1789) 1**, 2p244 defined sulfur oxide as a bond with oxygen.

^c Sulfur dioxide is more prone to water ('hydrophilic') than carbon dioxide. CO_2 dissolves also through the unstable CO_3 in water, but especially under pressure. In water it then changes to carbonic acid (H_2CO_4). When we open a bottle of sparkling water, it quickly disappears as CO_2 .

^d **Dalton (1808)** clarified molecular compositions like SO_2 and SO_3 .

Gav-Lussac;Thenard(early 1800s) investigated SO_3 and its formation via oxidation of SO_2 .

^e Carbon trioxide should also be distinguished from a negative 'carbonate' ion CO_3^{--} . With Ca^{++} , CO_3^{--} produces the very stable 'calcium carbonate' (CaCO_3), the building block of eggshells, shells, limestone and marble.

^f **Lewis(1916)** introduced the concept of shared electron-pair, elaborated by

Langmuir(1919) e.g. for sulphur.

^g **Goodyear(1844)** invented vulcanisation in 1839, but patented it later than **Hancock(1843)**

Sulfur smells, is used in medicines, and it is present in deadly poison

The influence of sulfur on olfactory senses is even more apparent when H_2S is released during rotting (rotten egg air). Probably our nose warns with aversion to poisons such as hydrogen sulfide H_2S and sulfur dioxide SO_2 (albeit not against the sulfuric sweetener E950).

With chlorine mustard gas (**Fig.255Gp143**) has been a deadly chemical weapon of war.

Penicillin (**Fig.255Hp143**) with different residual groups (R) kills bacteria by affecting their cell wall. Fortunately, our cell membranes have a different composition, not affected by penicillin.

Sulfanilamide (**Fig.255Ip143**) is a medicine that kills bacteria, disabling an enzyme that is essential to bacteria, but not for humans.

Sulfur is indispensable in mitochondria

Sulfur is *indispensable* in every organism, and not only in the two mentioned amino acids CYS and MET. Lipoic acid (**Fig.255Jp143**) helps enzymes (as 'co-factor') in the power plants of all our cells ('mitochondria'). There sulfur also plays a role in a crucial reaction chain that supplies all cells with energy ('citric acid cycle').

Sulfur is present in mucus

Sulfur is an important component in our mucus, a water-rich 'gel' with long chains ('mucin') composed of sulphided amines and sugars ('N-acetylglucosamine' and 'galactose').

The sugar layer is on the outside. It protects the chains from disintegration and it attracts water.

Without mucus, our stomach wall would dissolve in the stomach acid.

Our airways would dry out and no unwanted bacteria and viruses would be caught.

These are trapped in the mucus and brought to our esophagus with cilia, in order to be made harmless in the acid stomach and intestines.

You may produce more than a liter of beneficial mucus per day for all kinds of functions, and in as many as 20 different types.

Snails and molluscs appreciate that protective fibrous mucus more than we do.

CARBON CONNECTS WITH CHLORINE (Cl)

Chlorine (Cl) still lacks one electron in its outer shell and that makes it even more reactive (electro-negative) than oxygen. It tends to supplement the unpaired electron as a radical oxidizer ($Cl\cdot$) or to donate it as a reductant (Cl^-).

Chlorine is not present separately as Cl in nature.

Artificially, it can exist as toxic chlorine gas ('dichloro' Cl_2), the chemical weapon that preceded the likewise chlorinated mustard gas in the first world war.

In a chain it mainly links at the end. There it has often great influence, for example on the force relations in the molecule. It may change the shape of a protein molecule.

Chlorine easily connects with virtually every other atom.

Chlorine is a part of gastric acid and table salt

With hydrogen it forms hydrogen chloride (HCl) that disintegrates with water ('dissociates') into H_3O^+ and Cl^- (hydrochloric acid). The gastric wall glands of our stomach makes hydrochloric acid.

After leaving the stomach in the duodenum it is neutralized with sodium hydrogen carbonate $NaHCO_3$ (double carbonic acid soda, baking soda, baking powder or aperient salt)^a from the pancreas. In this process, it is transformed into kitchen salt ($NaCl$), the salt of the oceans, our largest stock of chlorine ions.

^a $NaHCO_3$ also makes water sparkling with carbon dioxide. It is used as baking powder with the carbonic gas to allow dough to rise, or as a aperient salt that helps with heartburn. As a food supplement it is called E500.

Chlorine connections are used as solvents and glues

If you replace a hydrogen atom in methane with chlorine, then you get chloromethane (CH_3Cl , 'methyl chloride'). In the past, it has been used as a coolant, but it is highly flammable and toxic. CFC'S (chlorofluorocarbons or 'freon' such as Cl_2CF_2) met the cooling purpose better, but these attack the ozone layer.

Replacing *two* hydrogen atoms in methane by chlorine, you get a less harmful solvent for hobby glue, a paint stripper or propellant in spray cans (CH_2Cl_2 , dichlorocarbon).

With *three* chlorines (CHCl_3 , trichlorocarbon) it becomes the intoxicating chloroform.

This is also used as a solvent. In case of *four* chlorines (CCl_4 , carbon tetrachloride) you have the carcinogenic stain water 'tetra'. The name 'tri' is not used for CHCl_3 , but for C_2HCl_3 ('trichlorethylene') a toxic solvent with two carbon atoms.

CARBON CONNECTS WITH METALS (CA, MG, K, NA, FE)

Metals enable nerves to function, maintain turgor and are required in enzymes

Ca and Mg are building materials of bones. K^+ and Na^+ ions change the potential of nerve axons, enabling electron transfer. They also maintain the moisture tension in cells ('turgor').

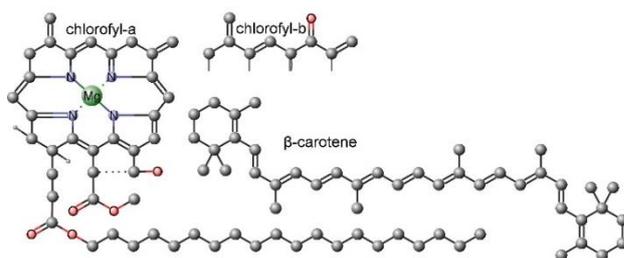
Zn and Mg are required in different enzymes.

Metals are indispensable in blood and leaf green

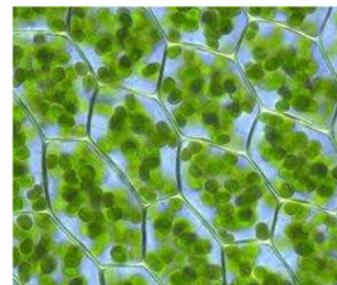
Hemoglobin (in red blood cells) consists of four long protein molecules in a globe each with a 'heme' component (**Fig.256**). Chlorophyll (leaf green, **Fig.257**) looks like heme, but it contains manganese (Mg) instead of iron (Fe).



256 Heme



257 Pigments in leaf green



258 Leaf green components ^a

Hemoglobine can hold 4 molecules of oxygen (O_2) or carbon dioxide (CO_2) and transport them inwards and outwards through the bloodstream. ^b

PHOTOSYNTHESIS CAPTURES ENERGY FROM LIGHT^c

Chlorophyll and carotene (**Fig.257**) capture red and blue light for the energy supply of plants.

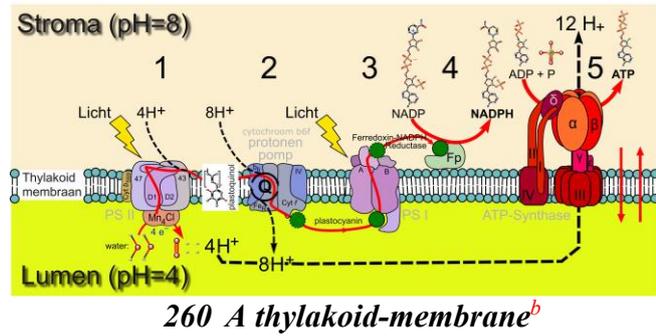
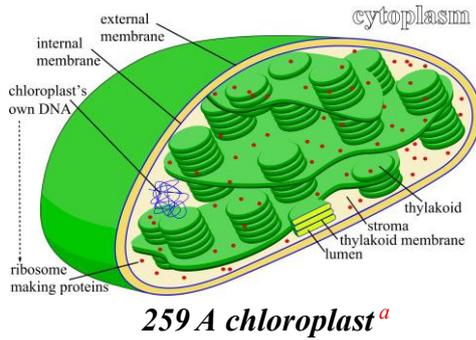
The green (and/or yellow) light is reflected back unused, and that is why we see leaves as green.

These processes occur in green components ('chloroplasts') within the cells of leafs (**Fig.258** and **Fig.259**p146). The collected energy is stored in sugars.

^a Foto **Kristian Peters** leaf chloroplasts of many-fruited thyme-moss (Plagiomnium affine) <http://www.dse.nl/~dekempvis/planten/algen.html>

^b In order to give you a sense of proportion: every red blood cell contains about 270 million hemoglobin molecules and you have about 25 000 billion red blood cells ...https://nl.wikipedia.org/wiki/Rode_bloedcel

^c **Helmont(1648)** demonstrated that plant mass comes mainly from water, not soil (precursor to photosynthesis understanding). **Priestley(1777)** showed that plants release a substance (now known as oxygen) that supports animal life. **Ingenhousz(1779)** demonstrated that plants produce oxygen only in sunlight and only by their green parts. **Senebier(1800)** Proved that carbon dioxide is taken in by plants and is necessary for photosynthesis. **Saussure(1804)** showed water is also involved and confirmed mass balance. **Sachs(1868)** identified chlorophyll as the site of photosynthesis and starch as a product. **Niel(1931)** generalized photosynthesis as $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ **Calvin c.s.(1950-1957)** elucidated the Calvin cycle, the dark reactions of photosynthesis, after multiple articles (1950–1957) in the Journal of the American Chemical Society



Chloroplasts are cells within a cell (**Fig.258**p145) with their own membranes and DNA. A chloroplast (**Fig.259**) on its turn contains hundreds of even smaller disc-shaped 'thylakoids', again with their own enclosing membrane (**Fig.260**). The surrounding 'cytoplasm' of the large cell is neutral (pH≈7). The gelatinous liquid 'stroma' of the chloroplasts is a little basic (pH ≈8). The internal 'lumen' of the small thylakoids, however, is acidic (pH≈4).

A thylakoid membrane contains 5 devices

In **Fig.260** the thylakoid membrane separating the basic stroma from the acid lumen inside contains 5 different protein devices. The devices 1 and 2 use solar energy (1) to pump (2) H⁺ from the stroma inwards to keep the lumen acidic, 3 and 4 to produce energy packages NADPH (**Fig.251**p141), and 5 ATP (**Fig.250**p141) feeding the production of e.g. sugar in the stroma.

This factory with five machines^c charges e.g. ADP with 30,5 kJ/mol into ATP. Every cell of any living organism is supplied by such ATP packages of energy. Other cells have their own charging factory (mitochondrion, p141 **Fig.300**p161), running on sugar instead of light.

(1) The first machine in **Fig.260** is called 'PS II' because the third ('PS I') has been discovered first. With the solar energy from its chlorophyll, this first system makes an energy-rich connection ('plastoquinol') with which the second system can do its work without light energy. PS II also splits water (2H₂O) in oxygen (O₂) and 4 protons (4H⁺), keeping the lumen acidic (pH≈4). It takes sunlight energy to take away the hungry o from its H prey. The O₂ is discharged to the outside air, where animals live by re-oxidizing c to CO₂.

(2) The acidification of the lumen is completed by the second machine ('Cytochrome b6f') which is also known as 'proton pump'. With the energy of 'plastoquinol' from PS II, it pumps against the current twice as many protons (8H⁺) from the stroma into the already acidic lumen inside.

(3) There is enough plastoquinol energy left, to make a large protein molecule ('plastocyanin'), with which the third machine can do its work. With that protein the third machine ('PS I') again uses light to make a different product ('Ferredoxin-NADPH Reductase' or 'FNR').

(4) With FNR, the fourth machine recharges NADP to NADPH for the Calvin cycle (p147).

(5) The fifth machine charges ADP to ATP ('ATP synthase') for the Calvin cycle in the stroma. The energy for that charging is obtained from the flow of acid protons (H⁺) back to the stroma.

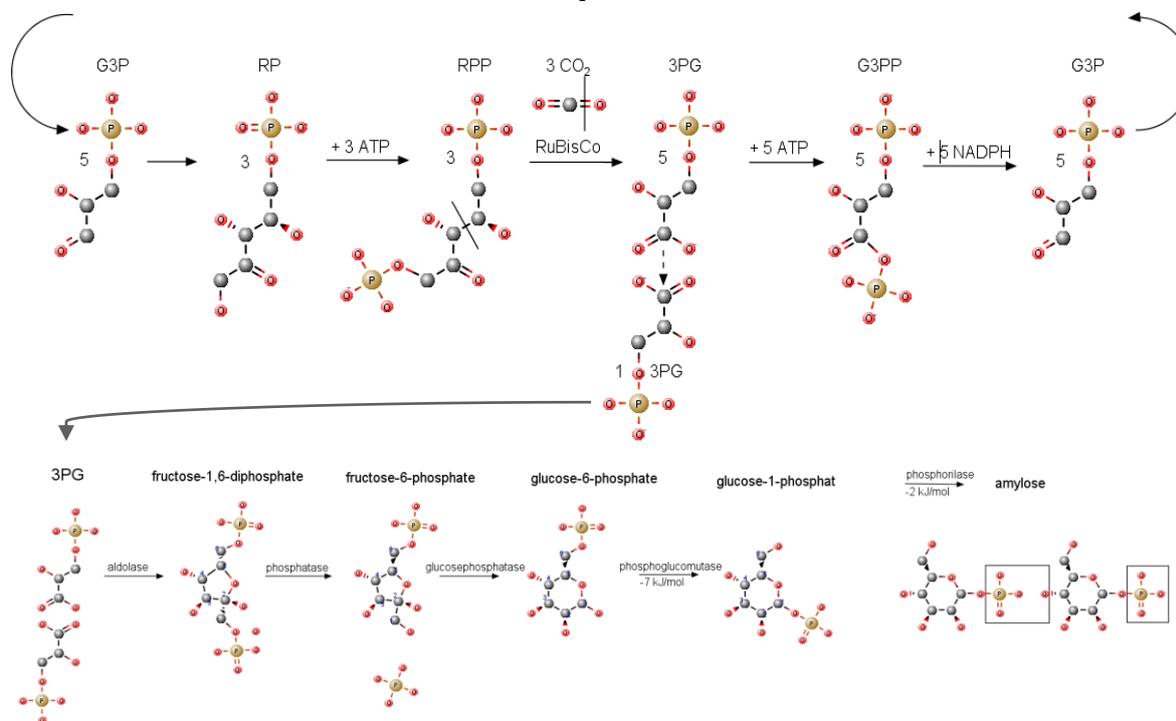
^a <https://es.wikipedia.org/wiki/Plantae>

^b Adaptation of a figure from <https://nl.wikipedia.org/wiki/Lichtreacties>

^c **Anderson;Boardman(1964)** separated PSII, PSI, and reconstructed their function. **History Anderson Vener c.s.(1997)** reconstructed the function of the cytochrome b6f complex. <https://pubmed.ncbi.nlm.nih.gov/11038603/> **Jagendorf;Urbe(1966)** confirmed that a proton gradient powers ATP synthase in thylakoids. Energized by sugar, the charging factory ('mitochondrion' **Fig.300**p155) does so in other cells.

