Designs change suppositions

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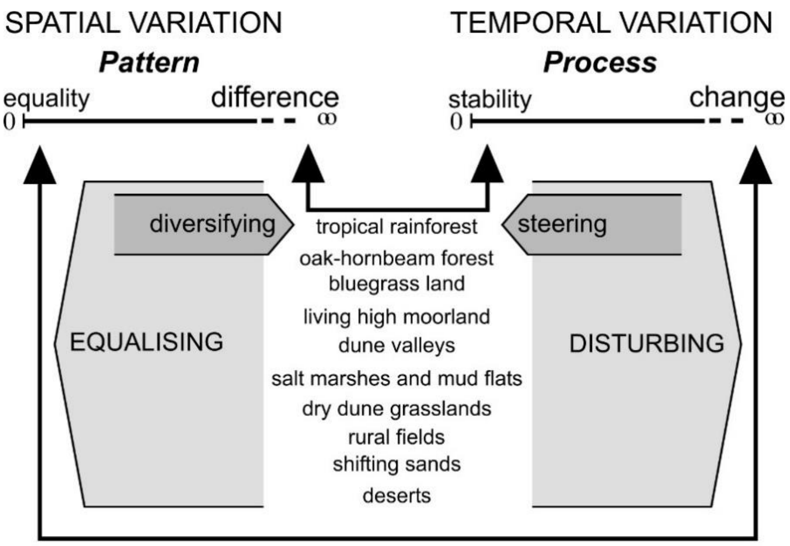
Dedicated to ecologist Chris G. van Leeuwen (1920-2005)



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

A package with pictures or more detailed calculations may be downloaded. These are numbered according to the figures in this text, and become active if you have installed Xara for pictures, the free downloadable math program Maxima or Excel for own editing.
The chemical figures are mainly drawn with the freely downloadable computer program ChemAxon's Marvin sketch.

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1. IMAGINATION IS BUILT ON SUCCESSIVE SUPPOSITIONS

This study aims to uncover unnecessary suppositions that hinder designing.[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 probability, desirability and possibility.

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a The medieval study of suppositions focuses on language and the meaning of words: https://en.wikipedia.org/wiki/Supposition_theory see **Spade(2002)Thoughts, words and things: An introduction to late mediaeval logic and semantic theory (WWW)**.
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 wat 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 objectives 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, objectives 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) objectives;
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 objective, 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 matter, 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. differentiates 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.

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a Buchanan(1992)Wicked Problems in Design Thinking(Design Issues)8 2 Spring p5-21

§ 2 STUDYING DESIGN METHODS HIDES SUPPOSITIONS

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 seldom one single goal.
It is mainly a vague and wicked[g] *field* of aims[h] caused by problems, stemming from a physical, technical, economic, cultural and organizational context, 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 suppostion is difference.
Without any difference nothing can be observed, chosen, imagined or thought. It is the basis of any next supposition, enabling succesively more complex imaginations. You cannot define difference as inequality[n], because that *supposes* a difference. Equality is a *value* of difference.

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

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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)Design and Analysis(Rotterdam)Uitgeverij 010**, or **Hoeven;Louwe(2003)Amsterdam als stedelijk bouwwerk Een morfologische analyse(Nijmegen)SUN** and other publications, e.g. referred in Jong(1995).

c E.g. **Jong(1995)Systematische transformaties in het getekende ontwerp en hun effect(Delft)Diesrede**, Speech on the University's birthday.

d E.g. **Schön(1985)The design studio, an exploration of its traditions & potential(London)RIBA publications Limited, and many following publications, Dorst(2015)Frame Innovation(Cambridge Mass)MIT and Dalke;Evans;Self(2013)Designerly Ways of Knowing and Doing(EKSIG)**

e E.g. **Jong;Voordt eds(2002)Ways to study and research urban, architectural and technical design(Delft)Delft University Press**

f E.g. **Roozenburg;Eekels (1996) Product design - fundamentals and methods(Chichester)WileySons**, **Eekhout(1997)POPO of ontwerpmethoden voor bouwproducten en bouwcomponenten(Delft)DUP**, later in English: **Eekhout(2008)Methodology for product development in architecture(Amsterdam(Delft)IOS press** and many of his other publications.

g **Buchanan(1992)Wicked Problems in Design Thinking(Design Issues)8 2 Spring p5**

h **Lawson(1990)How designers think, the design process demystified(Oxford)Butterworth Architecture p37-97** specifies the connected problems with different weights to be balanced differently in each specific context. Their weights depend on many more or less valid ***suppositions***.

i It's not so wicked. In 2005 I developed a computer program 'FutureImpact' 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)Operational context analysis as a part of design related study and research (WSEAS EEED)07**

j **Eekels(1973)Industriële doelontwikkeling(Assen)Gorcum** p140

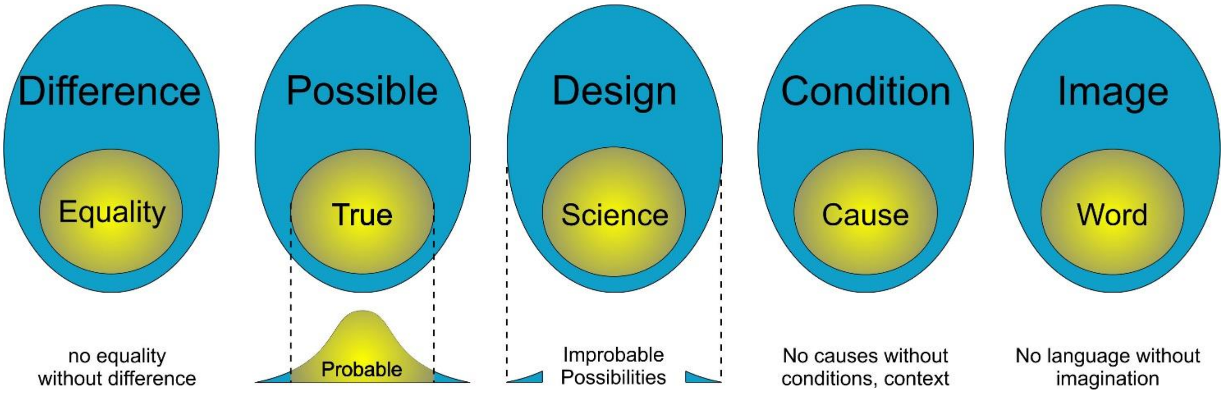
k "every formulation of a wicked problem corresponds to the formulation of a solution": **Rittel;Webber(1972)Dilemmas in a General Theory of Planning(Berkeley)working paper presented at the Institute of Urban and Regional Development, University of California, Berkeley**, cited by Buchanan(1992)p16. **Alexander(1977)PatternLanguage(Oxford)OxfordUniversityPress** saw the problem of many relations simultaliously earlier: **Alexander(1968)The Atoms of Environmental Structure(Cambridge Mass)MIT Press**

l **Cross(1982)Designerly ways of knowing(Design studies)vol3 no4 Oct p221-227**.

m **Glanville(1999)Researching Design and Designing Research(Design Issues)15 2 Summer p80-91**, and many following publications, cited by **Vahidov(2012)Science as design IN Design-Type Research in Information Systems: Findings and Practices(Montreal)Concordia University**

n **Russell(1903)The Principles of Mathematics(Cambridge)University Press**p179

§ 3 EQUALITY SUPPOSES DIFFERENCE



1 Equal ⊂ different ***2 True ⊂ possible*** ***3 Science ⊂ design*** ***4 Cause ⊂ condition*** ***5 Word ⊂ image***

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|—— – ∞ different.
A 'category' or 'set' contains objects not *equal*, but *less different* from eachother than from the rest. There are different differences e.g. stable 0|—— – ∞ change, united 0|—— – ∞ 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' (or 'subject'), however, is not a self-evident concept.

§ 4 '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]

6 Grip

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.

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. 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.

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a **Piaget(1937)La construction du reel chez l'enfant(Neuchatel 1971)Delachaux et Niestle** p6
b **According to Silbernagl(1991)DTV-Taschenatlas der Physiologie(Stuttgart)Thieme** 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) La psychologie de l'enfant (Paris) Presses universitaires de France**, 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 immediatly 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' IS AN INNATE LIMIT OF IMAGINATION ENABLING TO IMAGINE A SET OF TWO

Long after Piaget, Feigenson and Carey(2005)[a] discovered that a baby shortly after birth may distinguish sets of 2 and 3 elements, but not of 4. So, 3 is an innate limit, but a third object in one image enables to imagine 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 smoothened 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.

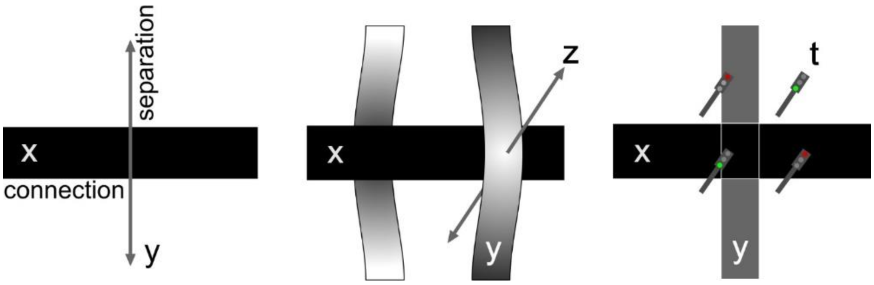
A drawing still may be precise; a painting restores the gradients and plasticity of imagination.
A deformable object (e.g. clay) makes it even sculptable.

a **Feigenson;Carey(2005)On the limits of infants’ quantification of small object arrays(Cognition)97 295–313**
b **Kraak(2006)Homo loquens en scribens Over natuur en cultuur bij de taal(Amsterdam)University Press**

§ 5 VERBAL LANGUAGE ENCOUNTERS PARADOXES AND BARRIERS

A PERPENDICULARITY PARADOX

070 Separation y ^ x separate in z or t.xar



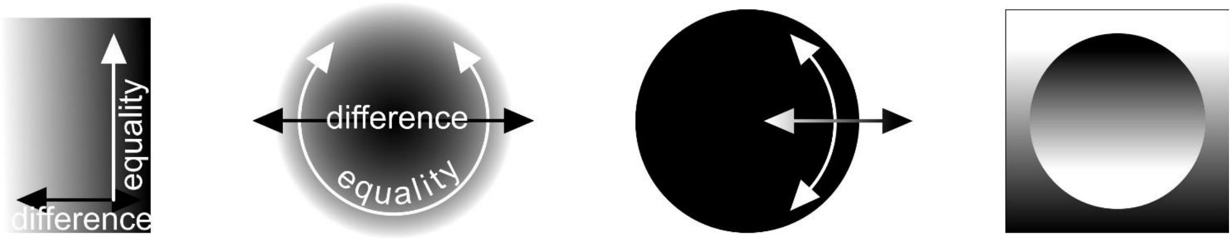
7 Perpendicularity paradox

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

008 Loodrechtheidsparad



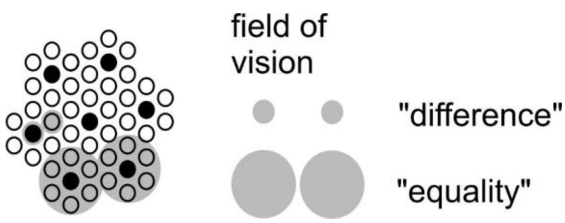
8 Inside-outside paradox

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 different directions. Linear language provides just the one of speech.

A SCALE PARADOX

009 Schaalparadox.xar



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=…1, 3, 10…m with wide tolerances as the 'frames' of vision. Take the word 'function'.

What is the function of a brick (nominal radius R=10cm), 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.

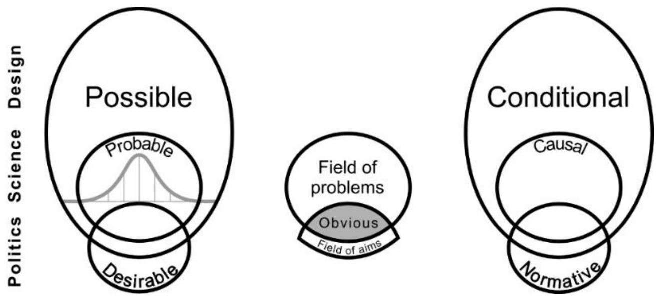
The mathematical concept of function y=f(x), the working of x on y, is limited to quantifiable properties x and y of objects. Direction is represented as one of these 'properties' (vectors).
The scale is determined by the units used. The function supposes a structure by which x operates through connections (+), separations (-) and their repetitive combinations *, /, Σ, Δ, ∫, 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 described 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.



10 Modalities

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*).

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 reciever 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 reciever 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 hided!) in verbal language. Design may ad, 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.