The Calvin cycle incorporates CO₂ in organic bonds making sugars and starch

261 The Calvin cycle makes '3PG'...^a



262 ... of which finally starch is made^b

In the stroma inside a chloroplast (the green granule in leaves), the charged compounds ATP and NADPH from the thylakoides offer the energy for the great achievement of green plants: processing the CO₂ we produce as animals and with our machines, causing a climate change.

The 'Calvin cycle' (**Fig.261**) incorporates carbon dioxide CO₂ from the air, in organic bonds with the crucial enzyme 'RuBisCo'. It makes from three large molecules RP six small ones '3PG'. Five 3PG molecules are re-used in the cycle, one is available for the production of sugar and starch (**Fig.262**).

Pairs of 3PG's (**Fig.262**) are transformed into phosphates of fructose and glucose, and finally into 'amylose', polymerizing into a long molecule. Together with 'amylopectin' (**Fig.241**p137), this 'starch' is the energy supply in each plant and the largest share in our food.

In **Fig.262**, the enzyme 'glucophosphatase' changes the pentagonal fructose ring into the hexagonal glucose ring with the same chemical formula (C₆H₁₂O₆P), but it is a different molecule ('isomer'). Enzymes making a different isomer are called 'isomerases'.

The next enzyme of **Fig.262** ('phosphoglucomutase') is also such an isomerase.

It only moves the phosphate group from carbon atom nr.6 into nr.1. That move delivers another kind of glucose phosphate with a profit of -7 kJ/mol energy. Phosphorilase removes phosphate, enabling the glucoses to polymerize.

Many reactions seldom take place without such enzymes, or outside a living organism.

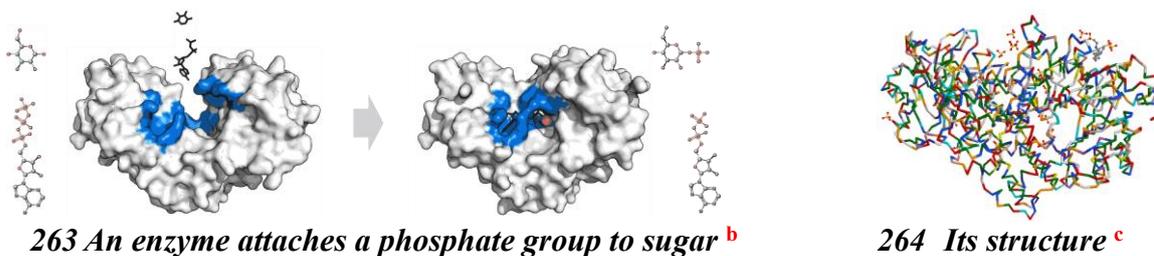
a G3P=Glyceraldehyde 3-phosphate); RP=Ribulose 5-phosphate; 3PG = 3-phosphoglycerate; RPP=Ribulose 1,5-bisphosphate; G3PP=1,3-bisphosphoglycerate. The abbreviations are not usual, but give some insight in the changing P-content.

The added or released phosphates, water and H are omitted. See also https://en.wikipedia.org/wiki/Calvin_cycle.

b The required enzymes are written above the arrows, for RuBisCo see e.g. <https://en.wikipedia.org/wiki/RuBisCo>.

The produced energies below the arrow -2kJ/mol and -7kJ/mol indicate that the reaction is a self-sustaining chain reaction (p130).

ENZYMES ARE PROTEINS, ENABLING OR ACCELERATING CHEMICAL PROCESSES ^a



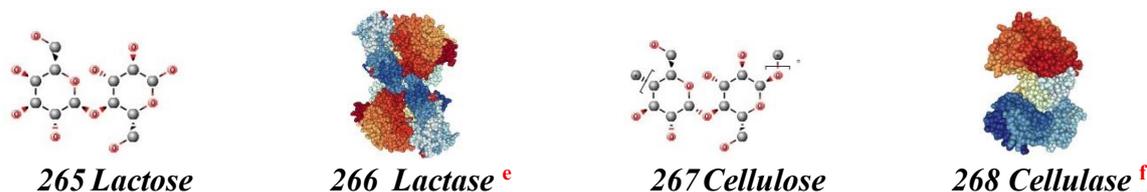
Names of enzymes usually end on '-ase', where a sugar ends with '-ose', an alcohol on '-ol', an aldehyde on '-al' and so on (238p137 and subsequent figures).

For each reaction you need a specific enzyme. The internet contains impressive catalogs ^d of those tens of thousands of enzymes that keep life going.

In **Fig.263** the enzyme 'hexokinase' (377 amino acids, 14 types) extracts a phosphate from an ATP battery and adds it to grape sugar (glucose). The enzyme grasps the two components fitting, and closes itself around the 'substrate' as a pliers. Once the phosphate is exchanged, the enzyme will release the new 'glucose-1-phosphate', and is ready for the next substrate pair.

This happens very fast and the enzyme itself remains unchanged. You need only a little of the enzyme to 'phosphatize' a whole glass of sugar water with ATP in the blink of an eye.

Plants construct the carbohydrates and proteins that animals digest and break down. Our digestion consists almost entirely of breaking down complex sugars, fats and proteins into simple sugars ('mono-saccharides'), fatty acids and amino acids, in order to rebuild them into substances usable outside the intestines of the organism.



Each substrate usually fits only to one enzyme as a key in its own specific lock.

For example, the enzyme 'lactase' specifically accepts only lactose and 'cellulase' only cellulose in order to make generally useful glucose (**Fig.240**p137).

Cellulose (**Fig.267**) is a polymeric sugar in fibers, an essential substance in plant cell walls. It is important in our diet as a source of fibre, but we cannot digest it. Ruminants such as a cow have an extra stomach ('rumen') with enzymes such as cellulase or enzyme-carrying bacteria. ^g

^a [Paven:Persoz\(1833\)](#) reported the first experimental evidence of enzyme activity of amylase, the first enzyme ever discovered. [Pasteur\(1857\)](#) demonstrated that fermentation was due to the action of living microorganisms. [Buchner\(1897\)](#) showed that cell-free extracts of yeast (Zymase) could ferment sugar outside living cells, refuting Pasteur's microorganisms. [Sumner\(1926\)](#) proved that enzymes are proteins and shared the Nobel Prize 1946 with Northrop;Stanley(1930s) who crystallized enzymes showing molecular structures (multiple papers in Journal of General Physiology and Journal of Biological Chemistry).

^b [Shafee\(\)Evolution and evolvability\(WWW\)](#) <https://en.wikipedia.org/wiki/Hexokinase>

^c Hexokinase according to <https://www.rcsb.org/3d-view/jsmol/3O08>

^d https://en.wikipedia.org/wiki/List_of_enzymes

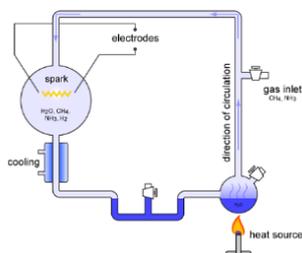
^e <http://www.rcsb.org/pdb/ngl/ngl.do?pdbid=3WEZ&bionumber=1> <https://www.rcsb.org/3d-view/jsmol/3WEZ/2>

^f <http://www.rcsb.org/pdb/ngl/ngl.do?pdbid=5E09> <https://www.rcsb.org/3d-view/jsmol/5E0C>

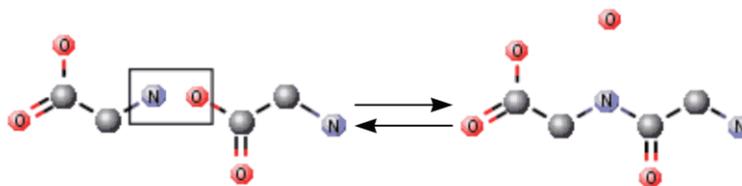
^g Our DNA has no sequence of amino acids for cellulase, but (in case you want to eat grass) here is the amino acid sequence of the cellulase: MDEGAKQTDIQSYVADMQPGWNLGNFADVGDETAWGNPRVTRELKTIADDEGYKSIRIPVTWENQMGNAPDYTNEDFFSRVEQVIDWALEEDLYVMLNLHSDSWLWIYNMEHNYDEVMAKYTALWEQLSERFQGHSHKLMFESVNEPRFRDVGIEIQENHHAFLLEELNTAFYHIVRESGGSNTERPLVPLTLETATSQDLLNRLHQTMKDLNDPNLIATVHYYGFWPFSVNVAGYTRFEEETQODIITFNRVHNTFTANGIPVVLGEGFLGFDSTDVIIQGEKLFKFEFLIHLHLNERDVTHMLWDNGOHLNRETYSWYDQEFHNLKASWEGRSATAESNLIHVRDGEPIRDQDQLHLHGNELTGLQVDGDSLALGEDYELAGDVLTKADAL TALMTPGELGTAVITAQFNSGADWHFQLVNDEPTLENTGSTSFAIPAHFNQDSVATMEAVYANGFAGPQNWTSFKFEGYTFSPVYDKGEIVITDAFFNEVRDDIHLTFHFWSGEMVEYTLKNGNHVQGRR see <https://www.rcsb.org/3d-view/5E0C>. If it does not work, then there are many other types of cellulase.

§ 35 LIFE SUPPOSES METABOLISM AND REPRODUCTION

THE ORIGINAL ABIOTIC ENVIRONMENT MAKES LIFE POSSIBLE, BUT NOT PROBABLE



269 Miller-Urey- experiment ^a



270 Two amino acids join to peptide and vice versa

Hot water under a lightning atmosphere raises organic components

Assume first: life emerged in hot *liquid water* (H_2O) under a stormy, lightning atmosphere, mainly consisting of methane (CH_4), ammonia (NH_3) and hydrogen (H_2), no oxygen (O_2), and therefore no ozone layer (O_3) stopping ultraviolet radiation. So, rocks and minerals were hardly oxidized. Such an atmosphere also exists on other planets, be it without *fluid* water.

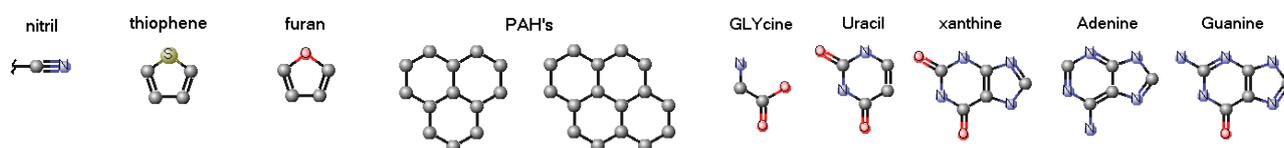
Miller^b simulated it in a closed circuit with water, methane, ammonia and hydrogen (**Fig.269**). Due to built-in electric discharges, a large number of different organic substances, such as amino acids, arose in that circuit. First supposition: with targeted supply of energy, these amino acids could join together as building blocks in chains to all proteins necessary for life.

There are, however, about 500 different amino acids. Of these, 20 appear to be suitable for life. Roughly calculated, the probability of 20 specific amino acids out of 500 is 1 to $3.7 \cdot 10^{36}$. (§ 22p76). The chance of an arbitrary protein string of say 100 amino acids in a particular sequence is 1 to 20^{100} . Both combined, the probability of a protein starting life is 1 to $3 \cdot 10^{166}$. Very improbable.

Moreover, it is unlikely that a long protein chain may form without immediately falling apart by oxidation. The backward arrow in **Fig.270** is quite probable with oxygen.

After 1952, different theories have emerged on the original environment as the first condition for developing life from dead matter ('abiogenesis').

Vulcanos under water deliver organic components under gradually varying conditions



271 Components found in volcanic emissions

272 Components found in meteorites

Assume next: the still thin, cracked earth crust has been broken often as volcanoes under water. The air pollution surpassed the current industrial pollution many orders of magnitude. The Earth became one big laboratory with a small chance on the ignition of life.

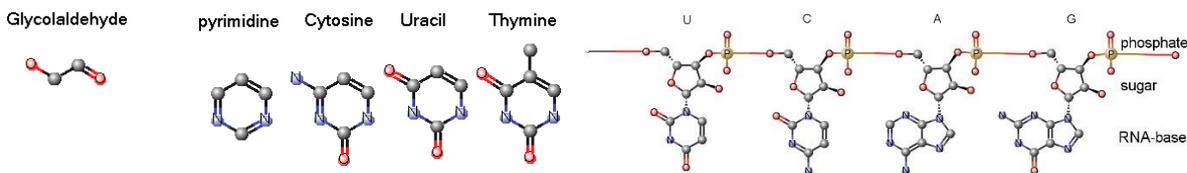
Emissions from the current volcanoes give an impression of materials that became available. "More than 200 compounds have been detected, carboxylic acids, esters (**Fig.242**p138), nitriles, pentagonal thiophenes, furans and variants of PAHs (**Fig.271**) with other components: chloro-, methyl- and sulfur."^c

^a https://en.wikipedia.org/wiki/Miller-Urey_experiment

^b Miller(1953)

^c Schwandner(2013).

Meteorites may have delivered a protein, some RNA bases and phosphor



273 Found in the Milky Way

274 Predicted in gas clouds around the sun

275 The four RNA bases UCAG (Uracil, Cytosine, Adenine and Guanine)

Third supposition: meteors caused high temperatures locally, adding (Fig.272p149), receiving and producing complex compounds. In meteorites (Fig.272), among others, the protein glycine (GLY on p139 and the two preceding figures) and the RNA bases ('nucleobases') Uracil, Guanine^a and Adenine were found (U, G and A on p140).

Carbon is the most common element in the universe after hydrogen, helium and oxygen. It appears for 20% as PAHs (Fig.271p149). These have also been found in many variants. Ionizing radiation around stars may form complex connections in conditions that do not occur on earth, but the earth has received many meteors^b, meteorites and comets in its life time.

Glycolaldehyde (Fig.273) also has been spotted in the center of the Milky Way. It can produce sugars ('formose reactions'). Computer models simulate the creation of other connections in gas clouds around the sun.

Some compounds are difficult to detect, but according to these models the other two RNA bases Cytosine and Thymine^c (Fig.274, C and T on p140) should have been present. With this, all four RNA bases U, C, A and G can be composed.

The origin of phosphor in organic compounds raises questions

In general, connection delivers energy, and separation requires energy. Separating Phosphor from ATP, however, delivers energy in nearly any living organism. Connecting phosphate to an organic molecule then requires energy and a complex enzyme (Fig.263p148).

At the start of life, neither such an enzyme existed yet, nor ATP delivering the energy required.

Phosphor is present in the earth's crust in many compounds (especially with metals), but not in a form that is accessible for living organisms. Most of them are solid, and insoluble in water. It is not clear by which chemical pathway and under what conditions this phosphor could ever become part of organic carbon.

A rare phosphate mineral, 'Schreibersite' (Fig.276p151), however, may connect phosphate to organic molecules via a conceivable chemical pathway. It is common in iron-nickel meteorites. A meteor shower in the early days of life may have brought sufficient Schreibersite to make that path plausible.^d

Fourth supposition: phosphor in organic compounds is provided by meteors or lightning.^e Once phosphates have been available, it may be reconnected easily into other compounds, crucial for life as we know it. Phosphor makes up about 1% of our total human body weight.

^a https://en.wikipedia.org/wiki/Murchison_meteorite

^b Meteors could have a diameter of 500km. Such an enormous impact may have caused the separation of the Moon. It gave so much heat that the oceans evaporated, and clouds to great heights enveloped the whole earth in darkness. Only after 3000 years rains would have filled the ocean again.

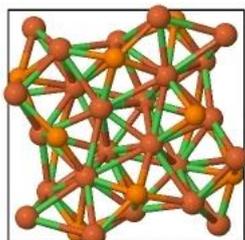
^c Thymine behaves in the DNA as Uracil in the RNA.

^d Pasek(2017)

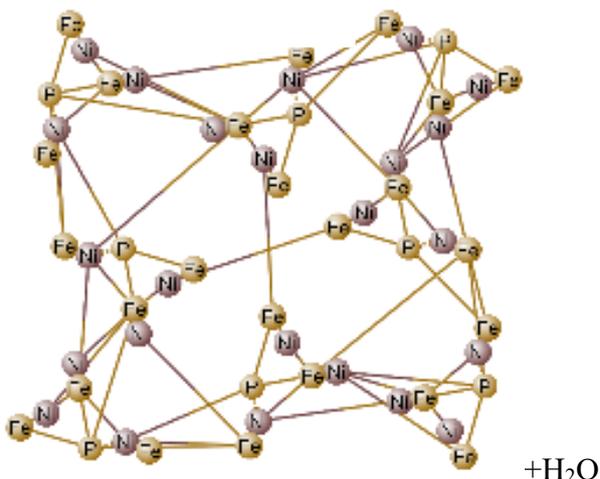
^e Perhaps not only meteors: <https://www.sciencenews.org/article/phosphorus-earth-earliest-life-forged-lightning-chemistry>



a



b

+H₂O

276 Extraterrestrial Schreibersite decomposes on Earth with water.^c

DNA and RNA bases are kept in sequence by a backbone of sugar and phosphate.

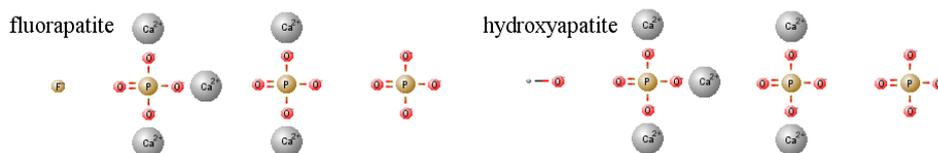
Phosphates deliver the energy for virtually all organic reactions.

The formation of cell membranes, the stabilization of the acidity in a cell, the formation of bones and teeth, all require phosphate.

The amount of organic phosphor on Earth, however, is limited to what we ever received from meteors or lightning. After death, the organic phosphor of organisms may remain as sediment.

A sufficient agricultural production for our exponentially increasing human world population depends on the availability of artificial fertilizer. Phosphate is the limiting component.

It is extracted as fluorapatite and hydroxyapatite (Ca₅(PO₄)₃F and Ca₅(PO₄)₃OH) from the finite stock that is still stored in a few mines worldwide. Morocco holds 75% of the reserves.



277 A precious resource of phosphate

This precious resource, mainly dispersed by agriculture in the oceans, cannot be recovered.

As soon as that stock is exhausted (2050-2100?)^d, then there will be a global food shortage in which only 3 billion of the fittest (read richest) may survive.^e

^a By Butcherbird - Own work, CC BY 3.0.

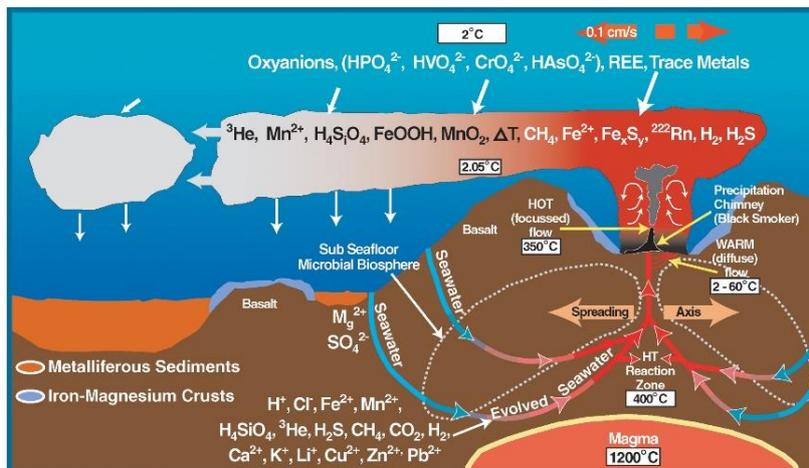
^b <https://www.mineralienatlas.de/lexikon/index.php/MineralData?mineral=Schreibersite>.

^c [Pantaleone\(2022\)](#).

^d https://en.wikipedia.org/wiki/Peak_phosphorus.

^e [Schroder\(2010\)](#).

GRADIENTS MAY HOUSE A METABOLISM



278 A seabed volcano ^a

Metabolism is a succession of reactions between the input and the output of an organism, keeping useful materials inside. Gradients around seabed volcanos produce such a succession, useful for *different* organisms on the way. In a water-rich environment under pressure, various building materials may settle on the bottom, where they may form a vertical gradient. (**Fig.278**).

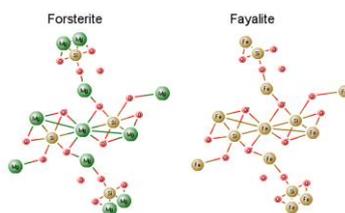
A *horizontal* gradient of descending temperature and chemical composition emerges around the volcano. These vertical and horizontal gradients provide an endless number of reaction conditions that may produce organic compounds ('metabolism').

The liquid magma ^b in the volcano itself cools off. A cooling white or black plume of smoke rises. Here, the widely varying and fluctuating temperature differences can provide the energy for unlikely organic compounds that can escape to the colder environment and stabilize ('thermosynthesis') ^c.

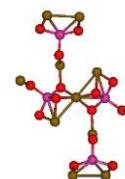
The first mineral that crystallizes (already at 1200°C) in the cooling magma is **olivine** (**Fig.279**). Such mineral weathers on exposure to CO₂ and water ('serpentinization' ^d). It therefore is found less on the earth's surface than in the magma and in the earth's crust.



279 Olivine ^e



280 Components of olivine 2D



281 Fayalite 3D

The components of olivine are forsterite (Mg₂SiO₄) and fayalite (Fe₂SiO₄). The magnesium-containing component of olivine ('forsterite', **Fig.280**) bonds CO₂ and decays into harmless and stable limestone or dolomite. This CO₂-bonding capacity of olivine is seen as an opportunity to combat climate change. ^f

^a https://en.wikipedia.org/wiki/Hydrothermal_vent

^b [https://nl.wikipedia.org/wiki/Magma_\(gesteente\)](https://nl.wikipedia.org/wiki/Magma_(gesteente))

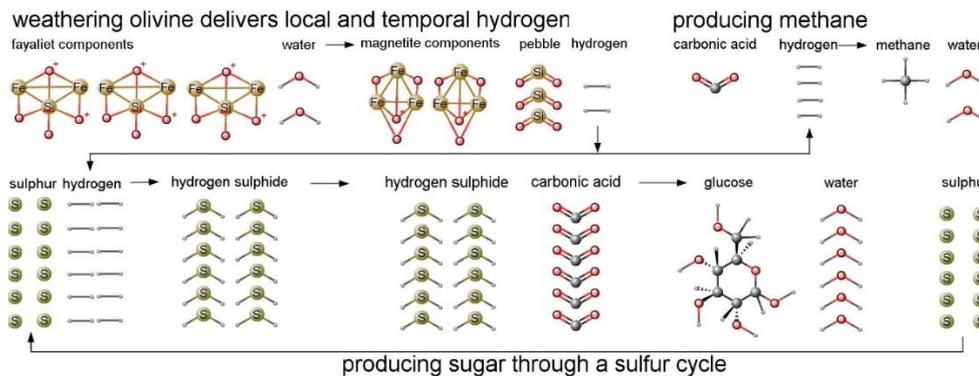
^c <https://en.wikipedia.org/wiki/Thermosynthesis>

^d <https://en.wikipedia.org/wiki/Serpentinite>

^e <https://nl.wikipedia.org/wiki/Olivijn>

^f A liter of olivine ('green sand') as soil cover or natural fertilizer compensates for the CO₂ emissions of about 1 liter of petrol. <http://www.innovationconcepts.eu/res/literatuurSchuiling/olivineagainstclimatechange23.pdf> <http://www.greensand.nl/>

Not sunlight or ATP, but hydrogen may have been the first energy supply of life



282 Hydrogen from olivine (fayalite), used to make methane and sugar in a sulfur cycle

The iron-containing component of olivine ('fayalite', **Fig.281**p152) falls apart with water in iron oxide ('magnetite'), gravel and loose hydrogen molecules (**Fig.282**).

This spontaneous reaction makes free hydrogen locally and temporally available before it is leaving into space due to its volatility. This has been observed in current deep-sea volcanoes.^a

It is conceivable that this process has provided the small packages of chemical energy in steps per molecule, necessary for reactions in the first life phenomena.

Free hydrogen may reduce *carbon dioxide* to methane with energy gains ($\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$).

There are still primitive single-celled organisms ('archaea' **Fig.298**p161) using methane as the only source of energy and carbon ('methanotrophs'), without oxygen ('anaerobic').^b

Free hydrogen can bond sulfur (s) with energy gains ($\text{S} + \text{H}_2 \rightarrow \text{H}_2\text{S}$).

This results in the required hydrogen sulphide (H₂S, smelling of rotten eggs).

To this day, 'purple sulfur bacteria' convert CO₂ into glucose C₆H₁₂O₆ with hydrogen sulphide by 'chemosynthesis': $12\text{H}_2\text{S} + 6\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 12\text{S}$, leaving pure sulfur (S) in small granules available for another cycle (**Fig.282**). In this cycle, hydrogen (H₂) is the volatile energy carrier and sulfur (s) facilitates access to more complex organic compounds.

Before oxygen could play a role as an oxidator (electron acceptor), micro-organisms 'breathed' sulfur. The 'sulfur cycle' has become much more complicated over time and now plays a crucial role in many life processes.^c

Microbial mat gradients may enable an early kind of metabolism

The oldest survivors known are 'microbial mats' (**Fig.283**p154), layered structures of a few millimeters thick. Their vertical gradient (gradual transition) of stacked (from bottom to top increasingly complex) life forms, sometimes with silicic bacteria^d at the top, protecting the mat against the aggressive outside world. The output of one layer is the input of the next layer.

They appear in shallow seas, on fluctuating flooded banks and even on dry land, surviving temperatures of -40 to 120°C (dependent of the species). *Gradients provide a reaction somewhere at the right place, fluctuations sometime at the right time.*

Wetting and drying up, freezing and melting may yield at once the right concentrations.

Dehydration may bond amino acids to chains, and fold them with stabilising bridges.

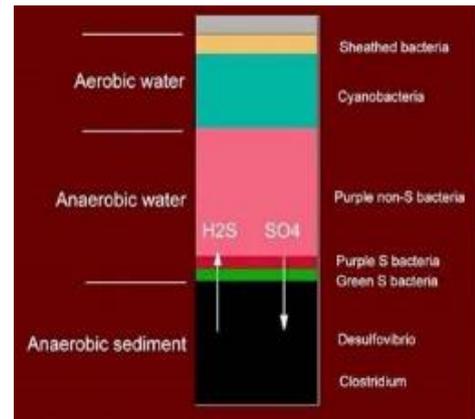
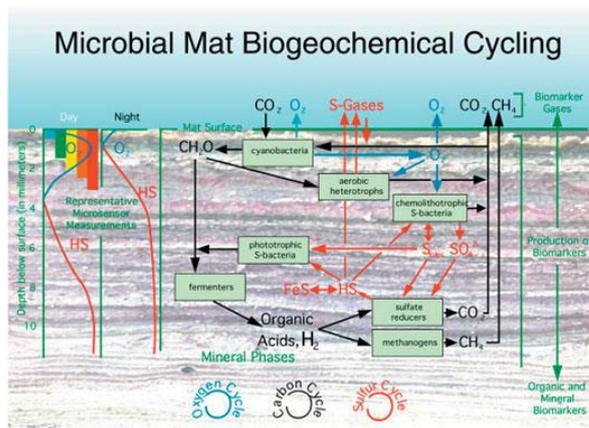
Cooking precipitates solutes or denatures macromolecules (compare cooking eggs). Freezing crystallizes the pure water first and concentrates the other compounds in enclosing *cavities*.

^a [Proskurowski\(2008\)](#)

^b [Wang\(2014\)](#)

^c https://en.wikipedia.org/wiki/Sulfur_cycle

^d <https://academic.oup.com/bbb/article/85/6/1324/6240178>



283 Microbial mat ^a

Compare the ecosystem of vertically successive environments with those in our intestinal flora. Our intestinal tract is a tube with changing environments; the microbial mat is a gradient.

In the digestive tract of developed organisms, all incoming nutrients are first broken down into elementary abiotic amino acids, sugars and required minerals, more or less in the same form as they should have been present at the beginning of life. Intestines are separated from the rest of the organism. Via a selective intestinal wall, components are delivered for re-assembling.

In the intestines the selection *and* degradation takes place by acid, alkaline lye, and a complex ecosystem (an 'intestinal flora' can be different in every individual), composed of many microorganisms having their own degrading enzymes.

These enzymes are not present in the organism itself, and there, they even might be harmful.

That breakdown costs dissolution energy, while building up liberates bonding energy (p136). The composition of complex proteins in the correct order of amino acids requires construction *and* degradation within the organism.

Providing and disposing energy at the right place and time must be done in a controlled manner (by enzymes) and should not be disturbed by aggressive undirected energies from outside.

REPRODUCTION REQUIRES MODIFIED REPETITION IN DIFFERENT ENVIRONMENTS

Reproduction supposes repetition, be it not always exact repetition.

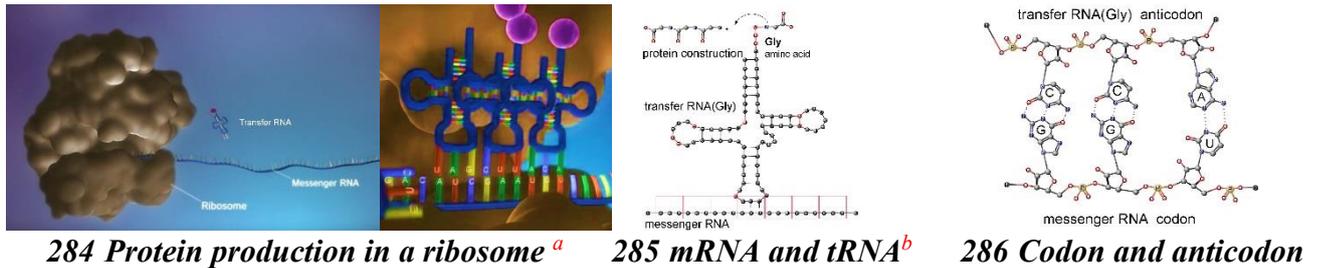
Before a fully grown multicellular organism can propagate as a whole, its *cells* must have repeatedly been multiplied by division ('mitosis'), and differentiated into different organs.

This supposes that individual cells have been separated in different environments by membranes. At their turn surrounded by a protecting skin, reproduced cells can develop into different organs ('cell differentiation').

Within the cells, reactions take place that have to *repeat* themselves, in order to have the right raw materials available in the right quantities for any life process. This repetition usually occurs in a cycle of consecutive reactions (**Fig.282**p153). Such a cycle keeps going by itself (exotherm) or by an external source that repeatedly delivers energy (endotherm).