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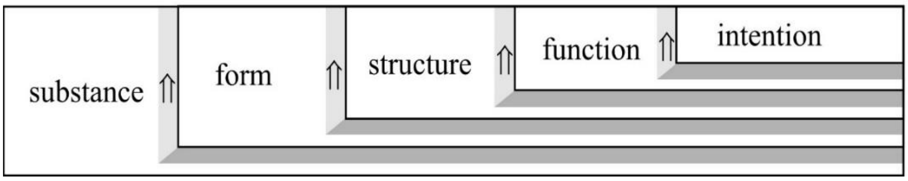
[a] "Wofon man nicht sprechen kan, darüber muss man schweigen"
Wittgenstein(1921)Tractatus logico-philosophicus; Logisch-philosophische Abhandlung(Frankfurt am Main 1963)Suhrkamp.

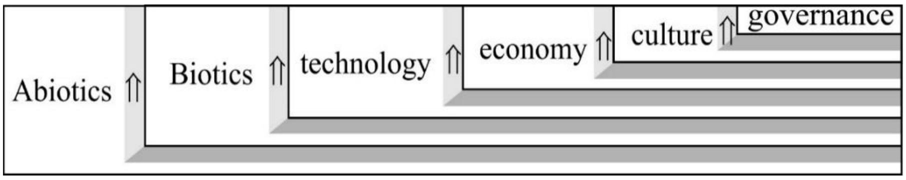
§ 6 SUPPOSITIONS (TACIT OR NOT) ARE STRICTLY SEQUENTIAL

011-012 from substance to intention

11 Object layers



12 Context layers



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[a], then I cannot imagine a function without an 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. Dispersed connections and separations without a form, do not enable a function.

If I define 'form' as a state of concentrated dispersion, then I cannot imagine a structure without a form, but I can imagine a form without structure. So, structure ⇓ form and form ⇑ structure. Form, however, supposes some substance (matter or content) that may 'take form'.
So, form ⇓ substance and substance ⇑ form.

These suppostions then appear to have a strict sequence: intention ⇓ function ⇓ structure ⇓ form ⇓ substance. The reverse sequence is a stepwise *enabling* 'possibility conditions' (⇑), not to be confused with *truth*-based logical then-if conditions (⇐), or sets containing (⊂) subsets.

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

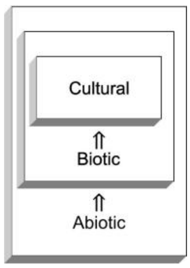
Governance, democratic or not, requires a *culture* that accepts compromise or coercion and violence. Subsequently, a culture will not survive without a sufficient *economic* basis.
No contemporary overpopulated economy will survive without *technology*.
Agricultural and industrial technology supposes *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).

Culture is defined here as 'a set of shared suppositions' (e.g. custom, language, religion, law). In a wider sense, however, it includes technology, economy and governance. That enables a contraction of context layers into Abiotics⇑Biotics⇑Culture ('ABC model').

014 ABC.xar

This study distinguishes A, B, and C (Chapters 6, 7 and 8) in order to study their suppositions seperately.



13 ABC model

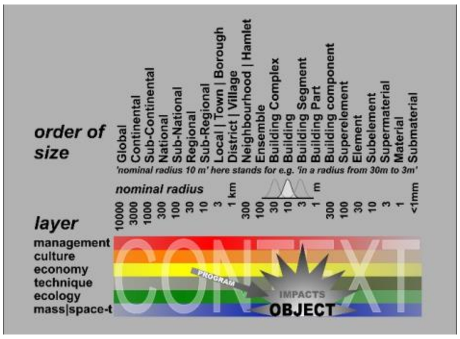
a Objects can be mutually separated always more (e.g. by distance), but not always less. Connection is the zero point of separation.

§ 7 CONTEXT ANALYSIS IS THE VERY START OF A DESIGN PROJECT

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**, p5).

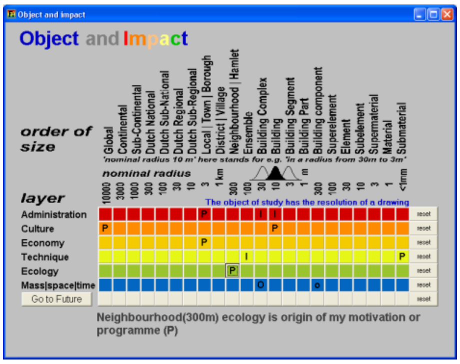
The beginning is *before* all that. The common suppositions deserve doubt and clarification.
What is the wicked *field* of problems[a] stemming from a physical, technical, economic, cultural and organizational *context* at different levels of scale?

Well, ask the stakeholders and future users what they want or fear.
The context of an intended design object contains the *possible* impacts *desired* or *undesired* by the stakeholders and users in the *probable* future context they expect (three modes).[b]
I suggest to use my computer program Future impact:

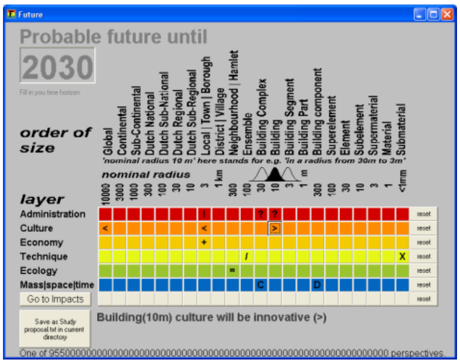


The context should be analysed at different levels of scale and in different layers of context.

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



Choose the intended largest (O) 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.



14 Context analysis

Specify the probable future context you expect .

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

a **Lawson(1990)How designers think, the design process demystified(Oxford)Butterworth Architecture p37-97** 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)Operational context analysis as a part of design related study and research (WSEAS EEED)07 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.

A context limits the *possibilities* of design. It limits them at different levels of scale and in different layers. The basic layer is the context of some mass, *probably* concentrating or dispersing in space and time. This abiotic layer ⥣ ecology ⥣ technology ⥣ economy ⥣ culture ⥣ governance.[a] The reverse, the object has *probable* impacts on that context, *desired* or not.

The future of context is difficult to grasp. Its analysis is based on suppositions. Experiences from the past, thoroughly studied by science and the humanities as *probabilities*, direct such suppositions. If science and the humanities are designed, then there may be alternative designs based on other suppositions.

§ 8 UNMASKING TACIT SUPPOSITIONS REQUIRES IMAGES

This chapter has been an attempt to signal some usual suppositions hampering designing.

The chapters 4, 5, and 6, will attempt to represent the current state of science at highschool level as they justly limit and extend possibilities of design. These are written as a layman explaining them to laypeople in order to avoid the tacit suppositions of professionals. The other chapters attempt to minimise and eventally change usual suppositions.

For image-oriented readers (as designers are) I tried to:

1 start a page with a pair of comparable *images* raising questions by their difference;
2 use colours relating the answering text below to the images at one 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 following text.

I have tried to eliminate unnecessary suppositions, and replace those that disable imagination. That impact is limited in the chapters 4, 5, 6 concerning exact sciences, but not excluded. These chapters are intended to represent what we mainly concern as valid and reliable, minimally necessary suppositions. That may raise, however, some questions.

What is their designerly content? Which discoveries are acually inventions, designs of a model? Do they cover a broader field of possibility beyond probability? The portraits of leading scientists and literature references in footnotes present some *designers* of the used models. A scientific model is a design, intended to *reproduce* a *discovered* reality.

---

[a] This sequence suggests a materialistic view. Environmental depletion forces the human sciences to recognize physical limits of technology, economy, culture and governance. History is therefore rewritten in this sense, e.g. also by **Frankopan(2023)The Earth Transformed: An Untold History(London)Bloomsbury**.

2. SCIENCE SUPPOSES A PHILOSOPHIC DESIGN

What is the designerly content of science?
Which discoveries are acually 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. These questions are considered to be answered (explained) when there is a model (a 'design') that behaves according to the observation. If such a model is previously unknown, it is often also called a 'discovery', but I will call it an invention, the design of a model.

Philosophy studies the reason for the existence of truth, desirability or less so possibility.
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 the reason for an 'existence' of truth and possibility as it is studied by philosophy?
This stresses the more so, if truth is *part* of a (actually not 'existent') *possibility* (***Fig.2***p7).
A possibility cannot be studied before it is designed. There is no 'existent' object of study (yet).

There is, however, a **context** in which such a design may develop.
Context analysis is the very start of a design project (**§ 7**p14).
The succesive contexts of that development are the subject of this chapter. I conclude:

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 assumptions.

This chapter may seem a history of science, but it is an attempt to find the conditional sequence of suppositions (and their rejections) at different levels of scale and viewpoint.
The history of science is only *used* here to that aim.

§ 9 THALES ENABLED REDUCING OBSERVATIONS TO MATH

15 Greek colonies[a]

16 Meandermouth silted[b]

17 Milete now[c]

18 Excavations[d]

19 Milete -450 as rebuilt a century or two after Thales[e]

As far as we know, western philosophy has begun around 600 BC in Miletus, a Greek colony with more than 80 own colonies. There, caravan goods were shipped from the east and distributed to the west. Trade with other cultures puts your own traditions into perspective. Gods appear 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, the tragical consequences of which Homer had tought any Greek since long.

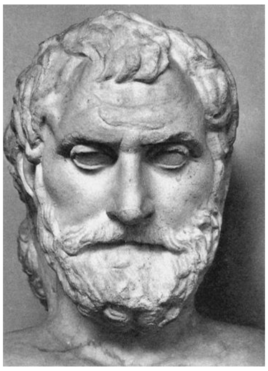
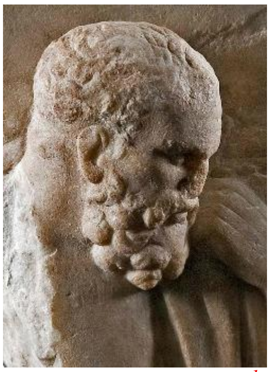
Due to the simplicity of the Greek language and its alphabet, many Greeks could read and write. So, that art was not the monopoly of priests who, based on inaccessible holy writings, could guard the 'true religion' centrally as they did elsewhere.

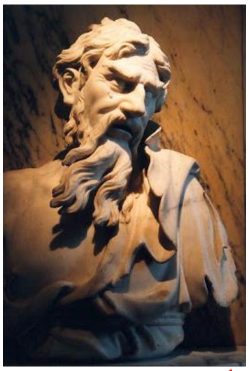
No island or city-state had sole rights to one truth, although the mother city Athens still had some orthodox pretensions towards her children. Greek Gods operated locally, but they met on Mount Olympus. They could deceive each other and argue.

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 quantifyable noun such as 'velocity' (*το* ταχος) 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 Berlijn
f **Krafft(1971)Geschichte der Naturwissenschaft I Die Begründung einer Wissenschaft von der Natur durch die Griechen(Freiburg)Rombach** p49



20 Thales?[a] ***21 Anaximandros***[b] ***22 Eratosthenes***[c] ***23 Herakleitos***[d]

Thales of Miletus (ca.625-545 BC) 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 Milete when 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, 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 shadow related to his own shadow. The 'theorem of Thales' is attributed to him.

The determination of height from a shadow, however, assumes parallel solar rays, and that is not self-evident due to perspective distortion (***Fig.24***).
The sides of a straight road also seem to point to one point, while they are actually parallel.

24 Visual deception through the perspective of parallel sun rays [f]

That the sun's rays are (practically) parallel is only apparent if on a flat surface your shadow has the same size everywhere at the same time (the same solar height).
It must attest to the understanding that the sun is practically at infinite distance from the earth.

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a **Thales Roman copy of a 4th century BC Greek original Vatican, Vatican, Galleria Geografica Inv. 2892; Herda(2013)Burying A Sage: The Heroon Of Thales In O. Henry (Ed.), Le Mort dans la ville (1–). Institut français d'études anatoliennes**.
b **Anaximandros Relief with seated Anaximander from Rome, Via delle Sette Sale, 2nd century BC. Rome, Terme Museum Inv. 506**
c **Eratostenes Etching of an ancient seal identified as Eratosthenes. Philipp Daniel Lippert Dactyliothec, 1767**
d **Heracleitos Carved Italian marble bust depicting Heraclitus at the Victoria and Albert Museum Knightsbridge London England. It has been dated to 1700-1750, and was created by an unknown artist.**
e **Henderson(2002)Greek mathematical works Thales to Euclid(Cambridge Mass)Loeb Harvard University Press**
f Photograph by Ton Wisselius

According to Anaximandros, 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.
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.
Supposing the earth as flat was common, because from a round earth all the water would drip down. That in itself assumes that everything falls down parallel vertically.
Apparently that too, was no longer self-evident for Anaximandros.

Two centuries later, Eratostenes of Cyrene (in modern-day Libya) determined the circumference of the earth fairly accurate, apparently using assumptions such as:
1 practically parallel sun rays adopted by Thales,
2 the earth assumed to be a free-floating globe by Anaximandros.

The interpretation of observations stands or falls with good or false assumptions.
Discovering tacit (seemingly obvious) 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.

Thales had reduced the world to water as a primordial cause, because water has all known aggregation states (solid, liquid, gaseous). 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.

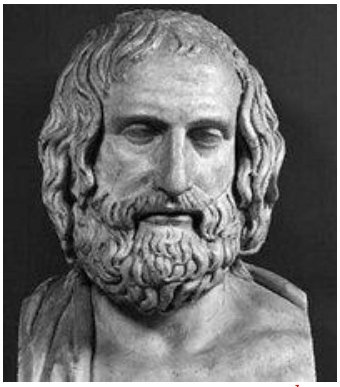
According to Greek mythology, Prometheus (‘Forethinker’, the master crafsman god), betrayed to men the divine secret of fire and science. It is as if he recommended the people:
1 *represent* materials as combinations of primal substances,
2 *reduce* their space to points, lines and planes (geometry), 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.

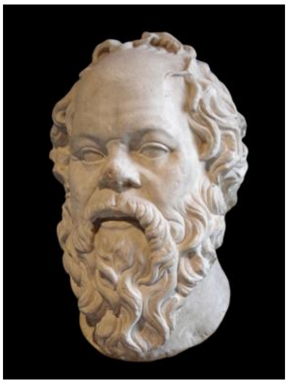
You may, however, also design and realize *deviating* realities yourself. Then, you need tools of imagination such as language, mathematical operators, similar to binders, knives, or sieves.
In the 14th century, Ockham also had a 'razor' that resembles a statement attributed to Einstein:
"Make everything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

§ 10 PLATO'S DIALOGUES ENABLED SCIENTIFIC DOUBT

25 Virtue as a goddess[a]



26 Protagoras?[b]



27 Socrates[c]

28 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 te 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 unacceptible 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 Ephesos, 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).
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 of 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 seems 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 assumes differences *between* the quantities that can be counted (variables), but equality *within* those variables (units).

a Popper (1976)Unended Quest: An Intellectual Autobiography(London 2002)Routledge

§ 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 already be present 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:	**Judgment forms:**
substance,	affirmative - negative,
quality,	general - special ,
quantity,	some - one-off,
relation.	necessary - possible.

29 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	**Induction**
Major: If I am in Delft, then I am in The Netherlands.	Aadorp is a place in The Netherlands, Aagtdorp is a place in The Netherlands, … …
Minor: Well, I am in Delft.	Zwolle is a place in The Netherlands.
Conclusion: I am in The Netherlands.	So: All places are in The Netherlands.

30 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.30***, 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 (idealism) produce the special cases; 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)Categories, On interpretation, Prior analytics(London 1933)Loeb Heinemann** writes 10, but they can be traced back to these 4.

The pure, substance-free form is an ideal (geometrical) idea, a mold, and any substance has some resistance to take its intended shape.

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.

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 cause or a final cause.
Mass resists against movement *and* attracts (gravity) or repulses (at collision).

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.

31Aristoteles' causalities

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

32Aristoteles' physics, biology and anthropology

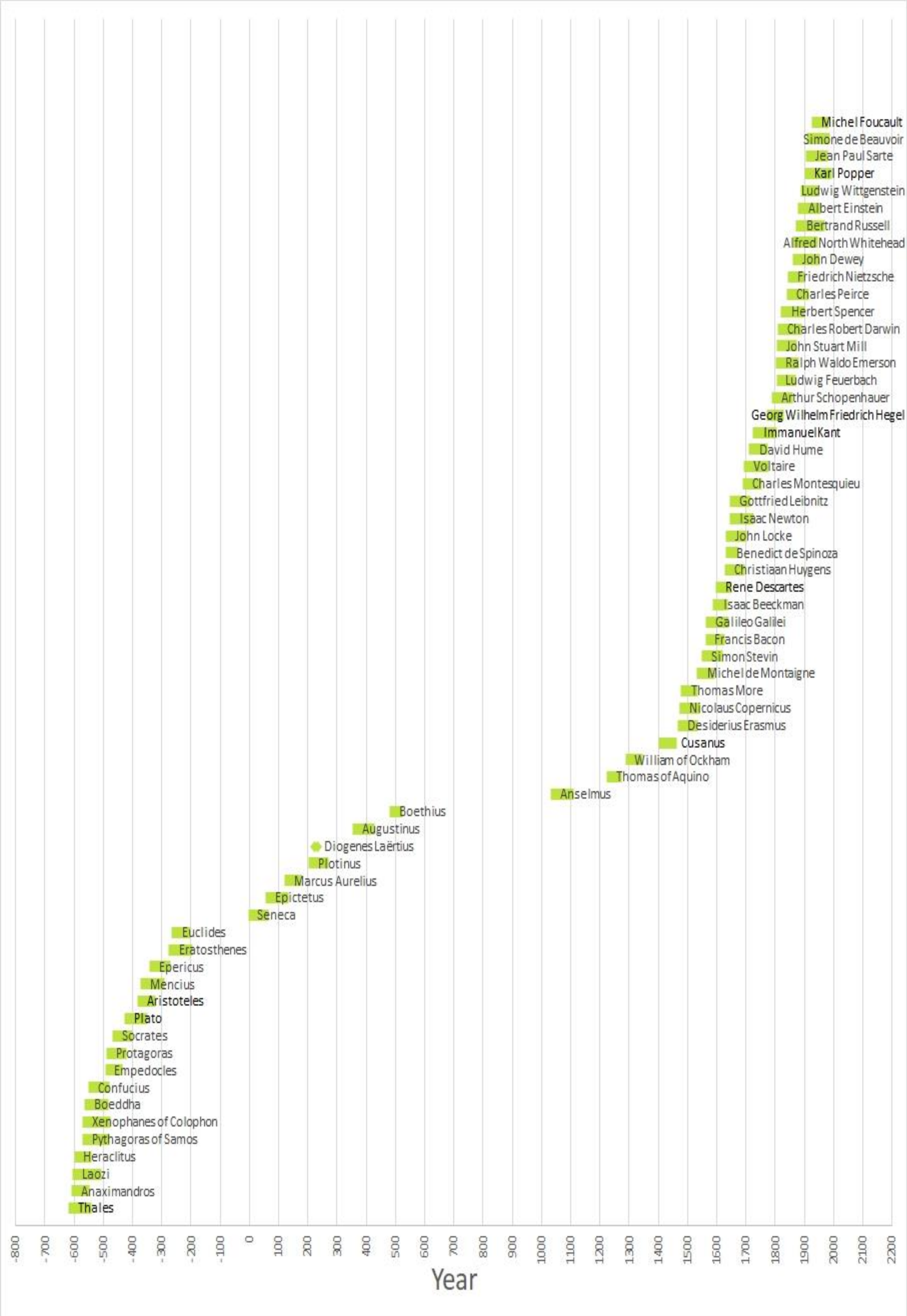
For his biology, the soul is the unmoved mover, the cause of form (entelechy). It is a precursor of the genes (a library of recipes for form generating processes in any cell) in current biology. The body is the moved, but resisting substance, the tool (organon) of the soul.
A human has a plant-nourishing, 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.33***p24).

a **Aristoteles(-335?)Metaphysics I(Cambridge Mass1996)Loeb Harvard University Press p17**

037 Tijdlijn.xlsx



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

§ 12 DESCARTES' DOUBT ENABLED CERTAINTY

34 Cusanus[a]

35Copernicus[b]

36 Descartes[c]

37Newton[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 counter-parts such as straight and round ('coincidentia oppositorum') with mathematical arguments.

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: the set of all sets cannot contain itself[i]. 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.

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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)Die Modernitäten des Nikolaus von Kues(Mainz)Historische Kulturwissenschaften**
f **Dijksterhuis(1975)De mechanisering van het wereldbeeld(Amsterdam 1980)Meulenhoff** p248 has a clear overview of Cusanus' ideas.
g **Cusanus(1440)De docta ignorantia On learned ignorance(Minneapolis1985)Arthur J. Banning Press**
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)The Principles of Mathematics(Cambridge)University Press**. 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 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 ('clairement 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."

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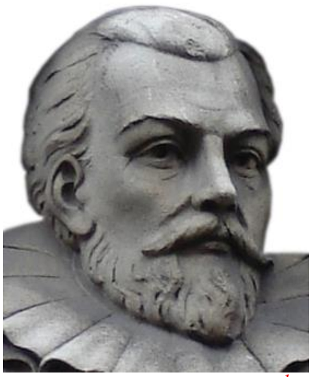
a **Descartes(1637)Vertoog over de methode(Amsterdam1937)Wereldbibliotheek** French:**Discours de la methode** English:**Discourse on the Method** . The first three parts are an entertaining, modest autobiography with a wealth of wise examples. In the fourth part, however, it becomes less accessible 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.

38 Frederik Hendrik v. Oranje[a]



39 Simon Stevin[b]

40 Baruch de Spinoza[c]

41 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 a comprehensive 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, paining 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)Ethica Ordine Geometrico Demonstrata** in English: **Ethics**
f **Dijksterhuis(1975)De mechanisering van het wereldbeeld(Amsterdam 1980)Meulenhoff**
g As elaborated earlier by Cusanus(1440) in a more rational way, referring to mathematics of infinity.
h **Descartes(1684)Regulae ad directionem ingenii Regulen van de bestieringe des verstants(La Haye 1966)Nijhoff English .**


42 Leibniz[a]


43 Hume[b]


44 Kant[c]


45 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 assumptions in advance! Even a causal relationship is a mental assumption.
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	General
	Multiplicity	Special
	Allness	Singular
2 Quality	Reality	Affirmative
	Negation	Denying
	Constraint	Infinite
3 Relationship	of inherence and subsistence (substantia et accidens)	Categorical
	of causality and dependence (cause and effect)	Hypothetical
	of community (interaction between active and passive)	Disjunctive
4 Modality	Possibility, Impossibility	Problematic
	Existence, non-existence	Assertory
	Necessity, Coincidence	Apodictic

46 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.

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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)Critik der reinen Vernunft I §9, §10(Frankfurt am Main1976)Suhrkamp p111-121** or **Kant(1787)Kritiek van de zuivere rede I§9, §10(Amsterdam 2004)Boom** p161, 168

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 assumption 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 philosophic truth-finding instead of being part of it.[c]
It concentrated on well-defined objects, operations, experiments, *reliable* observation and *valid* reasoning, but still primarily 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.2***p7).
An animal is not a dog. A dog is an animal. Design requires an addition to logic (**Chapter3**p41).

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 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 successively developing conditions of imagination ('suppositions'), made possible by only one a priori condition: making a ***difference***.
Difference enables to imagine a **place,** different places ('**space**'), a **direction**, and a **sequence**.
Equality may appear as zero-difference ⊥ difference (***Fig.8***p10).

Equal differences in all directions enable to distinguish a zero **change** '**object**' from its '**environment**' (non-object). It enables to imagine '**not**', an '**inside**' and an '**outside**'.
Different objects enable to imagine **plurality**, a '**set**', '**subsets**', a '**relation**' or a '**category**'.
Different sets enable to imagine **magnitude**, and **levels of magnitude,** scale (§ 31p125).

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[a] A dissociative identity disorder or schizophrenia may be a normal condition, oppressed by a culture that counts on agreements.
Minsky(1985)The Society Of Mind(NewYork 1988)Simon Schuster assumes a multitude of judgmental actors within one individual.
Bob Dylan(2020)Rough and rowdy ways() has sung "I contain a multitude".

[b] Some experiments with children in a series of publications, summarized in **Piaget (1966) La psychologie de l'enfant (Paris) Presses universitaires de France**, can be interpreted this way, even though Piaget himself claimed to be a Kantian. The quest for own identy (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.

[c] **Newton(1687)Principia the mathematical principles of natural philosophy(New York1846)Adee** still calls his physics 'philosophy'.

§ 13 SCIENCE OBSERVES DIFFERENCES RESISTING CHANGE

Hestia[a] Demeter[b] Dionysos[c] Hermes[d] Apollo[e] Athena[f]

47 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 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 assumptions that a daily imposed role requires.
Outside of that role, daily life is called into question. With masks, different roles were played.

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a **Hestia Giustiniani in the Museo Torlonia Rome**
b **Demeter in the Museo nazionale romano di palazzo Altemps**
c **Dionysos in the British museum**
d **Hermes of Praxiteles bearing young Dionysos in the Archaeological Museum of Olympia**
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 on the coast with Hermes, 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 the design of science.
With that own wisdom (Prometheus!) you could *change* reality into a new *object* yourself.