^a Fenchel(1995) Fig.4.12 p188. Downloadable from: <https://epdf.tips/ecology-and-evolution-in-anoxic-worlds-oxford-series-in-ecology-and-evolution.html>

Reproduction of large molecules requires a memory



284 Protein production in a ribosome^a

285 mRNA and tRNA^b

286 Codon and anticodon

The repeated formation of large, complex molecules such as proteins, amino acids in a strict order (p139), requires a memory^c. That memory is located in DNA and RNA.

An organism, containing only the genes that are the same in every living being now, has been reconstructed as the virtual 'Last Universal Common Ancestor' ('LUCA' p162).^d LUCA should have lived in hot water, in an anaerobic, chemically active environment with H₂, CO₂ and iron.^e

Fig.284- Fig.286 show in more detail than on p140 how RNA copies of DNA are applied in order to construct proteins from free amino acids.

It *repeats* itself endlessly throughout your body as a prototype of reproduction in living beings and in all forms of reproduction that subsequently have been developed.

Each of the 20 amino acids has its own means of transport: a transfer RNA ('tRNA') with a three-character code ('anticodon') of that amino acid (p140).

That specific tRNA searches in the cell 'its' amino acid and takes it to a protein factory ('ribosome' p140). As soon as the relevant code passes, it attaches itself with its amino acid baggage to deliver it for protein construction.

After delivery, it will 'search' in the cell for a new specimen of its amino acid again.

This happens about 60 times per second.^f A protein of 600 amino acids then is made in 10 seconds. The process ends when the ribosome reads a stop sign in mRNA.

The complete protein chain is then released and folds up with cross-connections to the unique stable form for that protein in which it can function.

RNA memory 'books' may have preceded DNA 'libraries'

Life may have begun by RNA chains (as single 'books') in an 'RNA world'.

The DNA 'library' in each cell then followed later.

There are still pathogens ('viroids') that simply consist of loose circular RNA chains ('plastids'), but they can only reproduce in a host cell with ribosomes and suitable protein enzymes.^g

It is conceivable, that such loose RNA chains bond their codons with anti-codons as negatives of the positive originals. Connected by a backbone they become a double 'library' such as DNA.

The backbones now consist of phosphate and sugar, but simpler alternatives may have existed.^h

At more than 140°C, amino acids may also link up to peptides without intervening RNA.

When their solution dries out, then they become longer polymers, proteins.

^a <https://www.youtube.com/watch?v=gG7uCskUOrA> gives an impression of this reproduction. More details are shown in <https://www.youtube.com/watch?v=kmrUzDYAmEI> en https://www.youtube.com/watch?v=8Hsz_Vmcy-Y

^b The cross-shaped structure of the tRNA molecule is the same for all tRNAs, but the amino acids that make up the chain are different. Only the red marked parts are the same in all tRNAs. The red-rimmed anticodon portion is shown enlarged in **Fig.286**.

^c **Schrodinger(1948)**

^d **Wade(2016)** . **Weiss(2016)**

^e https://en.wikipedia.org/wiki/RNA_world

^f <http://book.bionumbers.org/what-is-faster-transcription-or-translation/>

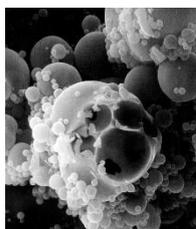
^g <https://en.wikipedia.org/wiki/Viroid>

^h Peptide nucleic acid (PNA) , threose nucleic acid (TNA) of glycol nucleic acid (GNA) . https://en.wikipedia.org/wiki/Peptide_nucleic_acid ; https://en.wikipedia.org/wiki/Threose_nucleic_acid ; https://en.wikipedia.org/wiki/Glycol_nucleic_acid

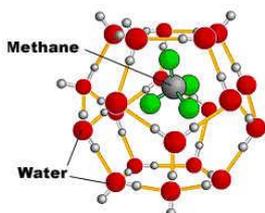
At 70°C, with phosphoric acid as a catalyst, protein-like structures ('proteinoids') are formed, in which 18 of the known 22 amino acids have been found.^a

In water, some of them are unilaterally water-averse (hydrophobic). They then make (in the same way as the phospholipids on p142) spherical 'proteinoid microspheres', also found in volcanoes. They, however, do not yet have the correct sequence to form a functioning protein.

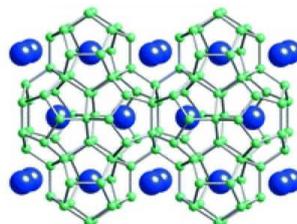
ENCLOSURE PROTECTS AGAINST EXTERNAL ENTROPY



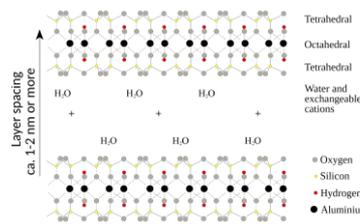
287 Microsphere^b



288 Methane clathrate in water^c



289 Hydrogen clathrate in silicate^d



290 Montmorillonite^e

Enclosure with a membrane, or a shell of chitin or chalk as found in 'foraminifera'^f, is often supposed as the first condition to give vulnerable life processes a chance in a chaotic environment. This is, however, not strictly necessary.^g

There are abiotic enclosures

The possibility of frozen cavities are already mentioned, but there are other abiotic-chemical reactions that form spherically sealed spaces ('microspheres').^h

In such microscopic balls with semi-permeable walls, also medicines are packaged to be slowly released into the body. Within such an enclosure a deviant inner environment may survive. If such a microsphere has a small opening (*Fig.287*), then a concentration gradientⁱ with some sequential metabolism can emerge there.

'Clathrates' are polymers that may enclose a guest molecule. The best-known example is methane, around which water may crystallise into an ice-like polymer (*Fig.288*).

When heated, the methane is released ('burning ice').^j Also CO₂ and H₂ can be trapped in water or in other polymers such as silicate this way, without escaping as gas (*Fig.289*).

The common type of clay montmorillonite (*Fig.290*) consists of small plate-shaped crystals with which air bubbles can be enveloped in water. If they come into contact with simple organic compounds with a lower surface tension than water such as ethanol, the plates are enveloped with them and form an adherent, semi-permeable armor.

The air in the bubble dissolves outwards, and the surrounding water may enter with organic components while the armor holds. Montmorillonite catalyses lipids into membranes and single

^a <https://en.wikipedia.org/wiki/Proteinoid> ; Fox(1992)
^b <https://www.stevenbrooke.com/bio/steven-brooke-biography>
^c <https://kumpul4ntul1s4n.wordpress.com/2011/05/05/mencairnya-methane-hydrates/>
^d <https://mrsec.org/highlights/storing-hydrogen-novel-clathrate-materials>
^e <https://en.wikipedia.org/wiki/Montmorillonite> By German version by Andreas Trepte, translated by User:Itub - Image:Montmorillonit.svg, CC BY-SA 2.5, <https://commons.wikimedia.org/w/index.php?curid=2356198>
^f <https://en.wikipedia.org/wiki/Foraminifera>
^g <https://newscientist.nl/nieuws/cel-kan-bestaan-zonder-membraan/>
^h Fox(1958)
ⁱ https://nl.wikipedia.org/wiki/Concentratiegradi%C3%ABnt#Ori.C3.ABntatie_in_eeen_concentratiegradi.C3.ABnt
^j http://www1.lsbu.ac.uk/water/clathrate_hydrates.html
https://www.reddit.com/r/chemicalreactiongifs/comments/58n5hy/fire_ice_a_methane_clathrate_looks_like_a_chunk/
https://en.wikipedia.org/wiki/Methane_clathrate

nucleotides into RNA chains. The semi-permeable wall does not allow these larger structures to escape outward, but remains open for the supply of smaller external components.^a

So, different kinds of enclosure may have preceded the formation of membranes.

Enclosed cells multiply

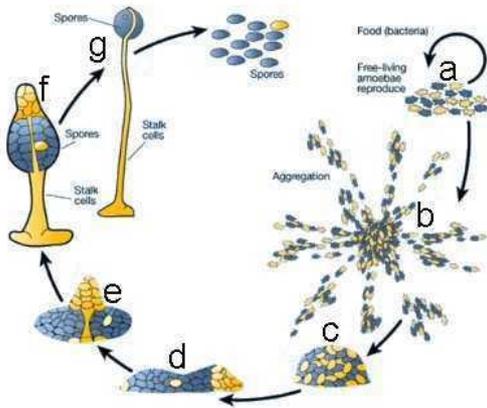
If the conditions of environment, metabolism, reproduction and enclosure are met at the chemical level, then life has cells that can differentiate and compete, the two conditions for natural selection and evolution.

Developing different forms of metabolism, reproduction and enclosure, they may survive in different environments, fulfill different functions in a larger body, raising the scale of external competition by internal cooperation.

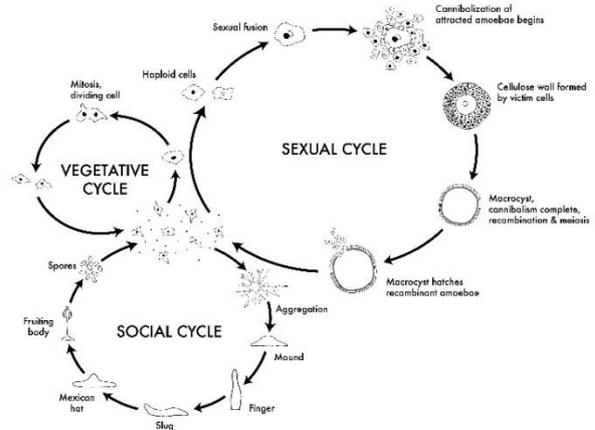
^a [Subramaniam\(2011\)](#)

§ 36 ORGANISMS ORGANIZE

CELLS GROUP, DIFFERENTIATE, ENCLOSE, REPRODUCE, UNGROUP AND COMPETE



291 Life-cycle *Dictyostelium discoideum*^a



292 Applied reproduction methods^b

The species '*Dictyostelium discoideum*^c' provides a nice picture of the way in which individual cells may group into an organism (**Fig.291**), get different tasks ('cell differentiation') and reproduce socially, sexually or vegetatively (**Fig.292**).

Dictyostelium discoideum has long been regarded as a fungus, but it turns out to be an amoeba, a cell with a nucleus ('eukariote'), with a flexible cell membrane that may extend to sham feet ('pseudopodia'), and able to move along solid ground. The amoeba feeds on bacteria and propagates vegetatively through cell division ('mitosis', **Fig.291a**).

If starvation threatens, then the amoebae produce cAMP as a signal substance.^d Around 100 000 scattered cells then move towards a point with the highest concentration of cAMP (**Fig.291b**). There they attach themselves to each other as a 'pseudoplasmodium' (**Fig.291c**).

This organism takes the form of a 2 to 4 mm long snail (**Fig.291d**).

This snail can move to the light and more nutrient-rich area as a result of secreting cellulose at the front as a lubricant which remains behind on the bottom as a snail trace.

Arriving in a nutrient-rich area, the cellulose-producing cells move within the organism to the middle and vertically upwards (**Fig.291e**) making a stem.

They strengthen the stem with cellulose on the outside.

The other cells move upwards (**Fig.291f**). The stem is extended from below as long as enough cellulosic cells remain, to attach the organism to the soil. At the top, the other cells dry out into spores with DNA, which are released in order to become new amoebae (**Fig.291g**).

In case of food scarcity, the individual amoebae can also breed sexually (**Fig.292**).

As soon as a male and a female cell are united ('zygote'), then one large closed cell ('macrocyt') recombines the genes ('meiosis' with 'cross-linking'), catches surrounding amoebas, enclose them in a cellulose shield, use them as food ('cannibalism'), and reproduce themselves.

Sexual reproduction is a risk coverage.

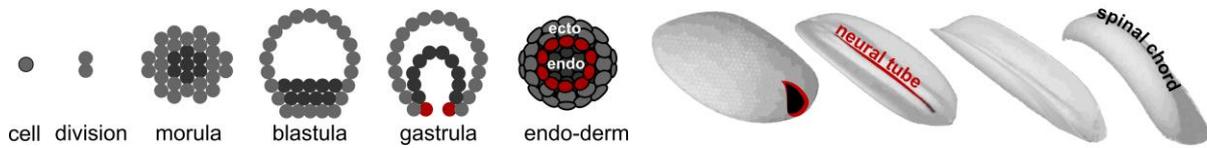
^a [Shaulsky](#)

^b [Brown](#)

^c https://en.wikipedia.org/wiki/Dictyostelium_discoideum

^d ATP and ADP have three and two phosphate groups (**Fig.250** p125). AMP has the same basis with one phosphate group. cAMP is a variant of this.

ORGANS SPECIALIZE



293 Cells develop 2 interiors and Polarity

294 Folding develops a third interior^a

In sexual reproduction of higher animals and plants, after being split into single ('haploid') DNA chains, these male and female 'gametes' cross-link in the fertilised cell ('zygote'). The crossed haploids are combined ('meiosis'^b), split as double 'diploids' and copied ('mitosis').

In small organisms, the cell with the recombined DNA may divide into two within an hour. Within 5 hours that is a clump of $2^5=32$ cells ('morula' **Fig.293**), differentiating its inner cells.^c At further growth into $2^7=128$, the cells move outwards, creating a cavity, enclosed by a wall of cells ('blastula' **Fig.293**),^d The blastula polarizes.^e Cells concentrate on one side.

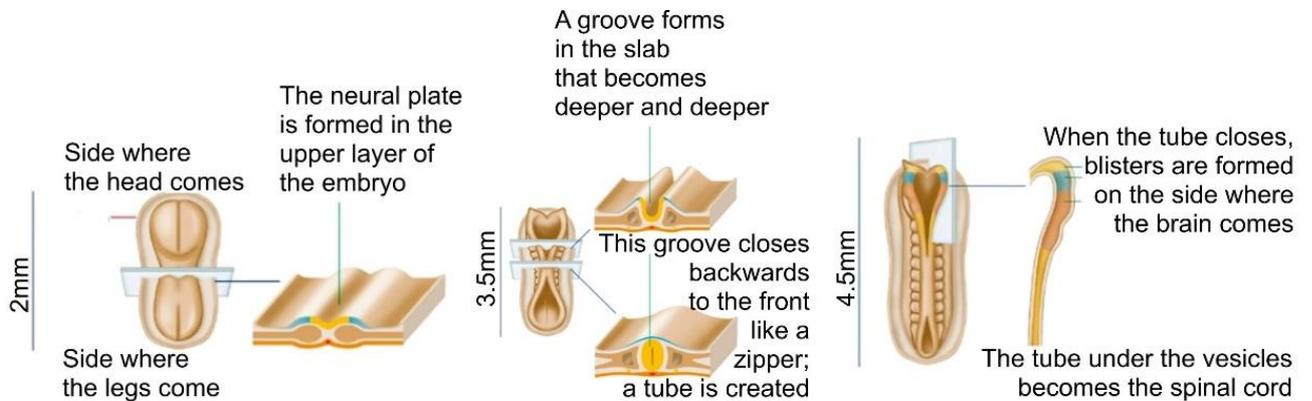
On that side they develop an indentation ('gastrula' **Fig.293**), with different cell types, and 2 different interior environments. The outer skin ('ectoderm') turns locally into an inner skin ('endoderm'). It gets other tasks (for example as a gut wall). The senses will arise at the **boundary** between the two, the opening of the bag. From there the neural system will develop.

The bag flattens and folds around a neural gutter (**Fig.294**) into a neural tube (**Fig.295**).

If it does not close properly, then the future child may be born with an 'open back'.

Muscles, skeleton and skin will develop on the inner 'dorsal side' (back side).

On the 'ventral' side (belly side) organs for metabolism and blood circulation will develop.