The assumption that every cohesion is composed of one or a few elements (water, earth, air, fire, change as such, or an indefinite 'apeiron') was a second step.
Whatever *separation* you assume, you can *combine* those basic components as you see fit.
Anaximandros' indeterminate 'apeiron' allows *the composition* to select its material.

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 into walled Athens. There a plague broke out, from 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) was even able to grant 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 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.

Descartes therefore decided in 1633 not to publish a similar study on physics.
His dualism between body and mind was already met with 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 his representation with coordinates. Newton's groundbreaking design of mechanics distinguished mass and weight. This also led to concepts that were difficult to define differently, such as force=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. Science after Newton 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 the 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, explosive industrial applications motivated the growth of science more than 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.

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a **Müller(2013)Die Modernitäten des Nikolaus von Kues(Mainz)Historische Kulturwissenschaften.**
b Stevin (1594) did that earlier.
c Discovered by Antonie van Leeuwenhoek as early as 1674.

New plasics (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, classical physics reached 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 our 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.

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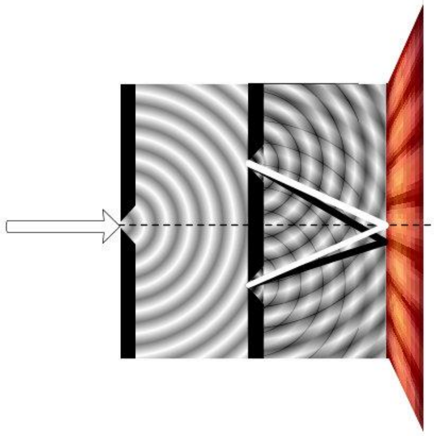
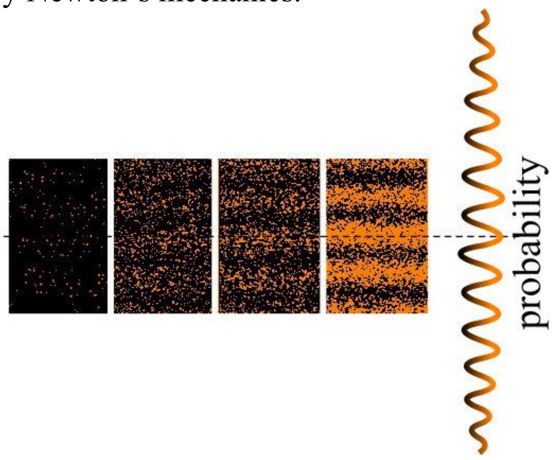


48 Light through two slits interferes



49 Electrons (particles) also interfere

Light projected through two slits onto a screen shows an interference pattern (***Fig.48***). 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.49***).[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.

Breuer(1987)p181 WRP.wxmx

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∗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).

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a Once preceded by the invention of celluloid in 1869.
b **Weizsäcker(1943)Zum Weltbild der physik(Stuttgart)Hirzel Verlag; Weizsäcker(1959)Het wereldbeeld in de fysica(Utrecht)Spectrum**
c https://nl.wikipedia.org/wiki/Tweespletenexperiment
d A body that absorbs all frequencies and emits them when warmed up.
e **Rayleigh(1900)Remarks upon the Law of Complete Radiation. In: Phil. Mag. Band 49, 1900, S. 539–540.**
f **Wien(1896)Über die Energievertheilung im Emissionsspectrum eines schwarzen Körpers. Annalen der Physik, Nr. 8, S. 662–669**
g **Planck(1900) Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum(Verhandlungen der Deutschen physikalischen Gesellschaft Berlin)2 Nr. 17, p. 245**
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: $E_k=h*f-W$ (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.

Solvay 1927 (2025_02_12 10).xar

50 Participants of the 1927 Solvay Conference in Brussels [f]

At the Solvay International Conference 1927 (***Fig. 50***) 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.

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a **Einstein(190503)Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt(Annalen der Physik)17p132–148**

b **Einstein(190504)Eine neue Bestimmung der Moleküldimensionen(Zürich)ETH PhD Thesis.**

c **Einstein(190505)Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen(Annalen der Physik)17 p549–560.**

d **Einstein(190506)Zur Elektrodynamik bewegter Körper(Annalen der Physik)17p891–921.**

e **Einstein(190509)Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?(Annalen der Physik)18 p639–641.**

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

This not interceptible 'communication faster than light' already plays a role in the development of quantum computers, but it cannot be explained properly.

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 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'll 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 democratic debate is then 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 science and skills when they are injured or sick.

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 the fields and forests shows other lives after death. It recreates the image of life. Young replaces old, fed by the deads. 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.

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[a] **Heilbron ed(2003)The Oxford Companion to the history of modern science(Oxford)University Press p690**, ‘Quantum field theory’

Priestley[a] Lavoisier[b] Ingenhousz[c] Calvin

51 The inventors of $CO_2 = C + O_2$

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.260***p142). 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 provides 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 (chloroplasts) *within* cells. 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.258***p141), they brought oxygen (O_2) into the atmosphere, allowing new life forms to emerge. Plants may have incorporated these photosynthesic 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 *reproduction.*
This 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 presupposes *regulation.*

Regulation here is the availability of specific processes initiated by signs.
The sign to unblock the process can be a changing environment or an arriving code.
I conclude a strict order of conditions that any living organism must meet: reproduction ***supposes*** (⇓) specialization ⇓ organization ⇓ regulation ⇓ metabolism.

Conversely: metabolism ***enables*** (⇑) regulation ⇑ organization ⇑ specialization ⇑ reproduction. Metabolism provides material and energy, regulation retrievable processes. Organization aligns it to a common effect. Specialization may also occur in time: the caterpillar is a specialist in feeding, the resulting butterfly in *reproduction*.

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 This makes the concept of 'probability' scale sensitive. What is improbable outside an organism, may be probable inside. What is improbable in the organism, may be probable within its organs. What is improbable in an organ may be probable within its cells.
f **Calvin c.s.(1950-1957)The Path of Carbon in Photosynthesis(Journal of the American Chemical Society)**
g https://nl.wikipedia.org/wiki/Blauwalgen

Abiotic :	difference	⇑ change	⇑ object[a]	⇑ separation	⇑ combination	⇑ B
Biotic :	metabolism	⇑ regulation	⇑ organization	⇑ specialization	⇑ reproduction	⇑ C
Conceptual :	imagination	⇑ safety	⇑ attachment	⇑ identity	⇑ influence	*(individual)*
Cultural :	empathy	security	loyalty	publicity	power	*(social)*

52 Successive conditions, stepwise enabling next possibilities

Biotic Metabolism is possible only if its environment provides for Abiotic (physical) conditions: difference ⇑ change ⇑ object ⇑ separation ⇑ combination (***Fig.52A***). The sequence may be applied at different levels of scale: A from quarks, atoms, molecules to observable objects or B from organelles, cells, organs, organisms to ecological organizations of coexisting organisms.

Yet the presuppositions of many humanities and engineering disciplines such as economics, management and design are already recognizable in the Biotic conditions. People distinguish themselves by extended *imagination*, enabling the conditions C. Science and design go through the same stages in order to reconstruct (model) an *existing* reality or construct a *new* one.

Differences in each Biotic condition of possibility creates millions of species (‘biodiversity’).
Within a species, the individuals differ. They grow up in different environments.
The study of one species (humans) already requires 32 medical specialties[b].
Physics seems to approach the horizon of its completion, but biology still seems endless.

Each species differs in metabolism, regulation, organization, specialization and reproduction.
The first Biotic *difference* is between input and output *metabolized* through a closed membrane.
Proteins are built into that membrane that *regulate* the input and output. The organism is *organized* in such a way that the interior is less disordered ('entropic') than the outside world.

This makes internal processes with physically improbable *specializations* possible.
Reproduction by *separation* or *combination* is one of those special functions, but there are more.
Even within one cell, the necessary 'organelles' can be identified that are attuned to each other.
One of them, the cell nucleus, *organizes* and *regulates* the others with archived laws and rules.

How all this works raises a multitude of largely still unanswered questions.
Some are Abiotic in nature. Which *differences*, *changes*, *cohesions*, *separations* and *combinations* play a Biotic role? Photosynthesis, enzymatic reactions, bird orientation, smell perception, DNA mutations may demand a quantum mechanical explanation.

Then the question remains *how* we distinguish ourselves from animals. For archaeology, it is the use of tools. For Harrison cs[c] it is the ability to oversee a series of actions, of which only the first is immediately executable and only the last is effective.
The intermediate actions are 'inter-functional', such as the use of tools (e.g. language).

The often mentioned differences such as self-awareness, language, technology, free will, morality, creativity can be summarized or derived from a difference in *imagination*.
Animals generally may oversee 2 representations (e.g. 'fight or flight'), humans at least 3[d].
The third then can be a summary (abstraction) of the other 2 (page 9).

We make representations (*reproductions*) of what we perceive per level of scale.
This enables to design changes that are not yet 'true' (observable). They *differ* from reality by a ‘*metabolism’* in our *imagination*, enabling next conditions (***Fig. 52C***).

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a ‘Object’ may be read as something remaining *different* from the rest and resisting *change* (‘coherence’).
b EU Member States(2008)b94_mb-01-31-2008--list-of-diplomas-certificates-and-other-titles-of-specialist-doctor(EU)14858
c **Harrison;Weiner;Tanner;Barnicot(1970)Human biology(Oxford)Clarendon**
d **Feigenson;Carey(2005)On the limits of infants’ quantification of small object arrays(Cognition)97 295–313**

Reproducing images is enabled by a series of successively learned suppositions.
These are often unspoken and also may *block* imagination, making something 'unimaginable'.
Culture is a collection of suppositions and conditions, shared at different levels of scale.
This is passed on to offspring (insofar as they do not encounter youthful resistance).

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

With generalization, exceptions fall by the wayside, but just these may have a major impact.
One design can change usual assumptions.
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 human 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 less 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.8***p10)

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.[b]
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.9***p10).

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a **Galjaard(1994)Alle mensen zijn ongelijk(Amsterdam)Balance**

b **Descartes(1684)Regulae ad directionem ingenii Regulen van de bestieringe des verstants(La Haye 1966)Nijhoff** 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 A PHILOSOPHIC DESIGN OF SCIENCE SUPPOSES A LANGUAGE

Design *constructs* models that may be realized. Science[a] **re***constructs* reality in models.
From prehistoric times, people have made models of reality in drawings, sculptures and stories.
Classical Greek sculptures reached in any detail a more realistic reconstruction than ever before.
They witness of precise observation. That is also a 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 succesive sounds, referring to objects and change.
Nouns refer to objects, verbs refer to change[b]. A noun may not 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 too has nouns (variables) and verbs (operators).
The '=' sign refers to an *equal* overall result by *different* operations (formulas)[c] at both sides.
The choice of variables, however, should obey a formal logic. They should not overlap.

The set 'people' may contain women and men. According to formal logic, however, the conjunction 'and' (⋀) 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'(⋁): people are women *or* men.

But that should not be understood as 'women ór men' with an exclusive 'ór' (⊕[d], *either*...or...).
Formal logic is the art of making a difference between *conjunctions* such as ⋀,⋁, and ⊕.
The coherence of a sentence as an *object* requires also a logic of *nouns*, *verbs* or their *sequence*.[e]
This study argues for more distinction in terms of scale and a conditional order of concepts.

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 '→' 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* (-) from the connection, but *delivered* (+) outward[f].

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* from some connection. So a required $e_a > 0$ also hides separations.

You may assume that a scientific model (for example a set of sentences) will never cover the observed reality completely, but it may be approached by refinement. A sentence may be refined by adding or subdividing nouns and verbs, but still it *is* not the observed objects or changes.
It may *become* a reality, by 'realizing' nouns and verbs into 3D objects and their change.

For 3D realization, the linear sentence 'table top + 4 table legs → table' is not a full instruction.
Lines in a 2D drawing indicate 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 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 its arms and grippers.

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a In this paragraph 'science' includes the humanities.
b 'To be' and 'to have' refer to a change approaching zero.
c The distincton between overall change (the equation) and changes in detail (formulas) is an example of the scale paradox (***Fig.9***p9).
d In the next chapter I will use the visually more expressive sign '>–<' instead of ⊕ for 'exclusive or'.
e This logic is usually called grammar.This, however, does not include a possibility based splitting or sequence of concepts.
The separation of mass and weight has been a key to Newton's mechanics.
Some actions are impossible before other actions ('conditional sequence'). A house is usually not built starting by the roof.
f The counter-intuitive minus sign is an example of the inside-outside paradox (***Fig 8***p9).

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 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 a*re* actions, (de)blocking a set of parallel or serial actions ('behaviour'). 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 (**§ 5,** particularly p11 and 12), 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, 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 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.292***p154). 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 'if ..then' conjunction has become 'action logic' adding ...'else'.

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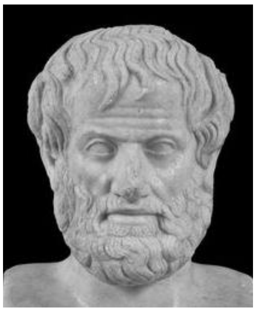
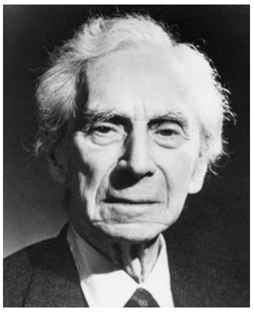
a See for example **Harris(2022)Zero to birth(Princeton & Oxford)University Press**

3. LOGIC SUPPOSES A LINEAR LANGUAGE



53 Aristoteles[a]

54 Frege[b]



55 Russel[c]

56 Gödel[d]

Leading designers of the contents of this chapter

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a **Akropolis Museum. Aristoteles(-330)Categories, On interpretation, Prior analytics(London 1933)Loeb Heinemann** and **Aristoteles(-330)Posterior analytics, Topica(London 1960)Loeb Harvard University Press,** Together called ‘Organon’ introduced logic as a science.

b **Frege(1879)Begriffsschrift eine der arithmetischen nachgebildete Formelsprach des reinen Denkens(Halle)Nebert** formalised logic.

c **Russell(1903)The Principles of Mathematics(Cambridge)University Press** supposed logic to be the final basis of mathematics.

d **Gödel(1931)Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I(Monatshefte für Mathematik und Physik)38: 173-198** proved a fundamental incompleteness of logic in mathematical proofs.

What is the designerly content of logic?
Which discoveries are acually 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 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 heterogeneous sets and logic detaches their overlaps.

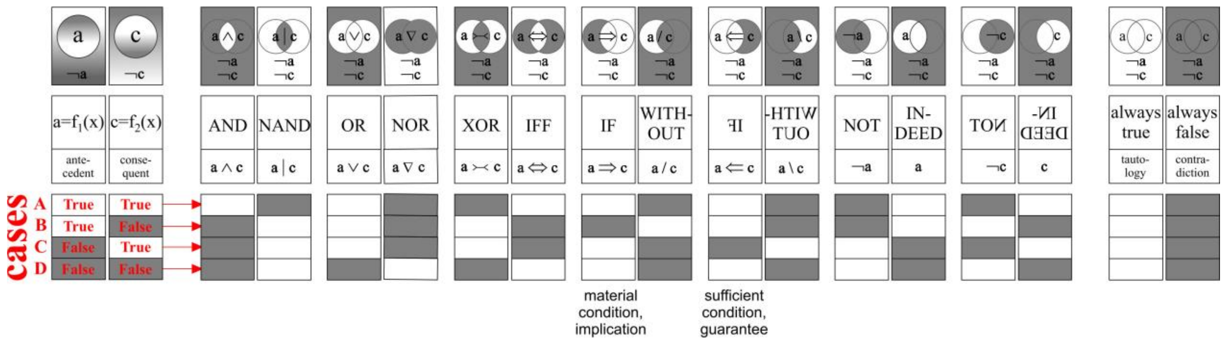
Logic formalises the art of combining sets (words) with conjunctions, but our capacity of co-action (co(a)gito means thinking) includes more. The limited fixation on logical *truth* within a *linear* language, limits the view on *possibilities* that are *not* (yet) *true*.
The ability to design, requires more space than the common logical space.

'If x then y is *true*' means something else than 'If x then y is *possible*'.
The first supposes the last ('if true then possible'), but not the reverse ('if possible then true').
'If x then y is *possible*', however, is most relevant for design. Modal logic pretends to include possibility, but it accepts 'It is true to be possible' instead of 'It is possible to be true'.

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

THE LOGICAL SPACE IS LIMITED TO VERBAL LANGUAGE

051 Truth table.xar



57 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 abbriviate the judgement 'it is circular' as ‘c’, then c∧¬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∧⊥¬c.
If you add a second judgement 'it is angular' (‘a’), then c∧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.57***, 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 expressions $a=f_1(x)$ and $c=f_2(x)$ mean that the words a and c here are two descriptions f of the *same* object x (for example a cylinder).

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.57*** 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 creates some surprises.

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⇒c') is true even if both a and c are false. This allows to say 'if blood is blue, then the earth is square'.

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a Peirce ed.(1883)Studies in Logic by the Members of the Johns Hopkins University(Boston)Little, Brown & Co was the first to design such a truth table, but Wittgenstein(1921)Tractatus logico-philosophicus; Logisch-philosophische Abhandlung(Frankfurt am Main 1963)Suhrkamp made it popular. Except Peirce and Wittgenstein, Russell in 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 FALSE JUDGEMENTS

In common language the word 'and' is also used for both predicates together (everything that is angular *and* circular). A better conjunction then is 'or' ('$\vee$'), if that at least does not have the meaning of *exclusive ór* ('either ... or' '>–<'): 'Do you want jam *ór* 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 '*ór*' (>–<).
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.58***). 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 *not* in the Netherlands. ($\neg N$)	If I am in Delft, 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)

58 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.58*** counts about 4000 examples from Aadorp until Zwolle proven to be true ('verifications'). It shows, however, how generalising with a short-sighted assumption ('in the Netherlands') can lead to a wrong conclusion.

[a] Quantifiers were introduced by Frege(1879)Begriffsschrift eine der arithmetischen nachgebildete Formelsprach des reinen Denkens(Halle)Nebert

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 acceptible 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.44*** 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 ... (∀)', the 'minor': 'There is a case for which ... (∃) applies'.
Induction has only observations 'There are cases for which applies ...' (∃).

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⇒DNA),
Minor: "Well, I found your DNA on the spot." (DNA)

Conclusion: 'So you raped her.'

59 An example of abduction

Abduction logically produces no truth, but it does offer a possibility (compare ***Fig.58*** p44: '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 '¬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' (⊥), 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.

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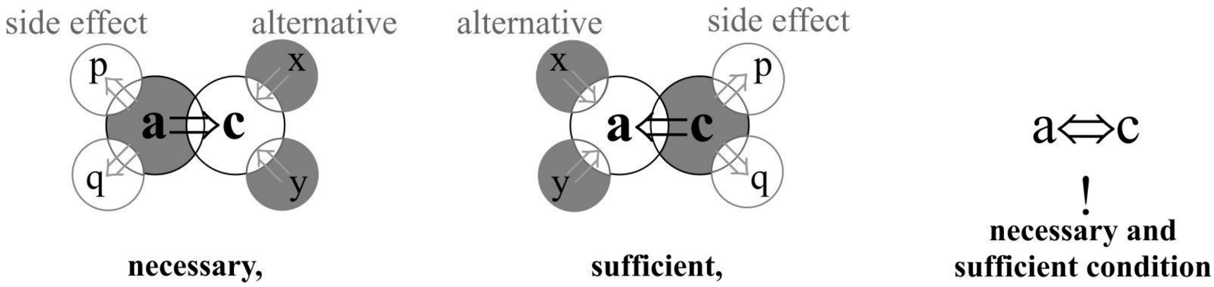
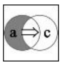
a **Popper(1934)The logic of Scientific Discovery(London 1983)Hutchinson**

b **Dorst (2013) Academic design (Eindhoven) TUE Inaugural speech** 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 § 17 p48 onwards I will summarize the restrictions.

§ 16 'IF' DIFFERS



60 Different logical conditions



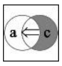
A 'NECESSARY CONDITION' ('IMPLICATION' ⇒) IS NOT NECESSARY

A 'necessary condition' has alternatives

If you take the car (a), then (c) you definitely will ride. if a then c, a⇒c
If you take the train (x) or (y) the cycle, then you also will ride. x⇒c or y⇒c
So, taking the car (a) is not necessary to ride.
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⇒c
You should also not have drunk too much alcohol (p) and
(q) you also need a warning triangle in your car. a⇒p or a⇒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' (⇐) IS NOT SUFFICIENT

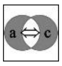
The logical arrow turns around, but the logical sequence of antecedent 'a' first, from which follows a consequence 'c' remains the same.
The 'sufficient' condition is therefore not a completely reversed 'necessary' condition.

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⇐c
You can, however, also take the train (x) or the cycle (y). a⇐x or a⇐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 requiremens (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⇐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⇐c or q⇐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' (⇔) EXPRESSES EQUIVALENCE

The equivalence 'a⇔c' ('a≡ 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⇔c concerns the same *truth value* (***Fig.57***p43). So, if a and c are both true or even both false, then 'a⇔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⇒c is 'a' *ante*cendent and 'c' con*sequence*.
'*Then*' in 'if…*then*', has a connotation of temporal sequence.
'Not without', however, sounds purely spatial, and the truth table of **57**p43 shows *spatial* equivalents in order to ex*plain* 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'.

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 though 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 in that sense all conditions for a collision are met, then the '*last condition added'* (that a driver loses control over the wheel) is called the 'cause' of the collision.
Every 'cause' is a condition that something can happen, but not every condition is also a 'cause'.

A negative 'cause of failure', however, is easier to determine if one condition of the many falls away 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⇒c), and 'only then a if c' ('a⇐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.2***p7).

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 (∀ dogs: dogs⇒animals).

Not for all animals applies 'if animal then dog' (¬∀ animals: animals⇒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' (∃ animal: animal⇒dog). The reverse '∃dog:dog⇒animal' is trivial.
In the meaning ('semantics') of 'dog', '∀dogs: dog⇒animal' is already decided.

MODAL LOGIC MAKES POSSIBILITY SUBORDINATE TO TRUTH

If you are looking for conditions to make something possible, 'modal logic' offers two new operators (□ and ◊). 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 ('□c').

An assertion 'c' (for example 'it is freezing') being not true now and here (¬c), *can* be true in other seasons, in other parts of the world, in any future~ or even possible world.
Possibly 'c' (◊c) is defined as 'not necessarily untrue' (¬□¬c).[b] So, possibity is defined by truth based operators and variables (¬, □, ¬, c), and consequently *part* of truth based reasoning.

If you accept that anything true must be possible, not the reverse (***Fig.2***p7), then this definition is not acceptible. ‘Must’ *supposes* ‘can’, not the reverse.

Moreover, the modal verb 'must' (the operator □) is subject to a wide range of suppositions[c].
If possible worlds necessarily 'must' be logical (relatable), credible (doxastical), existable (metaphysical), nameable (analytical), knowable (epistemical) or tolerable (deontical), then ‘must’ requires accepting less or more of these suppositions in the modal logic.

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 □ and ◊.
System 'T' adds that if p is necessary, then p is always true (□p⇒p). From this it can be proven

a Introduced by **Leibniz(1710)Essais de Théodicée sur la Bonté de Dieu, la liberté de l'homme et l'origine du mal(Amsterdam)Changuio**.
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)A new introduction to modal logic(Abington)Routledge** p17.
c **Divers(2002)Possible worlds(Abington)Routledge** p4.

that what is true is at least possible (p⇒◊p). That is not yet fixed in 'K'.
System 'D' adds to 'K' that what is necessary is also possible (□p⇒◊p).

A logical claim, however, can only be true or false. The statement a⇒◊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 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.

§ 17 DESIGN REQUIRES MORE DIMENSIONS THAN THE LOGIC SPACE

IF TRUE, THEN POSSIBILE

Modal logic makes possibility subordinate to truth, whereas what is true must certainly be possible, and that is more than a word-bound 'not necessarily not'.

Current logic is limited to 'truth values'. It does not include ⊥ paradoxes (***Fig.7***p10).
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 'practically possible' I can define 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 ⇓ a ('c supposes, is possible, by a'). For example: Culture ⇓ Biotics ⇓ Abiotics, where ‘⇓’ means 'is supposed in' or ‘is made possible by’. 'Makes possible', or 'enables' then gets the symbol ⇑: Abiotics ⇑ Biotics ⇑ Culture (***Fig.13*p13**).

The ‘supposes’ operators *include* the truth-valued implications: Culture ⇒ Biotics ⇒ Abiotics, in case there are no alternatives (necessity).
According to ***Fig. 60***p46, however, there are explicitly other alternatives x, y ... instead of 'a' making 'c' *possible*. Four exercises in the next section study when ⇓ and ⇑ are required.