295 Human differentiation in week 3^f

^a <https://www.youtube.com/watch?v=aOY16GlqrPw&feature=youtu.be>

^b <https://www.youtube.com/watch?v=kQu6Yfrr6j0>

^c <http://tunicate-portal.org/faba/1.4/document.html>

^d For some species of green algae (the genus Volvox) such a blastula colony is already capable of reproduction.

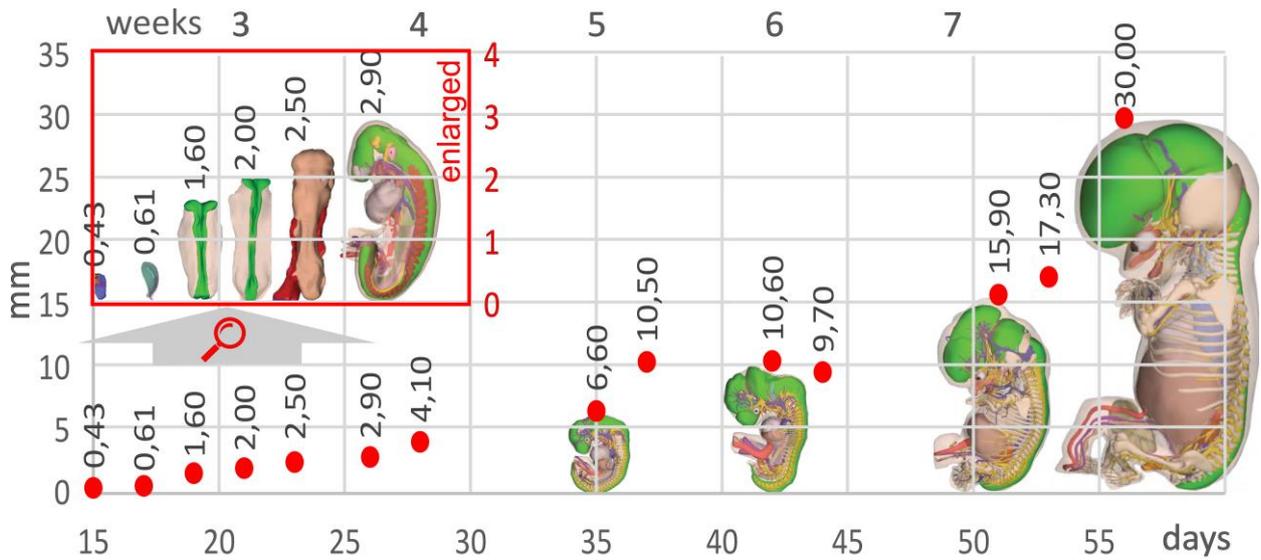
In the hollow sphere, there are indentations with new cells that loosen per 16 in the cavity and develop further until the old sphere falls apart.

Then they can swim out. <https://en.wikipedia.org/wiki/Volvox>

^e Sinnott(1963)

considers polarity and symmetry as the first form principles in all living organisms.

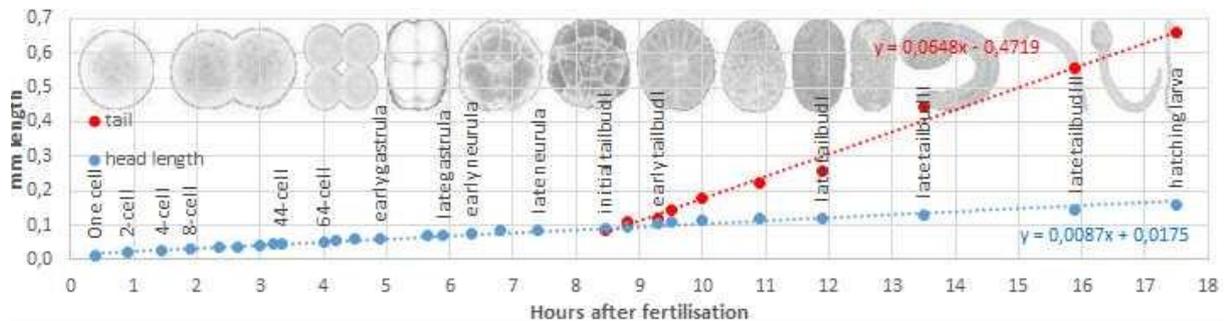
^f https://www.researchgate.net/figure/Figuur-6-Schematische-weergave-van-de-ontwikkeling-van-het-embryonale-brein_fig4_282133151



296 Human differentiation and growth in 60 days ^a

On day 17 (0.61mm), a brood bag has been developed at the endoderm on the belly side (not shown in **Fig.296**). On day 19 (1.6mm), the onset of skeletal, muscular and nervous systems can be recognized on the back and the beginning of metabolic blood circulation and other organs on the abdomen side. On day 23 (2.5mm) the first signs of sense development are added at the top.

A considerable body of knowledge has been accumulated on microscopic embryos of other species. In the sea, various types of 'sea squirts' grow, which propagate through a larval stage. The embryo development of the 'Ciona intestinalis' is described in detail (**Fig.297**)



297 Ciona Intestinalis differentiation and growth (with tail) in 18 days ^b

The cell division of Ciona intestinalis starts half an hour after fertilization, gastrulation after 5 hours, the development of a neural system after 6 hours.

The tail begins to grow after 8 hours and after 18 hours the larva is ready for its task.

Humans require 9 months and then still a long period of education.

Task division requires signals

The question is, of course, how cells (with exactly the same DNA) 'know' what to do in all these different environments in the organism. They get signals (unblocking stimuli) from their environment (temperature, pH, substances) in order to select the right parts of their DNA on the spot, neglecting the other 'books' of that 'library'.

^a <http://3datlas.3dembryo.nl/>

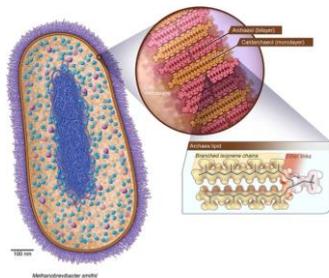
^b <https://anatomypubs.onlinelibrary.wiley.com/doi/10.1002/dvdy.21188>

The division of tasks between cells and organs is controlled by signal molecules.^a Cells receive and disperse enzymes and 'hormones' in order to initiate locally and temporarily the right processes. They spread from sending cells in the fluid between cells and organs ('plasma') in decreasing concentration ('gradient'), or via the circulatory system throughout the body.

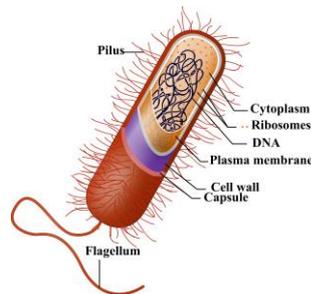
They are received by receptors in the cell wall as a message and transmitted to the liquid within the cell ('cytoplasm'). There they stimulate the right enzymes to their specialist activity.

Signal substances are also produced by special glands spread throughout the body ('cytokines'), by different cell types to their neighbors or between senses, nerve cells ('neurotransmitters'), muscles and other cells, or stimulate other organisms ('ectohormones' such as 'pheromones').^b

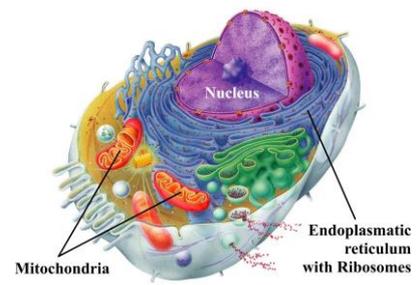
ORGANISMS DEFEND THEMSELVES AND REPRODUCE



298 *Archaea*^c



299 *Bacteria*^d



300 *Eukaryota*^e

Prokaryota use one outer defence wall

Unlike *organs*, *organisms* are directly exposed to a changeable, often aggressive outdoor environment. Primitive single-celled organisms ('prokaryota', including *archaea* and *bacteria*) protect themselves against that environment and against loss of their composition, usually by a single membrane ('*archaea*' *Fig.299*), or a two-fold membrane ('*bacteria*' *Fig.298*).

In addition, they still have protective layers, hairs and sometimes a whip ('flagella') to move on. The DNA of both is a closed ring, supplemented with loose DNA rings that can be exchanged with other prokaryotes ('plasmids'^f).

Prokaryotes rapidly divide (mitosis within 10 minutes) and also can rapidly change due to that plasmid exchange. In *bacteria*, the DNA is spread throughout the cell, but *archaea* concentrate it in a nucleic nucleotide without membrane or supporting protein ('chromatin' as in '*eukariota*'). Both have loose ribosomes (protein factories), but the protein production of *archaea* is more like that of *eukaryota* than that of *bacteria*.

Eukariota have inner walls

The third group of organisms (the one-cell or multicellular '*eukaryota*'^g to which we belong *Fig.300*), have organ cells within cells ('organelles', the cell nucleus, ribosomes, mitochondria and the like) with own membranes. Multicellular eukaryotes develop also an all-embracing defensive skin and, within them, individually enclosed organs.

^a https://en.wikipedia.org/wiki/Cell_signaling

^b <https://nl.wikipedia.org/wiki/Signaal molecuul>

^c Image by Gottlieb, Wachter, Sliman and Pimentel <https://en.wikipedia.org/wiki/Archaea>

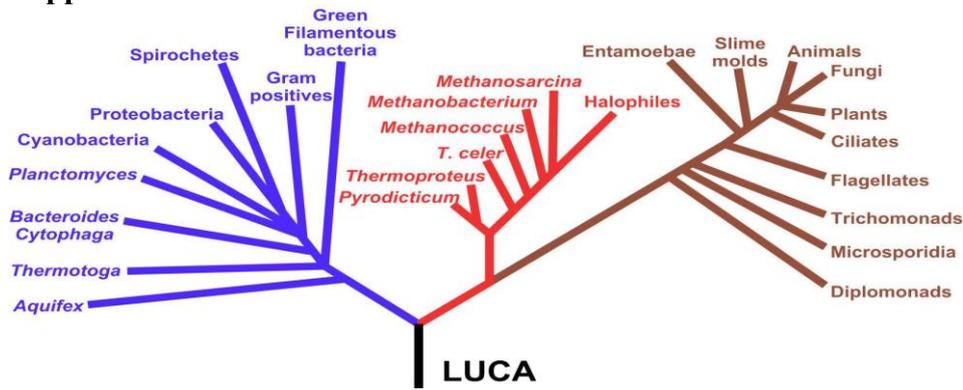
^d <https://www.labxchange.org/library/items/lb:LabXchange:c58e3762:html:1> <https://en.wikipedia.org/wiki/Bacteria>

^e Pearson Benjamin Cunnings <https://quizlet.com/be/259408991/cellule-animale-diagram/>

^f <https://en.wikipedia.org/wiki/Plasmid>

^g <https://en.wikipedia.org/wiki/Eukaryote>

LUCA is a supposed common ancestor



301 A phylogenetic family tree^a

The approximately one and a half million species of organisms that have been described, are perhaps only one tenth of the number of undiscovered and undescribed species.

The number of extinct species that has ever existed is probably another hundred times as large.

The hypothetical common ancestor LUCA (p155), reconstructed from the common denominator of all known DNAs has had numerous extinct predecessors.

The ribosome (the protein factory p140) is found in all organisms after LUCA.

It is not made by enzyme proteins, because these must first be made in ribosomes themselves.

It contains rRNA chains with its own recipe and reproduces without consulting a DNA library.

It thus contains hereditary material outside the DNA (such as the plastids on p155 in a bacterium), replicating alongside the DNA during cell division ('extra-chromosomal heredity').^b

The ribosome may have had a precursor to LUCA that has consisted exclusively of RNA (RNA world) without protein components.

Something similar applies to other organelles in the cell. In this way, the 'centriola' spinning the wires that have to pull the DNA apart also reproduces itself without a prescription from outside.

The mother and daughter centriola move to two poles before cell division.

In addition to this role in cell division, they also make a 'flagella'.

The mitochondrium (the energy factory **Fig.300**p161) has a two-fold membrane and its own genes with which it makes its own proteins and reproduces.

It is also considered a bacterium that has ever crept into LUCA, adapted, and made itself indispensable in all eukaryotic cells.

In plants, the double-walled chloroplasts for photosynthesis (p146) are regarded as entangled plastids that share their own authority.

^a <https://nl.wikipedia.org/wiki/Fylogenie>

^b Jinks(1964)

ECOLOGY BALANCES BETWEEN COOPERATION AND COMPETITION

In the wide variety of environments under water, on land and inbetween ('habitats'), various forms of cooperation arise with different kinds of task division.

Concentration gradients^a of food and signal substances^b enable a division of tasks.

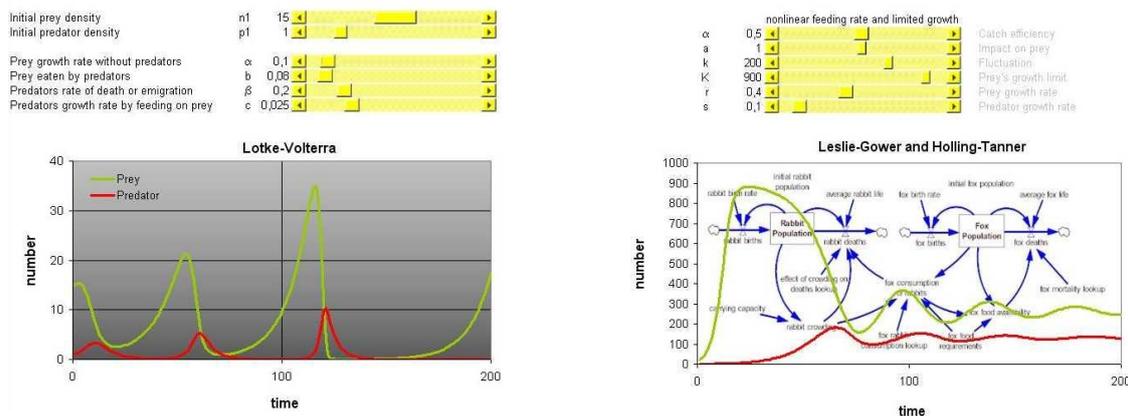
The microbial mat is a prototype of cooperation

A microbial mat (*Fig.283p154*) shows cooperation between organisms ('symbiosis') at the gradient between two very different environments: the dark mineral world of a solid, stable soil and the changeable open water or air. The different organisms live in layers. They cannot survive at another layer, receiving and delivering specific products from and to their neighbours.

The originally oxygen-free ('anaerobic') environment required another source of energy than light or oxidation. Bacteria and archaea that could use H₂, CH₄ or hydrogen sulphide H₂S were probably the first 'layer' or 'phase'.

Competition stabilizes a population

Competition includes predation. Predators prevent the overpopulation of their prey. If, however, the prey population becomes smaller, then *predators* will die, and the prey population expands again. This leads to a fluctuation of both mutually alternating populations ('population dynamics' *Fig.302*) that can be simulated mathematically (see also p74 and p75).



302 Predator prey simulations ^c

Such a negative feedback prevents exponential growth of herbivores causing habitat depletion. It keeps their population within bounds, but it also accelerates the evolution of both populations by killing the inaccurate specimens.

This accelerates the 'survival of the fittest' and increases their living space.

Preys have adapted in many ways to survive in an aggressive environment. They have strengthened their skin (sometimes patched, hairy or spiked), developed movement organs to be able to flee or defensive organs to fight. They have developed an immune system^d against aggressive micro-organisms, fearsome signals or poisons against other aggressors.