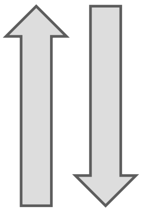
That 'c ⇒ a' is the only (or strictly necessary) possibility for c or a is not acceptable for designers in their search for nonlinear sideward possibilities. Unfortunately, this 'necessity' is often assumed as self-evident by 'scientifically trained' truth-bound advisors and experts.

If a designer wants to present a possibility as feasible, then '∃ possibility: possible ⇒ true' is not the right statement. ‘If animal then dog’ is not valid either. '∃ possibility: possible ⇐ 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 the meaning in common logic is different and inadequate for designers. The modality of common logic is not desirability or possibility, but '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.2***p7).

EXERCISE 1. MODALITIES ARE LOGICAL IMPLICATIONS.
Implying true ⇒ probable ⇒ possible ⇒ imaginable allows stating 'desirable' ⇒ imaginable, problems as probable∧¬desirable and aims as desirable∧possible∧¬probable (***Fig.10***p11).
So, the usual logical operators are sufficient for modalities.

EXERCISE 2. LAYERS OF *CONTEXT* DO NOT IMPLY (⇒), BUT SUPPOSE (⇓) 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 (***Fig11p13***)?
I distinguish the following layers of context with primitive definitions in brackets:



governance (management, administration, organization, based on a culture),
culture (a set of common assumptions and provisions, based on an economy),
economy (transport and exchange of goods and services, based on techniques),
technique (providing improbable opportunities, based on biotics),
biotics (a locally entropy-lowering metabolism, based on abiotics),
abiotics (matter with increasing entropy).

These may have an ↑or↓conditional stacking. Which is right?

The necessary condition cuts off possibilities
Suppose first: 'governance ⇒ culture ⇒ economy ⇒ technology ⇒ biotics ⇒ 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 '⇒', see ***Fig.57***p43). Governance implies a collection of shared self-evident assumptions: 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 assumptions 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 ⇒ 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.9***p10) 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 ⇒ culture ⇒ 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 ⇐ culture ⇐ economy ⇐ technology ⇐ biotics ⇐ physics'.
This means: 'then governance if culture', 'then culture if economy', and so on.
That is possible, but not necessarily true.

The inverted implication ⇐ therefore is not useful if you want to leave unrealized (stll 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' ⇐ does not suffice.

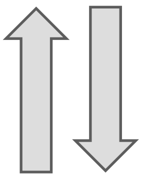
Design requires a possibility condition
I prefer 'Governance ⇓ culture ⇓ economy ⇓ technology ⇓ biotics ⇓ physics': 'governance is possible by culture', 'culture is possible by economy', and so on.
You may read 'is possible by' as 'supposes' if it concerns imagination.

In the opposite direction you can use ⇑ ('culture makes governance possible' or 'enables governance').
In a special case (∃) you can still hold '*this* governance necessarily implies a culture' (⇒).
The possibility conditionals ⇓ or ⇑ include ⇒ or ⇐, without becoming ⇔.

Releasing the *necessity* from 'if ... then', is a liberation for a designer who seeks possibilities instead of truths or necessities. The tacit, but common, assumption of truth and necessity, plays the leading role in every communication. A good designer questions current assumptions and only comes up with something new if some assumptions 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 (⇒), BUT SUPPOSE (⇓) EACH OTHER
The previous exercise concerned layered characteristics of the design *context* (***Fig.12***p13).
This exercise studies the conditional sequence of 'layers' of the design-*object* (***Fig.11***p***13***):



intentions (focus on a *field* of goals).
function (directed operations that may be intended),
structure (a set of separations and connections that enables directed operation),
form (a durable and thus recognizable state of dispersion that can get structure),
content (material, substance which can take form),

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. Is'nt it simply a logical sequence?

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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)Inleiding Milieuplanning(Delft)TUD Intreerede

The necessary condition (⇒) is not necessary
Assume first the implication: content ⇒ form ⇒ structure ⇒ function ⇒ 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 (⇐) misses opportunities
Assume then the 'sufficient condition': content ⇐ form ⇐ structure ⇐ function ⇐ 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 ⇓.

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 (⇑) separation, then separation supposes (⇓) connection.’
   This is not valid if connection is a special case of (zero) separation (§ 1p5).
6. ‘If separation enables (⇑) connection, then connection supposes (⇓) separation.’

Conditional 6 would indicate that large supposes small.
Some other arguments support that proposition.

a Cicero(-55)De oratore II 531(Cambridge Mass 1959)Harvard University Press Loeb.Heinemann p465

Counting starts by one, 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 pictural composition without components. The reverse I can.

§ 18 MINIMAL SUPPOSITIONS ENABLE LANGUAGE AND LOGIC

Abiotic :	difference	⥣ change	⥣ object[a]	⥣ separation	⥣ combination	⥣ B
Biotic :	metabolism	⥣ regulation	⥣ organization	⥣ specialization	⥣ reproduction	⥣ C
Conceptual :	imagination	⥣ safety	⥣ attachment	⥣ identity	⥣ influence	*(individual)*
Cultural :	empathy	security	loyalty	publicity	power	*(social)*

A Language makes a *difference* between words. It enables to imagine *change* by verbs, *objects* by nouns, *separation* by spaces and points in the text, and *combination* in sentences.

B Metabolising an image into text, is a human co-action[b]. Language *regulates* by adjectives and adverbs, *organises* by grammar, *specialises* by indicating an active subject and a passive object around a verb, and *reproduces* the formulated image in an expression.
Publishing expressions may change shared suppositions (culture).

C They enable to *imagine* someone else's (friendly or hostile) thoughts (empathy).
That enables security (*safety, certainty*)⥣loyalty(*attachment*)⥣public *identity*⥣power (*influence*).
With these presuppositions, language enables influence individually and socially.

These cultural conditions, however, step into a larger environment of imaginations.
The *influence* ('influx') from active source into passive receivers encounters the barriers of p10, and, for example, a scale paradox of agreement in a small circle and rejection in a larger one.

Speaking *about* language (in the same language), also hides an inside-outside paradox.
'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 form the outside, the other from the inside.[c]

In order to avoid eventual perpendicularity paradoxes, verbal language often requires sustaining physical sign language. Learning words in childhood depends on images and sign language, for example concerning *directions* such as 'left' and 'right'.
Even adults need additional emoticons expressing the intention of the 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 cannot not fully cover imagination.
Whereof you cannot speak, you should sculpture, draw, (with gradients) paint or act physically.

---

a 'Object' may refer to a part of reality remaining *different* from the rest and resisting *change* ('coherence').
b 'Co(a)gito' is latin for 'I think' as a parallel action.
c A variant of Russell's paradox that a set cannot contain itself as an element. **Russell(1903)The Principles of Mathematics(Cambridge)University Press** p101

Logic *supposes* verbal expression, language. ‘Truth’ does not exist without a verbal language. Formal logic specifies (makes a difference between) 16 conjunctions such as 'not' (¬), 'and' (∧), or 'if…then' (⇒), and it decides conclusions to be true or not true.

Modal logic[a] extends logic with 'possibly' (◊) and 'necessarily' (□), but it still accepts 'it is true to be possible' ('an animal is a dog'), instead of 'it is possible to be true' (‘a dog is an animal’).

A hidden supposition of verbal language and thus of formal logic is its linearity.
'*If* you take the car, *then* you will ride'. But in a wider scope, a necessary condition ('If..then' ⇒) is not 'necessary'. The car has *possible* alternatives (train ⇒ ride) and side-effects (car ⇒ drivers licence). In the same way a sufficient condition (⇐) is not 'sufficient'. It neglects alternatives.

Logic forbids contradictions 'x and not x' (x∧¬x) or 'if x then not x' (x⇒¬x), but a road connects *and* separates perpendicular (⊥) to the connection.
So, if logic would contain a ⊥ operator, then x∧⊥¬x could be allowed.

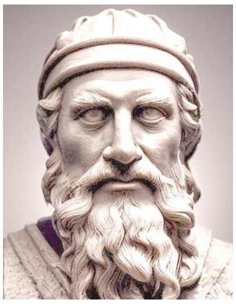
Logic hides another supposition. Logic values a⇒b as true if both a and b are true. So, it allows 'if blood is red, then the earth is round'. The two judgements, however, do not have anything in common, or as Ryle(1947)[b] states: a and b should be of the same 'type'. You also cannot imagine something ‘redder than round’.

Logic contains a subset of the suppositions of language, particularly the first row A.
It makes a *difference* between variables and operations that *change* the image of a judgement, but subordinating possibility to truth (p48) and the lack of Ryle's requirement (note b p54), the *coherence* of types (⥣ *separation* ⥣ *combination*), are still weak points in its design.

The other rows B and C are realised in the wider context of verbal language.

a **Hughes(2005)A new introduction to modal logic(Abington)Routledge** p17: *Possibly* 'x' (◊x) is defined as 'not necessarily un*true*' (¬□¬x).
b **Ryle(1949)The concept of mind(Chicago)University Press** 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

61 Euclides[a] *62 Schooten*[b] *63 Euler*[c] *64 Gauss*[d]

With Descartes (*Fig.36*p25) 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)Renate Descartes Geometria editio secunda(Leiden)Elsevier translated the French version of Descartes(1637)La Geometrie 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)Introductio in analysin infinitorum(Lausanne)Bousquet 2 and Euler(1765)Elements of algebra(London 1840)Longman coined the still usual expressions f(x), Σ, π, i (√-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)Disquisitiones Arithmeticae(Gottingen1863)SUB and Gauss(1827)General Investigations of Curved Surfaces(Princeton1902)University library made decisive contributions to almost every area of mathematics, as well as to physics, astronomy and statistics.

What is the design content of mathematics? Which discoveries are acually 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, even no longer imaginable as real objects (as 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. 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).

An exact repetition of operations on the result of the previous operation ('iteration'), may yield an infinite variety of images (fractals), but that variety is still smaller than that of nature.
Life does not repeat its operations exactly. Mutations then cause an unimaginable biodiversity.
Mathematics extends imagination of repetition, but any unique contradicts repetition.

The quantitative reduction of observed differences and changes requires fitting functions (showing *equal* behaviour as observed: ‘truth’), adaptable by ‘parameters’.
That 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 (Ἀεὶ ὁ θεὸς γεωμετρεῖ).
On the contrary, similar cases are re(pro)duced by human models enabling predictions.
Equalities between *different* models of the same case are accepted as a proof of ‘truth’.

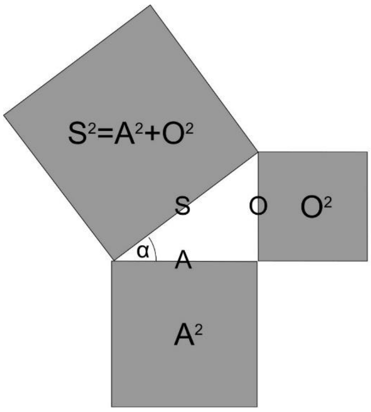
a Abramowitz;Stegun(1965)Handbook of Mathematical Functions(New York)Dover needed already more than 1000 pages.

§ 19 ANALYTIC GEOMETRY QUANTIFIES LOCATION AND DIRECTION

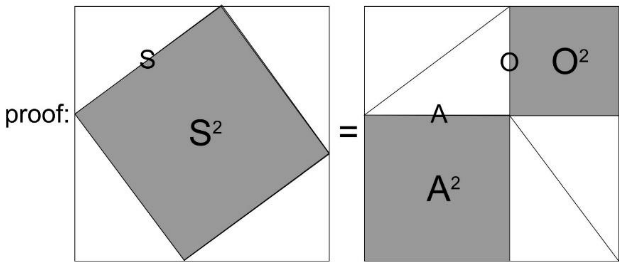
ANALYTIC GEOMETRY SUPPOSES CLASSICAL GEOMETRY [a]

055-056 Pythagorean theorem

055-056 Pythagorean theorem



65 Pythagorean theorem [b]



66 One of its proofs

Fig.65 shows a triangle with side lengths A=4 ⊥ O=3. Pythagoras predicts $S^2 = A^2+O^2$.[c]
So, $S = \sqrt{S^2} = \sqrt{(A^2+O^2)}$, in this case $S=5=\sqrt{25}=\sqrt{(9+16)}$. ***Fig.66*** 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 determinded 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(α), sin(α), tan(α) ór cot(α), then you know α ='arccos(A/S)', α = '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°=2π radians then a radian = 180°/π = 57.295… 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 added an separate coordinate system enabling such numbers ('analytic geometry'), based on one arbitrarily chosen point ('origin') and direction, determining ⊥ 'axes'.
Lines became sets of points, even describing any curve. But adjacent points do not have a size. You cannot add them into the length of curves. That required the invention of 'integration.'

These suppositions enable more complex geometric forms and their transformations than classical geometry.

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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 α = atan(O/A).
e Usually abbreviated to cos(α), sin(α), cot(α). A 'tangent' is abbreviated to tan(α). A mnemonic for the ratios of cos, sin, tan is 'cASsOStOA'.
f π = 3.141592653589793… , the ratio perimeter/diameter of a circle, where diameter = 2*radius. So, perimeter=2*π*radius or 2πr.
g 'Radian' may be abbreviated as 'rad'.

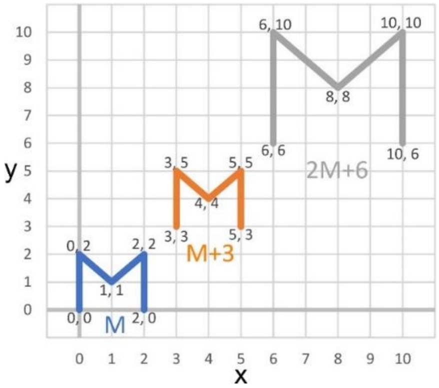
FIGURES MAY BE DRAWN AS A GRAPH AND TRANSFORMED

M.xar

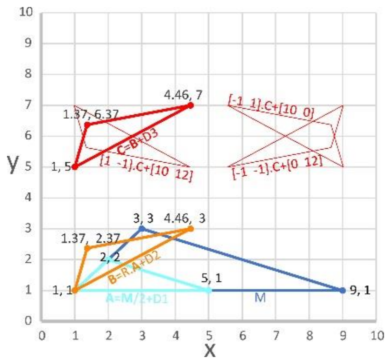
M.xls

M.wxmx

Driehoek2.xar



67 *Coordinates*



68 Transformations

Driehoek 058f.wxmx

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 $\boldsymbol{M}$).[c] If $\boldsymbol{M}=\begin{bmatrix}0&0&1&2&2\\0&2&1&2&0\end{bmatrix}$, then $\boldsymbol{M}$, $\boldsymbol{M}+3$ and $2M+6$ fully describe ***Fig.67***. The formulae produce the coordinates of the two 'transformations': $\boldsymbol{M}+3=\begin{bmatrix}3&3&4&5&5\\3&5&4&5&3\end{bmatrix}$, $2\boldsymbol{M}+6=\begin{bmatrix}6&6&8&10&10\\6&10&8&10&6\end{bmatrix}$.

Using symbols for different (changing) quantities clarifies how they are composed: if $\boldsymbol{M}=\begin{bmatrix}x_1&x_2\\y_1&y_2\end{bmatrix}$, then $\boldsymbol{M}+a=\begin{bmatrix}x_1+a&x_2+a\\y_1+a&y_2+a\end{bmatrix}$, $a\boldsymbol{M}=\begin{bmatrix}ax_1&ax_2\\ay_1&ay_2\end{bmatrix}$, $a\boldsymbol{M}+b=\begin{bmatrix}ax_1+b&ax_2+b\\ay_1+b&ay_2+b\end{bmatrix}$, and $\boldsymbol{M}[a\ \ b]=\begin{bmatrix}ax_1&ax_2\\by_1&by_2\end{bmatrix}$.[d] $\boldsymbol{M}[a\ \ b]$ distributes a *row* $[a\ \ b]$ ↴ over the *rows* of $\mathbf{M}\begin{bmatrix}x_1&x_2\\y_1&y_2\end{bmatrix}$. But, a 'dotproduct' $\boldsymbol{M}\bullet\begin{bmatrix}a\\b\end{bmatrix}=\begin{bmatrix}ax_1+bx_2\\ay_1+by_2\end{bmatrix}$[e] distributes a *column* 'vector' $\boldsymbol{v}=\begin{bmatrix}a\\b\end{bmatrix}$ ⤴ over the *columns* of $\mathbf{M}\begin{bmatrix}x_1&x_2\\y_1&y_2\end{bmatrix}$, *and **sums** the products*.[f]

Dotproducts.wxmx

$\boldsymbol{M}=\begin{bmatrix}x_1&x_2\\y_1&y_2\end{bmatrix}$ cannot be distributed over $\boldsymbol{v}=\begin{bmatrix}a\\b\end{bmatrix}$, so you cannot reverse $\boldsymbol{M}\bullet\boldsymbol{v}$ into $\boldsymbol{v}\bullet\boldsymbol{M}$. The vector *column* should have the same length as the *rows* of $\mathbf{M}$. Two matrices with the same length and width such as $\mathbf{M}=\begin{bmatrix}x_1&x_2\\y_1&y_2\end{bmatrix}$ and $\mathbf{A}=\begin{bmatrix}a_1&a_2\\a_3&a_4\end{bmatrix}$, can be multiplied without a problem: $\mathbf{AM}=\mathbf{MA}=\begin{bmatrix}a_1x_1&a_2x_2\\a_3y_1&a_4y_2\end{bmatrix}$, but a *dotproduct*, $\mathbf{A}\bullet\mathbf{M}=\begin{bmatrix}a_1x_1+a_2y_1&a_1x_2+a_2y_2\\a_3x_1+a_4y_1&a_3x_2+a_4y_2\end{bmatrix}$, differs from its reverse: $\mathbf{M}\bullet\mathbf{A}=\begin{bmatrix}x_1a_1+x_2a_3&x_1a_2+x_2a_4\\y_1a_1+y_2a_3&y_1a_2+y_2a_4\end{bmatrix}$.

Fig.68 reads $\boldsymbol{M}=\begin{bmatrix}1&3&9&1\\1&3&1&1\end{bmatrix}$ $\boldsymbol{A}=\frac{\boldsymbol{M}}{2}+\boldsymbol{D}_1=\begin{bmatrix}1&2&5&1\\1&2&1&1\end{bmatrix}$ $\boldsymbol{B}=\boldsymbol{R}\bullet\boldsymbol{A}+\boldsymbol{D}_2=\begin{bmatrix}1&1.37&4.46&1\\1&2.37&3&1\end{bmatrix}$ $\boldsymbol{C}=\boldsymbol{B}+\boldsymbol{D}_3=\begin{bmatrix}1&1.37&4.46&1\\5&6.37&7&5\end{bmatrix}$. The transformations $\frac{M}{2}$ and $\mathbf{R}\bullet\mathbf{A}$ alone, also change the *location* $\begin{bmatrix}1&\cdots\\1&\cdots\end{bmatrix}$ of the triangle. So adding $+D_1=\frac{1}{2}$ restores $\begin{bmatrix}1&\cdots\\1&\cdots\end{bmatrix}$, $+D_2=[0.634,-0.366]$, restores $\begin{bmatrix}1&\cdots\\1&\cdots\end{bmatrix}$, and $\mathbf{D}_3=[0\ \ 4]$ adds the move into $\begin{bmatrix}1&\cdots\\5&\cdots\end{bmatrix}$. R rotates $\mathbf{A}$: $\mathbf{R}\bullet\mathbf{A}=\begin{bmatrix}a&b\\-b&a\end{bmatrix}\bullet\begin{bmatrix}x_1&x_2&\cdots\\y_1&y_2&\cdots\end{bmatrix}=\begin{bmatrix}ax_1+by_1&ax_2+by_2&\cdots\\ay_1-bx_1&ay_2-bx_2&\cdots\end{bmatrix}$, see the next page for details.

A.R is RT.AT.wxmx

You then can mirror $\mathbf{C}$ with the *y-axis* as a mirror: $[-1\ \ 1]\bullet\begin{bmatrix}1&1.37&4.46&1\\5&6.37&7&5\end{bmatrix}=\begin{bmatrix}-1&-1.37&-4.46&-1\\5&6.37&7&1\end{bmatrix}$. Adding $+\begin{bmatrix}10\\0\end{bmatrix}$ makes the x's positive and restores the location right from the y-axis. Multiplying by $[1\ \ -1]$ makes the *x-axis* the mirror, and $[-1\ \ -1]$ does both. In ***Fig.68*** 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'.

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a **Oresme (1350–1360)Tractatus de configurationibus qualitatum et motuum(Venice 1482)Blasius** invented the first graphs visualising the relation of two variables on perpendicular coordinates 'latitudo' and 'longitudo' (three centuries before Descartes).

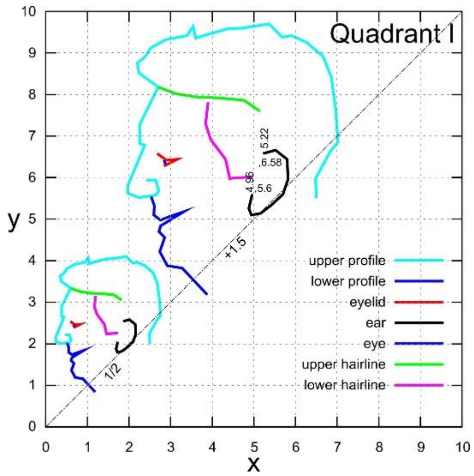
b **Katz(1993)A history of mathematics(New York)HarperCollinsCollegePublishers** p623: "In 1858, **Cayley** introduced single letter notation for matrices and showed not only how to multiply them but also how to add and subtract."

c Vectors (single rows or columns) and matrices (with rows and columns) are usually written **bold**, matrices in **bold CAPITAL**. For example: **v** and **M**.

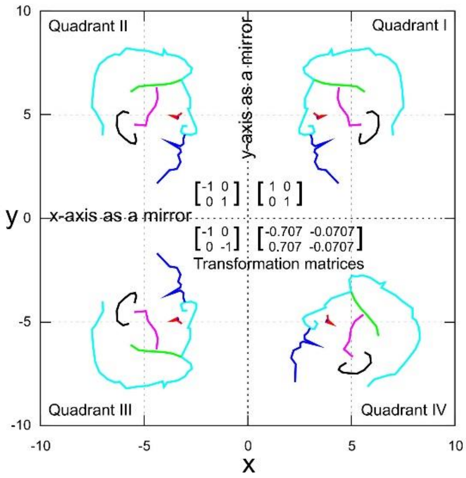
d Simple multiplication signs are omitted in order to distinguish a simple product from two kinds of 'matrix multiplication': the 'dotproduct' (•) and 'crossproduct' (×), see ***Fig.74***p55. A simple product as ax, however, is sometimes made explicit as a*x (with a star-like sign for simple multiplication), for example if 'ax' is used elsewhere as a single two-letter variable.

e The simple multiplication requires a 'rowvector' [a b]**M**, the dotproduct a columnvector $\begin{bmatrix}a\\b\end{bmatrix}\bullet\boldsymbol{M}$. Transposing is noted as $[a\ \ b]^T=\begin{bmatrix}a\\b\end{bmatrix}$. The dotproduct is further explained on page 55.

f Inventors of the dotproduct: **Lagrange (1736–1813)**, **Grassmann (1809–1877)**, **Hamilton (1805–1865)**.



69 Multiplying x and y equally



70 … or by different numbers

In ***Fig.69***, 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, also 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.69***, should be 'transposed' into a suitable matrix[a] M: $\begin{matrix} x \\ y \end{matrix}\begin{bmatrix} 3.72 & 4.02 & 4.3 & 4.32 & 4.2 & 3.92 & 3.66 & 3.44 & 3.38 & 3.46 \\ 5.08 & 5.16 & 4.94 & 4.46 & 4.1 & 3.84 & 3.64 & 3.6 & 3.76 & 4.1 \end{bmatrix}$, where x and y are not represented in pairs, but each get their own row for a different operation.[b]

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:
$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \bullet \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} ax_1 + by_1 & ax_2 + by_2 & \dots \\ cx_1 + dy_1 & cx_2 + dy_2 & \dots \end{bmatrix}$ or $\begin{bmatrix} a & 0 \\ 0 & d \end{bmatrix} \bullet \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} ax_1 & ax_2 & \dots \\ dy_1 & dy_2 & \dots \end{bmatrix}$, 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 $\begin{bmatrix} ½ & 0 \\ 0 & ½ \end{bmatrix} \bullet \begin{bmatrix} x_1 & x_2 & \dots \\ y_1 & y_2 & \dots \end{bmatrix} = \begin{bmatrix} \frac{x_1}{2} & \frac{x_2}{2} & \dots \\ \frac{y_1}{2} & \frac{y_2}{2} & \dots \end{bmatrix}$.[c]

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.70*** 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 $\begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$ (qIII) both axes are. Moreover, four numbers enable a rotation.