The human population has disabled many of its predators. Its *habitat* then limits its exponential growth by exhaustion (the logistic curve p83). Overpopulation may cause a chaotic period of decline and ascent due to floods, water and food shortages (phosphor!), new diseases or wars. The 'fittest' (read 'richest') will survive. A *stable* sustainable population^e requires birth control.

^a https://nl.wikipedia.org/wiki/Concentratiegradi%C3%ABnt#Ori.C3.ABntatie_in_eeen_concentratiegradi.C3.ABnt

^b <https://nl.wikipedia.org/wiki/Feromoon>

^c https://en.wikipedia.org/wiki/Lotka%E2%80%93Volterra_equations ; <http://www.sciencedirect.com/science/article/pii/S0022247X09004442>

^d Oskam(1972)

^e <https://academic.oup.com/bioscience/article/54/3/195-204/223056> Fresco counts on 10 mld: Speksnijder(2018)Fresco(Volkskrant)0303

Cooperation requires signals and receptors

The most common kind of cooperation ('symbiosis') is the sexual. Combining two gametes from different organisms creating a new zygote variant requires coordination in space and time.

For example, male moths have developed antennas that can detect even one molecule of a species-specific female pheromone at great distance.^a

Through zigzag movements in the air they seek the higher concentrations that lead to the female. That pheromone is spread only when the time is right.

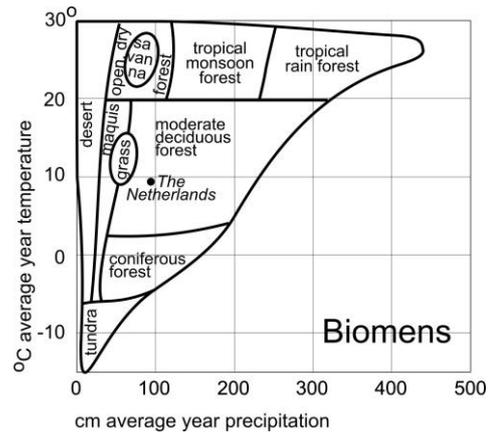
Vegetation is the basis of all food chains. Since plants usually cannot move, their sexual reproduction is dependent on massively distributed male gametes, which happen to hit a female gamete of the same species. Specialized insects reduce that hazard, but in flowering plants the pistil receptors should be able to recognize and allow this gamete from countless pollen species.

In the cell, enzymes have an accurate pattern recognition mechanisms by their shape (p148). RNA demonstrates this ability in searching the DNA library and assembling proteins.

Our immune system recognises incoming aggressive elements. That alarm starts in our mouth and nose. The fabulous smell distinction in dogs is known, but plants also have such an alarm system. They are even able to warn their neighbors with chemical signals.

Ecologies differ by level of scale

frame	abiotic frame	grain	biotic components	ecologies
R kilometres radius (nominal)				
10000	earth	3000	biomen	Geography
1000	continent	300	areas of vegetation	
100	geomorphological unit	30	flora-counties	
10	landscape	3	formations	landscape ecology
metres				
1000	hydrological unit, biotope	300	communities	synecology
100	soil complex, ecotope	30	ecological groups	systems ecology
10	soil unit, boundaries	3	symbiosis and competition	cybernetic ecology
millimetres				
1000	soil structure and ~profile	300	individual survival strategies	autecology
100	coarse gravel	30	specialization	biology
10	gravel	3	integration	
1	coarse sand 0.21-2	0,3	differentiation	
micrometres (µ)				
100	fine sand 50-210	30	multi-celled organisms	microbiology
10	silt 2-50	3	single-celled organisms	
1	clay parts <2	0,3	bacteria	biochemistry
0,1	molecule	0,3	virus	



303 Different ecologies at different levels of scale and resolution

‘Local characteristics such as soil, temperature and precipitation enable a vegetation on which a local food pyramid of organisms may develop. Its ‘habitat’ may be studied at many levels of scale (‘frames’) with each a determined resolution (‘grains’). **Fig.303** expresses a frame by its ‘nominal radius’ R, its grain by $r \approx R/3$. ‘Nominal’ R is something between R/10 and 10*R.

So, geography may study the living Earth R=10000km divided in biomens’ R=3000km.^b

‘Synecology’ studies 'biotopes' R=1km with components called 'communities' R=300m.^c

‘Autecology’ studies the environment R=1m of individuals r=0.3m, for example their strategy for survival as 'ruderal', 'competitor' or 'stress-tolerator' ^d.

The combination of factors at all of these levels creates an unimaginable biodiversity.

^a https://nl.wikipedia.org/wiki/Concentratiegradi%C3%ABnt#Ori.C3. ABntatie_in_een_concentratiegradi.C3. ABnt

^b <https://en.wikipedia.org/wiki/Biome>

^c For The Netherlands see **Weeda(2000)**

^d **Grime(1989)** distinguishes 'rapid growth, reproduction and clearing the field' ('ruderals'), 'slowly building up capital to overshadow neighbors and then propagate' ('competitors') and 'specialize in locations where others cannot survive' ('stress tolerators'). The latter category can survive extreme temperatures, nitrogen shortages or long periods of drought. Grime quantifies the proportion of these three categories per species. This also means the conditions that characterize the environment for the applicants.

Biodiversity is a risk coverage for life

The rapidly declining biodiversity may entail the risk that crucial signals and nutrients will disappear from the biosphere, resulting in unrestrained disasters. Unlikely small quantities may be decisive. These easily may escape our attention, leaving us unaware of the effect.

Before we have sufficiently understood these ecological relations, scientific modesty and restraint in generalizing conclusions is appropriate. About 1.5 million species are known and described, but there may be ten times more still unknown or undescribed species.

In order to understand the operating of one single species (humans), we need over 30 different medical disciplines, but our knowledge about how the human body and mind work is still limited.

Moreover, within a species each specimen is different and reacts differently on environmental factors (signalling substances, medicines). In order to complicate matters further scientifically, each copy ends up in a different context. Generalization then is tricky.

EVOLUTION SELECTS BY ERRORS

Without mutations, there would have been no evolution: we humans would not exist. The mutation rate of genomes is estimated to be 10^{-10} per base pair per cell division.^a A mutation may be harmful, harmless or advantageous for survival, but that effect may be different in different environments.

Evolution by such rarely successful events, combined with the subsequent selection by different environments cannot be understood by generalizing with statistical means. At every point in the evolution it could have been very different with minimal changes in mutation and environment. There are countless other evolutions imaginable.

The chance is little, but the number of chances is large

A successful mutation is improbable, but the number of cells, environments and their combination is unimaginably large.

An environment in which any metabolism can emerge spontaneously, does not guarantee that it will happen within a foreseeable future (despite Murphy's law). It is even not certain, if such an environment somewhere on earth remains long enough the same as a stable laboratory for the observation of a very rare event.

It is, however, imaginable that a stable gradient of environments has existed around volcanoes everywhere on the ocean floors, as long as the earth's crust still has been thin and breakable.

Suppose that 'laboratory setups' of $0.3\mu\text{m}$ (the size of a small cell) in the oceans were distributed over 1,338 billion km^3 of water (the amount that is still present on earth), then there were 10^{37} testlocations. If only one billionth of them had a suitable environment for a 1 second reaction, then on earth there were still 10^{28} reactions *possible* per second, or $3 \cdot 10^{36}$ per year.^b

If only one billionth of them yields a suitable organic molecule, then there are still $3 \cdot 10^{27}$ organic molecules that could be composed. The probability that 1000 molecules of that $3 \cdot 10^{27}$ coincidentally are the right combination for the formation of a primitive organism in a billion years is difficult to calculate, but that coincidence is conceivable.

On an even smaller scale you also may imagine the possibility of emerging larger molecules. Two particles flying towards each other, result in collision or passing each other. In case of pure repulsion, both result in divergent movements, increasing entropy, but if they collide, then the particles may break into smaller pieces and reconnect to larger ones.

^a Baer;Miyamoto;Denver(2007)

^b Shapiro(1986), calculates the number of proteins composed during the Earth's existence as 10^{51} .

The emergence of larger molecules enables an origin of life. We may suppose a sequence from primitive to complex. We can date specimens found in the soil and compare their content, shape, structure, their DNA sequences, and conclude dated mutations. Then, an evolutionary history can be reconstructed into phylogenetic relationships, a tree-like structure (**Fig.301**p162).

In the development of similar *forms* and *structures* we see separate organelles and organs appear, of which we then may reconstruct the *function*, based on the experience with actually living organisms, which we consider as a temporary end point.

Nevertheless, the tree structure with vertical branches is not the whole story, because there are genes that have been exchanged (extra-chromosally), 'horizontally', between the branches outside the DNA of the chromosomes.

Plastids or whole bacteria that entered a cell became indispensable for its evolution. They reproduce on their own authority. For example, in a branch suddenly complicated organelles from another branch can appear that cannot be inherited from their own ancestors.

The trunk is now LUCA, but we cannot reconstruct the roots.
We can only reconstruct them in different supposed environments.

§ 37 BIOTICS ARE BUILT ON SUPPOSITIONS

Biotics suppose (↓) different differences at different *levels of scale*:

different molecules with different behaviour, coherence, ability to separate and to combine;
different cells with different behaviour, coherence, ability to separate and to combine;
different organisms with different behaviour, coherence, ability to separate and to combine.

Any level of scale has a different vocabulary and its own route on the staircase of **Fig. 15**p14.

[Lavoisier\(1789\)](#) [1](#), [2](#) distinguished 30 unseparable *elements*, combinable in *molecules*.^a

[Hooke\(1665\)](#) observed *cells*, Leeuwenhoek(1670s–1680s)^b observed their difference.

[Linnaeus\(1753, 1785\)](#) distinguished about 7000 plants and 5400 animals (*organisms*) by name.

If ‘**difference**’ has a different content in biochemistry, cell biology and organismal biology, then their next suppositions (↑ change, ↑ object, ↑ separation, ...) also will have a different content. Like ‘difference’, also ‘**change**’ is sensitive to scale. Studying changes in organisms over hours (embryology) is a different discipline than studying changes over millions of years (evolution).

An **object** such as an ‘organism’ resists changes in its environment, keeping its own dynamics. That enables to imagine (↑) values of **separation** (including zero: connection) of the organism, outward from its environment and inward (division) into parts (organs) enabling a **combination**. A similar stacking of suppositions applies at other levels of scale such as of cells and molecules.

BIOCHEMISTRY

If ‘large supposes small’ (p57), then organisms ↓ cells ↓ molecules.

That is why this chapter started by biochemistry (↑ cell biology ↑ organismal biology). And chemistry supposes **different** substances, their behaviour (**change**) and coherence (as **objects**).^c

^a Lavoisier also replaced phlogiston theory by an oxidation theory of combustion, while still explaining heat as a material substance (caloric). Heat has been recognized later as motion by Rumford(1798).

^b See [Dobell\(1932\)](#) and [Delft\(2022\)](#)

^c [Helmont\(1648\)](#) demonstrated that plant mass comes mainly from water, not soil (precursor to photosynthesis understanding). [Priestley\(1777\)](#) showed that plants release a substance (now known as oxygen) that supports animal life. [Ingenhousz\(1779\)](#) demonstrated that plants produce oxygen only in sunlight and only by their green parts. [Senebier\(1800\)](#) Proved that carbon dioxide is taken in by plants and is necessary for photosynthesis. [Saussure\(1804\)](#) showed water is also involved and confirmed mass balance. [Sachs\(1868\)](#) identified chlorophyll as the site of photosynthesis and starch as a product. [Niel\(1931\)](#) generalized photosynthesis as $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$. [Calvin c.s.\(1950-1957\)](#) elucidated the Calvin cycle, the dark reactions of photosynthesis, in multiple articles.

The greatest achievement of chemistry is not combining, but **separating**^a substances. After the separations of Lavoisier(1789), [Mendeleev\(1870\)](#)^b completed his table of elements. Lavoisier enabled a century of inventing **combinations** found in biotic substances.^c

The *in vitro* synthesis and breakdown of these substances for their determination already involved a simple form of **metabolism** (with varying inputs and outputs) through chemical instruments. Justus Liebig(1837) founded modern biochemistry inventing many of the necessary instruments and important applications.^d

However, their metabolism *in vivo* required the unraveling of complex chemical pathways **regulated** by enzymes^e and **organized** by RNA^f in separate **specialized** locations, finally enabling **reproduction** of species by a complete set of instructions within any cell: DNA.^g

CELL BIOLOGY

A cell as an **object** resists disturbing external changes through a **separating** enclosure.^h Eukaryotic cells also **separate** (divide) their *interior* into different compartments. This enables to **combine** functions that require different environments within a cell.ⁱ

The external and internal functions of a cell have an input and a different output (**metabolism**). Their production and mutual exchange is **regulated** by templates produced in the cell nucleus and sent out when signals of a local shortage arrive. Regulation *enables* **organization**, but its final complexity also *supposes* an organization *inherited* from earlier developments.

The logic of regulation \uparrow organization \uparrow specialization \uparrow reproduction remains valid in a cyclic evolution of their *increases*: Δ regulation \uparrow Δ organization \uparrow Δ specialization \uparrow Δ reproduction. That leaves the question of the first cell, reproducing itself without any heritage of biotic conditions. The answer could be found in rare abiotic conditions finally enabling reproduction.

Abiotic *gradients* and *fluctuations* offer a great variety of *environments* and *stages*, occasionally offering the right conditions for chemical **separation** \uparrow **combination** \uparrow **metabolisms**, **regulated**, **organized** and **specialized** (as still observed in layers of ‘microbial mats’ p153). The **reproduction** of single cells is still internal separation (division) without combination.

A single cell can survive in specific environments for which its nucleus provides templates. A cell may increase its adaptability in combinations with other cell specialists.

^a Stevin(1580) invented the Dutch word for chemistry: ‘scheikunde’: the art of **separation**. And indeed, mixing is easy, but the art is to separate.

^b Mendeleev published the periodic table of elements in 1869 shortly before simultaneous inventor Lothar Meyer did.

^c E.g.: [Vauquelin;Robiquet\(1806\)](#) found asparagine, [Braconnot\(1820\)](#) glycine, [Chevreul \(1823\)](#) esters, [Paven;Persoz\(1833\)](#) starch, [Dumas;Péligot\(1834\)](#) ether, [Liebig\(1835\)](#) aldehyde, Berzelius(1838), [Mulder\(1838\)](#) protein, [Gerhardt\(1844\)](#) amide, [Wurtz\(1847\)](#), [Hofmann\(1865\)](#) amine, [Gmelin\(1848\)](#) ketone, [Lippmann\(1895\)](#) sugars, [Fischer\(1899-1906\)](#) amino acids, polypeptide, protein.

^d See [Liebig;Playfair ed\(1842\)](#).

^e [Paven;Persoz\(1833\)](#) reported the first experimental evidence of enzyme activity of amylase, the first enzyme ever discovered. [Pasteur\(1857\)](#) demonstrated that fermentation was due to the action of living microorganisms. [Buchner\(1897\)](#) showed that cell-free extracts of yeast (Zymase) could ferment sugar outside living cells, refuting Pasteur’s microorganisms. [Sumner\(1926\)](#) proved that enzymes are proteins and shared the Nobel Prize 1946 with Northrop;Stanley(1930s) who crystallized enzymes showing molecular structures (multiple papers in Journal of General Physiology and Journal of Biological Chemistry).

^f [Brenner;Meselson \(1961\)](#), [Jacob;Monod\(1961\)](#), [Palade\(1955\)](#) related the ribosome to protein synthesis. Nobel prize(1974).

[Zamecnik;Hoagland\(1956\)](#) found RNA and amino acids involved. [Siekevitz;Palade \(1958\)](#) found biochemical evidence.

^g [Miescher\(1871\)](#) isolated ‘nuclein’ (later identified as DNA), see [Byrne and Dahm\(2019\)](#).

[Kossel](#) isolated Guanine(1881), Adenine(1885), Cytosine(1894), Thymine, Uracil (early 1900s). [Levene and Jacobs\(1919\)](#) supposed a string of them, see [Hargittai\(2009\)](#). [Chargaff cs\(1950\)](#) and [Chargaff \(1952\)](#) hinted base-pairing rules, see [Chargaff’s legacy](#).

[Watson and Crick\(1953\)](#) finally found the double helix structure and base pairing of DNA.

^h [Overton\(1896\)](#) suspected lipidoid cell walls. [Gorter;Grendel \(1925\)](#) proposed the lipid bilayer model. By extracting lipids from red blood cells and measuring surface area, they proposed that the membrane consists of a bilayer of lipids. [Danielli;Davson\(1935\)](#) proposed the protein-lipid-protein sandwich model, and suggested proteins coat both sides of the lipid bilayer, forming a stable structure. [Singer;Nicolson \(1972\)](#) described the membrane as a dynamic structure with proteins embedded in or attached to a bilayer of lipids.

ⁱ [Köllicker\(1857\)](#) separated mitochondria from a cell structure. [Altmann\(1890\)](#) observed ‘bioblasts’ (later identified as mitochondria).

[Benda\(1898\)](#) coined the name mitochondrion, but supposed individual cells within cells. [Lohmann\(1929\)](#) found ATP and three phosphate groups involved in energy transfer. [Lipmann\(1941\)](#) linked ATP/ADP to metabolic energy transfer. [Kalckar\(1941\)](#) created a unified theory of biological energy metabolism. [Claude\(1946\)](#) studied the chemical composition, [Palade\(1952\)](#) visualised it. Mitchell(1961) modelled ATP synthesis. Nobelprize(1978)

BIOLOGY OF ORGANISMS

Similar to cells, a multicellular organism as a coherent **object** resists ('survives') disturbing external **changes** by external and internal **separation** (protective skin and separated organs). The diversity of multicellular organisms has been developed in millions of years (evolution)^a. The internal differentiation of an organism (embryogenesis) takes seconds to months.

Evolution supposes many reproductions and a limited lifespan, enabling some fittest to survive. Embryogenesis supposes reproduction by **division** of cells, evolution by **combination**^b. Division diversifies cells little, sexual reproduction more by countless possible combinations. Both reproductions diversify by mutations and by adaptation to different environments.

Gradients^c offer an infinite variety of environments for diverse organisms and cells. The greater diversity of organisms, the fitter adaptations to different environments (niches). The greater a genetic potential of cells, the better they specialize *within* an embryo. The task of the genetically equivalent cells in an organism is a specific **metabolism**.

Within an embryo, metabolisms enable gradients, in turn **regulating** the metabolisms. The location in a gradient determines which parts of the genetic potential are switched on or off. If diffusion between cells becomes insufficient, some cells elongate to tubes. Regulation ↑ **organization**, a coherent exchange of matter and information between cells.

Organization ↑ **specialization** of organs with a specific metabolism of input → output. For example, the intestinal tract: matter → different matter, a **reproductive** organ: matter+own tissue → clone, or matter+gametes → zygote ↑ embryo, a neural system: impression → expression.

The impression may be sensory or combined information, the expression a trigger to action. That action may be a muscular re-action or a co-action in the neural system (**imagination**). Imagination ↑ a metabolism of impressions into neural **concepts**. Concepts ↑ **reproduction** of impressions.

Specialization *within* a species into male and female ↑ *diversifies* reproduction of organisms. Specialization *between* species ↑ symbiotic or competitive interactions (ecology). At that higher level of scale populations again metabolize, regulate, organize and specialize. A human population metabolizes itself (reproduction and education) and its environment.

^a [Darwin\(1859\)](#) established evolutionary biology with the concept of selection by survival of the fittest.

^b [Mendel\(1865\)](#) long unnoticed but rediscovered around 1900, translated as [Mendel\(1865\)](#), founding the current science of genetics.

Wall(2016) describes the quest of 88 years to translate the foundational laws of Mendel into a chemical model.

^c Including fluctuations as gradients in time. The diversity of environments includes a diversity of stages.

7. CULTURE SUPPOSES A SET OF SHARED SUPPOSITIONS

§ 38	Culture has tacit suppositions	170
	Culture includes suppositions about abiotic and biotic conditions	170
	Hunter-collectors map their space, farmers their time	170
	A commercial-industrial culture maps time <i>and</i> space	172
§ 39	'Culture' varies across levels of scale	174
§ 40	Art changes suppositions (conditions of imagination)	176

This chapter studies culture as a consequence of human imagination, enabled by suppositions. Culture is designed, invented by man. It covers a broader field than actual reality or possibility. Culture enables *and* limits imagination by experimental and traditional suppositions. It offers techniques of adaptation and accommodation in order to survive.

Cultures **differ** across abiotic, biotic, and social environments. They differ in climate, soil, available resources, and opportunities for exchange. Coastal cultures differ from inland cultures. They differ in scale. A local culture differs from a national culture. They differ at home, in traffic, at work, in different social circles, and in different locations. They differ in suppositions.

Cultures **change**. Their suppositions change. Some suppositions change little, such as many certainties in current science. Other suppositions change drastically by inventions. The most influential inventions led to agricultural (neolithic) and industrial revolutions. They continue to leave their mark in the diversity of cultures even today. What are those marks?

I didn't yet find them in the existing literature, but I recognized them in my own observation of the differences between Indian and Creole villages and their inhabitants in Surinam around 1970. I assumed a recent hunter-gatherer past among the native Indian people and a centuries-old agricultural background among the Creoles deported from Africa.

Among the Indian people, there was no observable greeting or farewell, but there was not any reluctance upon meeting them. They could tell me all about the surrounding area, but not how old their village was. They gave me a beautifully decorated boat without reservation or agreement, and after the handover, they turned away without seeing how I would handle it.

They seemed unconcerned about whether or when I would return the boat. Did time play no role for them? Did "property" have so little meaning to them?

The Creoles greeted me enthusiastically, knew the history of their village, their property and said their goodbyes at length. They invited me to the meal, planned to prepare it and, upon my departure, asked when I would return. Concerns about ancestors, life and death preoccupied them more than what the Indians seemed to realize about their past and future.

This final chapter is an attempt to give the concept of 'culture' a coherent follow-up to the previous chapters, starting from these simple observations.

§ 38 CULTURE HAS TACIT SUPPOSITIONS

CULTURE INCLUDES SUPPOSITIONS ABOUT ABIOTIC AND BIOTIC CONDITIONS

'Culture', defined as 'a set of shared suppositions' includes the 'norms and values' in cultural anthropology^a and sociology^b, but it also includes inherited abiotic and biotic conditions, techniques and economics^c, tacitly experienced as self-evident, but recognized in archeology.

The archeologist should be able to distinguish human remains from anything else. A wooden pole or a flint should show signs of human *technique*, indicating their use in a specific abiotic, biotic and economic past context. Geology may reveal details about the abiotic context. Ecology may reveal a biotic context enabling human livelihoods and possible economies.

Plants cannot move. A plant is bound to its specific environment.

It has genetic *recipes* to survive limited fluctuations in that environment ('ecological tolerance'). Its cells receive signals (p160) by which they choose the recipe from their genetic library for appropriate adaptation, but not from a shared culture beyond the inherited recipes.

Animals can move. They can search for an environment in which the ingredients to fulfill their specific needs are available. They have advanced organs to receive rapidly changing information and to respond conformingly. They react on external signals through movement, sound or smell. What you might call their 'culture' is an adoption of the behavior of relatives.

People and some animals, however, do have the ability to supplement their genetic recipes with transferable technical means, in order to *adapt* themselves to the environment or even to *accommodate* that environment to their own needs. With their more developed technical means, humans create material conditions to survive differently in different environments.

The skill ('*technè*' in Greek) to **imagine** a 'means' between a need and its fulfillment requires the ability to imagine that means between two objects (three in one image: §2p5), before it may be realised. That imagination then can be extended by many previously learned or developed (often unspoken) *suppositions*, built up gradually in a *conditional* sequence (education).

Transferring the suppositions of a culture to the newcomers is a first condition of culture itself. It requires individual conceptual abilities, techniques (manipulating, walking, speaking, listening, reading, writing, applying), before norms and values can be learned.

HUNTER-COLLECTORS MAP THEIR SPACE, FARMERS THEIR TIME

No culture may survive without an economic basis. That basis has been hunting and gathering for millions of years. Some 10 000 years ago, however, the invention of agriculture gradually drastically changed the recourses, technology, economy and culture.

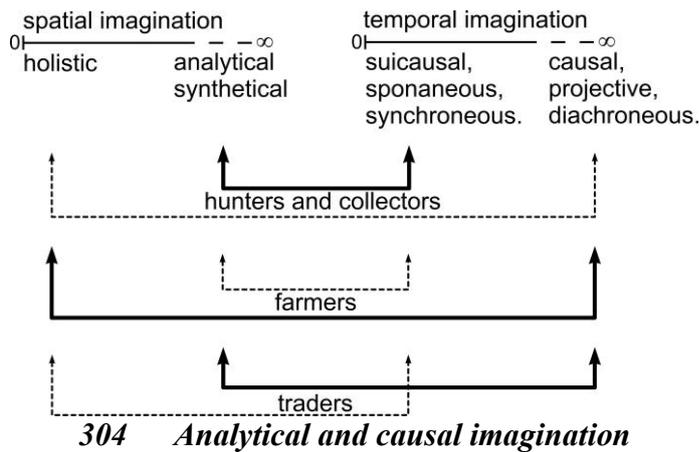
The sedentary way of life of agriculture required more planning (mapping time) for sowing, harvesting, animal husbandry and defence than wandering, hunting, and gathering.

The land was brought 'in culture' and regarded as occupied property (territory). It was more closed off from an otherwise little known 'barbarian' outside world.

^a Levi-Strauss(1955), Mead(1959), or Grottanelli ed(1965), give mostly separate descriptions of different cultures ('ideographic'), albeit sometimes per theme. Levi-Strauss(1962) then interprets 'culture' as a collection of unconsciously applied social rules such as the common incest prohibition ('structuralism', 'structuralist anthropology'). Kloos(1972) already has a more materialistic basis. Diamond(1997) is, however, a more recent example of ecological-cultural anthropology, which beautifully explains the environment and technology as a practical condition for still very different cultures.

^b Doorn(1969) for example, follows Durkheim's rule that social phenomena can only be explained by other social phenomena. I do not share that circular view, as well as the linguistic limitation of language philosophy: Boomkens(2011) p209 and the limitation to an upperclass of Elias(1939).

^c Daryll Forde(1934), already suggested in his title (according to me rightly) a conditional sequence. His 'ecological anthropology' sets the material ('habitat') and technical conditions first, as preconditions for divergent human cultures without becoming deterministic. Gurvitch(1967) has more attention to material, technical and economic conditions than usual sociology. History is rewritten in this sense by Frankopan(2023).



The division of extended *space* ($R=10\text{km}$) and a distinction of places (mapping space) is more relevant for hunter-gatherers than for sedentary farmers. Let me call that focus 'analytical', and its zero-point 'holistic'.

Farmers occupying a limited space ($R=0.3\text{km}$) focus on a division of *time* and a distinction of periods for sowing and harvesting (mapping time). Let me call that focus 'causal' and its zero-point 'sui-causal'.

The 'holistic-causal' farmers have little interest in different spaces beyond their property. Their imagination of territory is 'holistic'. The analytic-suicausal focus of hunter-gatherers keeps a subordinate role beyond everyday practice (dotted line in *Fig. 304*).

That 'counterculture'^a remains active in free time and as a domain of artists and priests.

The 'analytical' hunter-gatherers, having little interest in time, take time as 'sui-causal'. For them, a causal-holistic counterculture is left to medicine men who may exorcise spirits.

In the annual flooding Nile delta of ancient Egypt, the land covered with divinely fertile sediment had to be allocated, mapped and divided every year.

The farmers did not do that themselves. They leaved it to the surveyors of the godly Pharaoh. That counterculture is more reminiscent of the fighters, hunters and collectors.

The most recent commercial-industrial culture divides its space *and* time (analytical-causal), keeping a holistic-suicausal, counterculture.

These three ideal typical cultures are reminiscent of Michelsons^b 'lifestyles' in the urban environment: 'consumers', 'familists', 'careerists', or to the three survival strategies of plants at Grime (note c p164): 'grow fast, reproduce and clear the field' ('ruderals'), 'slowly build up capital to overshadow the neighbors and then reproduce' ('competitors') and 'specialize in locations where others cannot survive' ('stress tolerators').

The origin of western civilization is generally situated in ancient Greece. Its large coastal length, made the trade culture everywhere contrasting with relics of the original cultures in the interior. Harvest festivals then have provided an annual confrontation between farmers in the interior and traders at the coast (§ 13p33).

The source of religion is mourning

For the ideal-typical hunter-gatherer, the deceased are good and evil spirits, still wandering around or taking place in physically present plants, animals or people. Only the medicine man knows their origins and may provide a good relationship with them by magic.

Killing or eating 'inspired' animals may have a sacred meaning to nourish the deceased or to incorporate their abilities for oneself.

The scarab is an example of worship in ancient agricultural Egypt as a result of assumed divine spontaneous generation. Gods have no cause, they are their own cause ('sui causa').

That this beetle also lays eggs went unnoticed.

^a 'Counterculture' is a term borrowed from Roszak(1968) He describes how (in the 1960s) such 'counterculture' could rebel.

^b Michelson(1970)

For the ideal-typical farmer, plants, animals and people are in a causal time series of ancestors (the biblical genealogies), but these must have begun suicausal.

The deceased then move to that timeless space without cause and effect ('eternity').

Religion plays a role in almost all cultures. Why?

It cannot be explained solely by conceptual representations mentioned above.

The loss of parents will affect almost every individual in every culture.

This is particularly drastic in times when parents died young and left young children.

Religion then is the denial that accompanies a grieving process: the comforting continuation of the life of ancestors in nature or in eternity.

It may explain the emphasis on guilt: 'Our Father, forgive us our trespasses'.

Sedentary agriculture enables the exchange of surpluses, products, and thus trade with an increasing role for reliable, precise *calculation* and recording, *writing*.

A COMMERCIAL-INDUSTRIAL CULTURE MAPS TIME AND SPACE

The final commercial-industrial culture combines the classifying ability from both original cultures. This way of life requires a development of an analytical-causal 'if I buy this *here now*, then I will be able to sell it with a profit *there later on*'.

The holistic-suicausal couterculture is still recognizable in current religious practices.

The role of *miracles* (magic) as a counterculture of causally compelling daily life, *praying* as talking with your deceased (for)fathers or their union in one God the Father, the *sacrifice* that repays them or Him, the *Communion* as a physical union of God's Son within yourself.

Monotheism (one All-father) ended conflicts between tribes, each with their own primal father. New wars arose when spokesmen of the common God themselves were given a sacred status with interpreting and regulating authority (Catholics, Shiites). If that authority is challenged, a conflict arises with those who appeal to the original sources (Protestants, Sunnites).

Identity is difference with the rest and stability in itself

The properties of an individual or a community are combined in a unique *identity*^a.

Individual identity is evident in a small community (say 30 people).

There are sufficient differences between origin, age, gender, appearance, behavior and property to be able to 'place' and distinguish somebody.

Identity enables to divide tasks according to each others abilities (specialization).

In addition, a common living space offers the individual also a *group identity*, different from that of other families, tribes or communities. Identity has different levels of scale.

Mobile hunter-gatherers live in a wide *space* (R = 10km) in which they have to know the way. Within the agricultural, smaller, isolated, uncluttered habitat of the occupied or inherited land (R = 300m) and the own 'property' acquired therein. There was more need for *time* division: a representation of seasons, storage for times of scarcity^b, a known past and a desirable future.

Between the two 'original cultures', you could expect a preferred development of either *spatial* or *temporal* imagination (**Fig. 304**), a different acquired capacity for *overview* or *foresight*.

By higher densities, a commercial-industrial culture splits identity

In a large, crowded, mobile population, that individual identity is split into different *roles* in different groups with different subcultures of living, working, learning or recreating together.

^a I associate "I" with a continuously repeated neural cycle (p50) with a consecutive set of suppositions of the self-image around a virtual point in which all subjective perspectives come together (p153).

^b This is especially true for seasonal grain harvests. In tropical conditions, many crops can be harvested all year round, but droughts may work as seasons.

Private ownership takes on the meaning of a mobile territory (prestige, authority)^a. Identification with self-chosen idols reduces your own place in time and space, descent and origin, to an administrative identity. A police officer asks 'name and address, please'. That may be interpreted as descend and provenance, determination in time and space.

Migrants with an agricultural background are miserable, 'elend'^b, 'out of the land' in an as yet unintelligible, barbarian world. Without your own ancestral origin (family) or place (land), your own ancestral culture remains the only anchorage, a ground of group identity, a territory.

Forced 'integration' then is destruction of identity, a territory to be recaptured. Assimilation then is primarily regaining identity.

An undermined self-image cannot do more than searching for a group identity, a supposed *own* culture, justifying to conquer your place instead of being nobody. Within the current commercial-industrial culture itself, there are similar identity-seeking remains from primordial cultures with a prehistoric tribal bond ('blood and soil').

Following the example of their idols (for example the scoundrels in the parliament), they sow hatred against the new competitors, harvesting hate the reverse. Ascending conflicts set the clock back, but these help *their* lost identity in the saddle.^c

This two-sided resurrected prehistoric relic refers to the dramatic transition from a more than 3 000 000 year long hunter-gatherer living into an agricultural existence ('neolithic revolution', some 10 000 years ago) and the resulting commercial-industrial culture in which the small communities dissolved. That period covers less than 1% of human evolution.

In such a short time the human nature has not yet been fully adapted to those revolutions.

Written words extend memory

The revolutionary invention of writing, probably made a great impression at the time. The people went, the written words remained. The ideas behind those words seemed to lead a life of their own. They became 'flesh' in anyone reading them.

This undeniable repetition of ideas without humans gave written words something superhuman. What had been written from time immemorial seemed to be the evidence of ideas as an immortal higher reality preceding mankind.^d

Surviving ideas

A predecessor of that belief is, that human spirits being freed from a body by death, can stay alive as good or evil spirits. An agricultural ('neolithic') variant is, that unconsciously sleeping ideas are passed on to future generations as seed, once awakening somewhere if they fall in good soil.

Failing mortals then may at least gain comfort and hope from their descendants.

These in turn are loaded with expectations and written prophecies from their ancestors.

^a [Jong\(1978\)](#).

^b The etymology of the German (and Dutch) word 'Elend' (miserable) is 'out of land'.

^c Identity, for example, also plays an important role in [Elias\(1965\)](#)

^d [Kraak\(2006\)](#), argues that the writing does not follow your thoughts as is generally assumed ('display myth'). Your thoughts follow the way you can write them down. We have become 'literate' at school.

I do not share his claim that the alphabet is not based on sound reproduction, but that our thinking is forced into a straitjacket as soon as we learn to read and write in lines and rules, seems plausible to me. It is the straitjacket of verbs that require an actor and a causal result. There is little room for the *conditions* of action, the context, the image that you cannot describe as an action. However, precisely that context is the object of spatial *design*.

That does not mean, of course, that this limited way of thinking has not yielded impressive results from the Old Greeks onward. The invention of writing is in that light an unrivaled human achievement and a revolution, but through its success it has obstructed other parts of our imagination.

§ 39 'CULTURE' VARIES ACROSS LEVELS OF SCALE

'Culture' has a different meaning in 10m, 30m, 100m ... 1000km nominal radius (R)

A family culture (R=10m) differs from a continental culture (R=1000km). You may check to what extent the smaller is part of the larger, and derive conditions from it. A family counts on a national defense, legal protection and a technical infrastructure on a larger scale. An urban culture supposes a commercial-industrial culture *including* the nurturing by rural cultures.

Culture fluctuates in decades between traditional and experimental

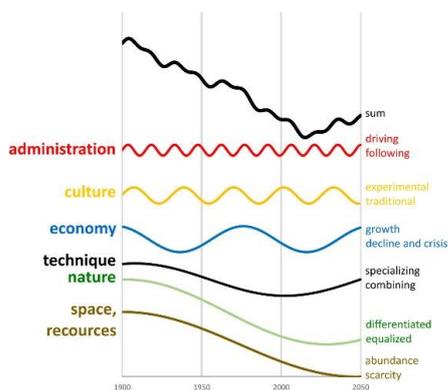
The transfer of culture ('tradition') to a child stumbles after about 15 years on a natural resistance that partly reverses existing standards and makes generations^a different.

This may result in a synchronous cultural wave with a period of about 15 years (especially with a baby boom or a large-scale migration).^b If the next puberty neutralizes the previous, the values of the generation before those of the educators (grandparents or ancestors) may return.

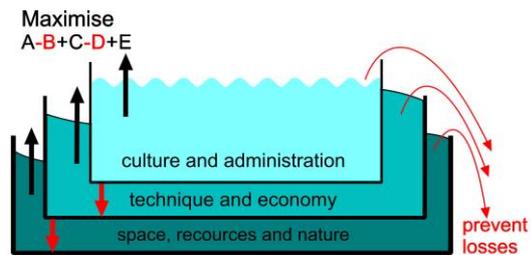
The roughest extremes that can be distinguished in such a cultural phase change is a transition from 'traditional' to 'experimental' and vice versa (*Fig.305*).

The associated administrative context layer varies with the shift in forms of government between 'following' and 'directing'.

Culture itself goes up and down with economic waves of growth and crisis. Economic decline brings war, migrations, birth waves and innovations, but also a rise of conservatism.



305 Fluctuating context layers^c



- A Increase carrying capacity (more and heavier ecologic capital)
- B Decrease economic pressure (decoupling)
- C Increase economic carrying capacity (economic capital)
- D Decrease social pressure (social effectivity)
- E Increase social carrying capacity (social capital)

306 Context: pressure and carrying capacity

The governance and science that underlies and produces it involves long periods of **specialist** innovation on the order of a century (for example, until 1960), followed by a period of careful **combination** in commercial applications such as the smartphone.

But one day one will have to return to the *specializations* in order to be able to cope with the decline of nature from which one alienates, and the exhaustion of raw materials.

The sum of all wave movements ('zeitgeist') moves and depends strongly on the influence (the amplitude) that you assume for each context layer.

The technique, the technè, the design, is an underestimated driving force in history.

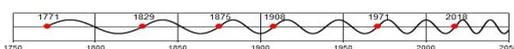
Its influence is only surpassed by the decline of our abiotic and biotic basis (*Fig.305*).

Fig.306 symbolizes their finite carrying capacity under the pressure of shaky containers with increasingly lighter liquids.

^a Becker(1992) distinguishes for example generations born between 1910-1920, 1930-1940, 1940-1955, 1955-1970.

^b Roszak(1968) describes the protest generation after WWII of the 1960s.

^c with variations such as the Schumpeter-Freeman-Perez paradigm for the economy:



Elements of culture are once designed

Designs *make* the difference of cultures. Language, agriculture and means of transport are *invented*, and changed the culture. Elements of science and humanities are *invented*, enabling the industrial revolution, causing a culture of separated production and consumption. An industrial culture is still causal-analytic, with a suicausal-holistic counter-culture.

Innovative design changes culture by replacing common suppositions, but a design cannot neglect some scientific suppositions to make its realisation *possible*.

I use the staircase of suppositions (**Fig. 15p14**) that I proposed in order to classify some elements of culture as *realisable* designs.

Every language, counting, cooking, administration, governance, education, mathematical formula, scientific research, scientific experiment, report, construction of an argument, telling a story, reconstructing history, requires a strict sequence of actions, words, numbers or operations.

Culture is mobile and vulnerable

The movement of **Fig.305p174** is still a coarse simplification of the wave ridges that come rolling up from all directions. Crossing each other (interference) they form a chaotic moving landscape with changing images that mutually look different from each own position.

Every culture is also vulnerable by the possibly lacking conditions bearing it (**Fig.306p174**). Some forms of increasing scarcity can no longer be solved by technology.

Poverty is confronted daily with those conditions and their scarcity.

It becomes out of the picture in a culture with growing prosperity supposing 'The technology has solved everything so far and it will also solve new problems.'

The horizon of risks you can oversee becomes smaller.

Insurers are selling fear and you should not think of a failed electricity or water supply, your car stopping on the highway without quick help, or the wine will be up tonight.

Half of your income is spent on securing your future: army, police, a legal system, pension, health insurance, ensuring home and household defects.

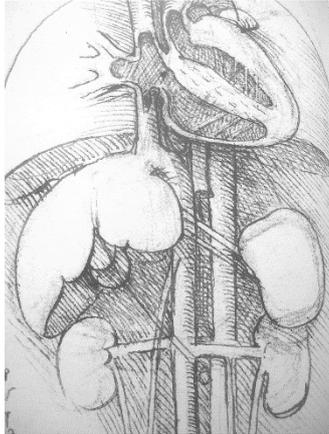
The remaining saldo on the bank can be hacked or reduced due to inflation or a crisis.

For all that you have spent hours every day, building up the stress that undermines physical resistance for escape or fight (only allowed after working hours and compensated in holidays, sports or crime). This culture-pessimistic image of an industrial-commercial society individualizes its members within their own hard-won and secured house with safe friends.

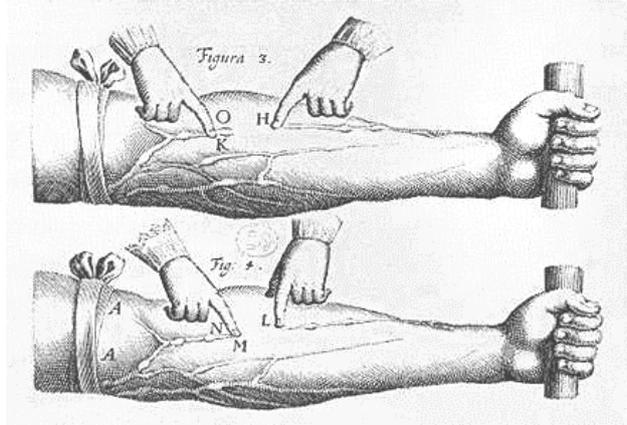
At another level of scale it is the call for walls around the nation: 'own people first'.

Newspapers and internet select what its readers want to read and readers in turn deny what they do not want to read. This way every period in history creates its own history.

§ 40 ART CHANGES SUPPOSITIONS (CONDITIONS OF IMAGINATION)



307 Leonardo da Vinci's drawing of the heart in 1509^a



308 Proof of blood circulation through Harvey in 1628^b

The precise anatomical drawings of Leonardo da Vinci (**Fig.307**) show the way in which artistic imagination can shift boundaries in a scientific representation.

Leonardo and Vesalius had to observe carefully and to draw the anatomy first before Harvey (**Fig.308**) could imagine a circulatory system and then prove how it works.

Visual arts, poetry or music shift the boundaries of your imagination with images, words or sounds.^c They not only bring about the enthusiasm^d or even ecstasy ('ek-stasis'), which we experience with 'beauty', but also the ex-sistential (out-standing) experience by which you step out of the boring or chaotic daily life for a moment.

Since the invention of photography overloaded us with realistic images, we stepped aside to non-figuration after impressionism and expressionism. That is also a kind of withdrawal.

Poetry frees you from the boundaries of everyday linear language and shifts your imagination with metaphors connecting chaotic and rationally experiences, with or without rhythm and rhyme. Rhythm and measure (rap) creates a bridge to the music.

In music, recognition and surprise alternate as themes and variations (**Fig.309**p177).

The compositions as a whole mutually vary between the rare extremes from monotone to chaotic, more or less restrained by rhythm and measure.

The *order* of sounds ('melody') settles remarkably easily in the memory, even if it fuses in fugues, or if the key changes. This sensitivity to sequence indicates an important neural capacity, reminding to that of complex muscular action for any simple movement (dance).

These are parts of the artistic-religious *counterculture*, a counterweight to monotony or chaos in everyday routine of production and consumption.

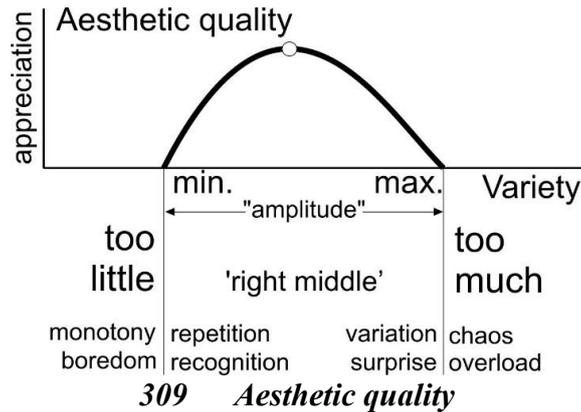
^a Zöllner(2016) p446-448

^b Harvey(1628) p28a

^c A verbal definition of 'art' does not show what it *is*, but what it *does*.

^d 'Enthusiasm' is originally Greek for 'the god entering' and 'ecstasy' for 'step out', apparently out of yourself.

They were probably both experienced in the Bacchus cult. The Latin equivalent for 'step out' (ex sistere), is literally the same, but probably has a very different emotional value, connected with 'birth' and 'existence'.



You cannot perceive, choose or think without a difference.^a

Difference appears in the senses, equality in the mind. Creating a piece of art, the artist fluctuates between observing and reflecting the unfinished result. Once finished, any other observer of the result balances between too little or too much variety (the variable of diversity).

Between boredom and overload fluctuate recognition and surprise.

Too much repetition demands surprise, too much differences demand recognition.

The optimum is personal and temporal.

Coming home from a busy, confusing day requires a sleek interior.

Coming home from a boring day as usual, requires distraction, for example more ornamentation.

I found more differences, ornaments and colors in the interior of those who are doomed to annoying work than in the businesslike, 'nice tight', quiet interior of those who have a busy job.

The turbulent, early Middle Ages demanded strict, Romanesque architecture, the calmer later Middle Ages a more flamboyant Gothic.

The discovery of America opened a world full of uncertainties. Science then wanted to 'know for sure'. Renaissance returned to 'the ancients'. When the pendulum moved to carefree abundance for the rich, baroque architecture counteracted their boredom.

The storm surge of the industrial revolution required again familiar neoclassicism.

When the revolution had gone and the sciences self-confident, art nouveau and surrealism took their task to surprise. The world wars called for modernism, the peace for post-modernism.

If everything is made equal, and suitable for repetitive operations, then your attention weakens, you get 'bored', and you want to be surprised by new impressions.

You move between monotony and chaos, recognition and surprise (an aesthetic amplitude).

^a [Jong\(1992\)](#) proposition 1. [Spitz\(1945\)](#) even reports cases of 'sensory deprivation' that may have caused the death of babies in a hospital

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