In ***Fig.70 IV*** the ↻ angle of rotation α = 135º = 135 π/180 radians = 2.36 radians, applied on an already mirrored ***I***. The ↻ rotation matrix is $\begin{bmatrix} \cos(\alpha) & -\sin(\alpha) \\ \sin(\alpha) & \cos(\alpha) \end{bmatrix} = \begin{bmatrix} -0.707 & -0707 \\ 0.707 & -0.707 \end{bmatrix}$.[d]

Finally, the figures ***70*** are moved into a proper location by adding some [Δx, Δy]: […]+[Δx, Δy].

a Sylvester(1850)On new class of theorems in elimination between quadratic functions(Philosophical Magazine)xxxvii 213—218 introduced the term "matrix", which he used to describe an array from which determinants could be derived. Cayley(1858)A memoir on the Theory of Matrices(Philosophical Transactions of the Royal Society of London)148 17-37 defined matrix multiplication, and the inverse of a matrix.

b Transpose the coordinates back in [x,y]-pairs, in order to make the results readable for a graphics program.

c So, the matrix $\begin{bmatrix} 1/2 & 0 \\ 0 & 1/2 \end{bmatrix}$ can be replaced by the single factor ½. A single factor replacing a matrix, is called the 'eigenvalue' of the matrix.

d The ↺ rotation is $\begin{bmatrix} \cos(\alpha) & \sin(\alpha) \\ -\sin(\alpha) & \cos(\alpha) \end{bmatrix}$ as has been applied in ***Fig.68***p52.

POINTS, LINES, ADDING VECTORS AND ⊥ VECTORS

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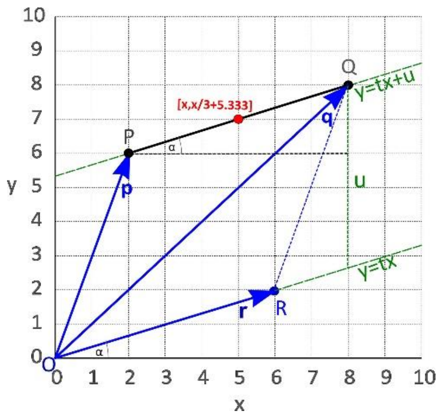
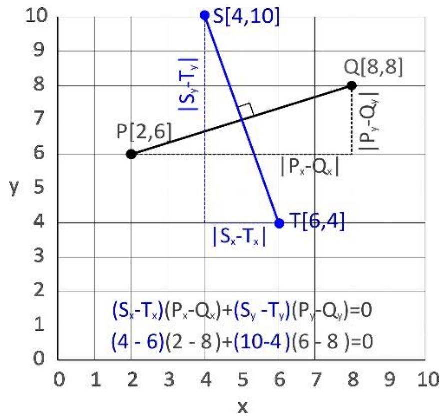
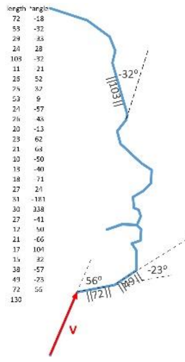
Ritter.xlsx







71 Points, lines, vectors ***72 ⊥ Line segments***[a] ***73 No grid***

The most simple description of a line is y=tx (***Fig.71***). 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*2+u and 8=t*8+u, solves t=1/3, u=5.333…, then read the line y=tx+u as y=x/3+5.333….

061 Points,lines,vectors.wx

For any x, any point of PQ or its carrier now is defined by [x , x/3+5.333…] or f(x)=x/3+5.333…. The slope t=1/3 is also reconizable as $\tan(\alpha) = |P_y\text{-}Q_y|/|P_x\text{-}Q_x| = 2/6 = 1/3$. So, α = atan(1/3) = 18.435°.

$PQ = \begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \end{bmatrix} = \begin{bmatrix} 2 & 6 \\ 8 & 8 \end{bmatrix}$ has a length $\left\|\begin{bmatrix} P \\ Q \end{bmatrix}\right\| = \sqrt{(P_x - Q_x)^2 + (P_y - Q_y)^2} = \sqrt{(2\text{-}8)^2 + (6\text{-}8)^2} = 6.324$ (Pythagoras).

In ***Fig. 72***, ST ⊥ PQ, because the dotproduct = 0 ($\begin{bmatrix} P_x - Q_x \\ P_y - Q_y \end{bmatrix} \bullet \begin{bmatrix} S_x - T_x \\ S_y - T_y \end{bmatrix} = (P_x\text{-}Q_x)(S_x\text{-}T_x) + (P_y\text{-}Q_y)(S_y\text{-}T_y) = 0$).

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. 71***, the vectors **p**$\begin{bmatrix} 2 \\ 6 \end{bmatrix}$ and **r**$\begin{bmatrix} 6 \\ 2 \end{bmatrix}$ are *added* into **q**$\begin{bmatrix} 8 \\ 8 \end{bmatrix}$, always fitting in a parallelogram. A vector, not starting at O$\begin{bmatrix} 0 \\ 0 \end{bmatrix}$ (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 $\begin{bmatrix} a \\ b \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} ax \\ by \end{bmatrix}$ behave the same way in any sequence, irrespective if you use colums or rows. A dotproduct[c] of vectors produces a single number ('scalar'), with the same behaviour : $[a, b] \bullet [x, y] = [a, b] \bullet \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a \\ b \end{bmatrix} \bullet \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} \bullet \begin{bmatrix} a \\ b \end{bmatrix} = ax + by$, but if you locate a row *after* a column, then it produces a matrix: $\begin{bmatrix} a \\ b \end{bmatrix} \bullet [x, y] = \begin{bmatrix} ax & ay \\ bx & by \end{bmatrix}$.

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 64). You even can get rid of any grid, starting with an arbitrary position, direction and length, a totally free vector **v**, (***Fig.73***) 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)Elements** used lines with direction and length for geometric translations, the geometric foundation for later vector-like thinking. **Archimedes(ca.-250)On the Equilibrium of Planes and On Floating Bodies** used lines with direction and length to model mechanical effects. **Newton(1687)Philosophiæ Naturalis Principia Mathematica** 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)Mechanica sive motus scientia analytice exposita I II** and **Euler(1765)Theoria motus corporum solidorum** formalized Newtonian mechanics in analytical terms, a major step. **Lagrange(1788)Méchanique analitique(Paris)Desaint** 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.

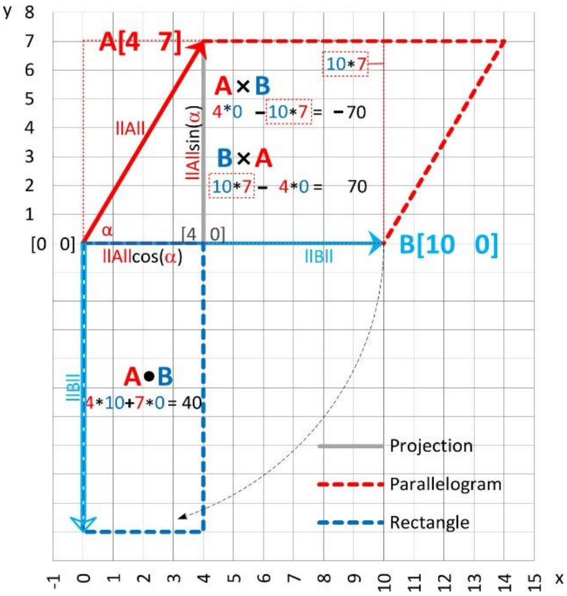
MULTIPLYING AND PROJECTING VECTORS

DotCross Borisenko(1968)p014

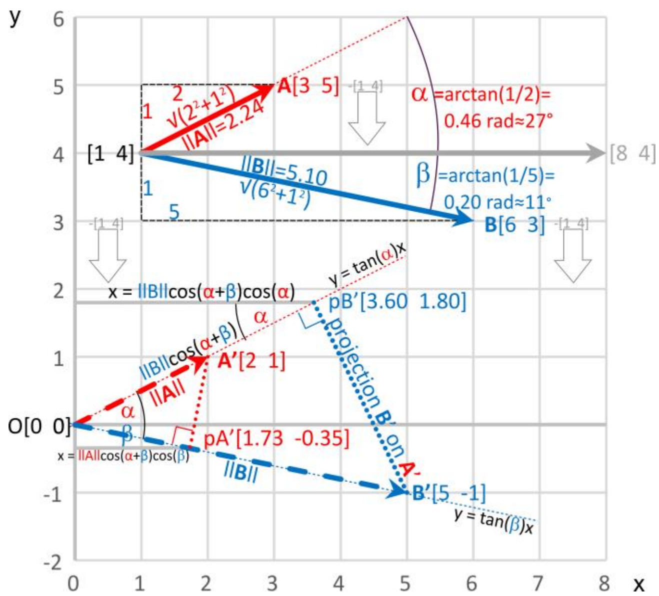
DotCross.xar

Borisenko(1968)p006.xlsx

Borisenko(1968)p006 projectie.xar



74 Dot- (•) and crossproduct (×)



75 Perpendicular projections

Fig.74 shows a dotproduct $A \bullet B = a_x{*}b_x + a_y{*}b_y = 4{*}10+7{*}0 = 40$ as a surface.
So, you can also calculate that by length*width: $\|B\|{*}\|A\|\cos(\alpha) = 10{*}8{*}0.5 = 40$.
If the surface $A \bullet B = 0$, then A and B are apparently rectangular: $\alpha = 90°$ or $\pi/2$ rad.

The ⊥ projection [[4 7],[4 0]] on B has a length $\|A\|\sin(\alpha)$.
Multiplying that length by $\|B\|$ delivers the surface of a parallelogram.
Calculate it as $B \times A = b_x a_y - a_x b_y = 70$, called the 'crossproduct'.[a]
If the surface $B \times A = 0$, then A and B are parallel.

In ***Fig.74*** $\|B\|{*}\|A\|\sin(\alpha) = B \times A = 70$, 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 ↺ or negative ↻.
Imagine the vector in 3D as a screw, skrewed in ↻ or out ↺ ⊥ the plane of ***Fig.74*** at [0 0].

Fig.75 (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.75 (below) shifts A-[1 4], B-[1 4] and [1 4]-[1 4] into A', B' starting at the origin O[0 0].
That allows a more simple calculating of the ⊥ projections A'pA' on B', and B'pB' on and 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 $S{*}\cos(\alpha)$.

$S{*}\cos(\alpha) = \|B\|\cos(\alpha+\beta)\cos(\alpha) = 3.60 = x_B$. That's on the line $y_B=\tan(\alpha)x_B$. So, the y_B-coordinate = $\tan(\alpha){*}3.60$, and $\tan(\alpha) = ½$. You now may draw the end point of the ⊥ projection of B on A pB'= [3.60 1.80]. A similar approach counts for pA', resulting in pA'[1.73 -0.35].
Shifting all coordinates -[1 4] brings them simply back to the original position.

---

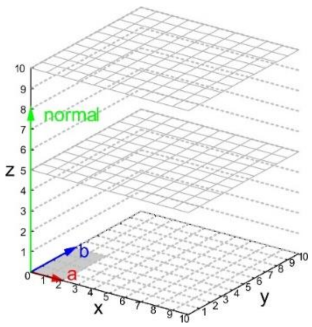
[a] Lagrange(1788)Méchanique analitique(Paris)Desaint laid the foundation of the dot product. **Grassmann(1840) Theorie der Ebbe und Flut(Prüfungsarbeit)** in **Grassmann(1844)Die lineale Ausdehnungslehre, ein neuer Zweig der Mathematik(Leipzig)Verlag von Otto Wigand** formalized the operations of vector algebra. **Hamilton(1843)On quaternions; or on a new system of imaginaries in algebra(Proceedings of the Royal Irish Academy)** outlined quaternion multiplication, which in modern terms decomposes into the dot and cross products. **Gibbs(1901)Vector Analysis: A Text-book for the Use of Students of Mathematics and Physics(New York)Charles Scribner's Sons** developed the cross product, based on Hamilton

VECTORS IN 3 DIMENSIONS

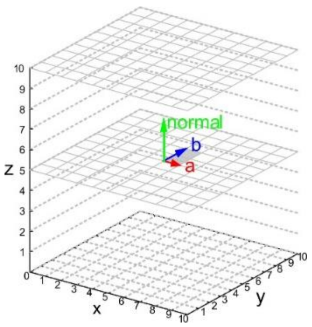
3D.xar

070 Verplaatsen, Vergroten, Draaien, vl

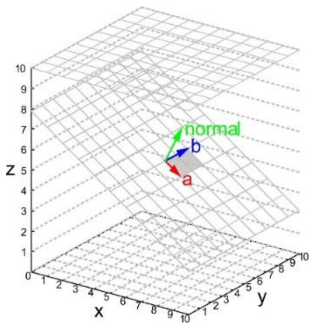
070 tekst.wxmx



76 The normal⊥a∗b



77 Reduced and displaced



78 Rotated

Cross product.wxmx

A third dimension requires vectors with 3 dimensions $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$.

A z-vector ⊥ **a** and b (their 'normal'), is a crossproduct **a** x **b**=[a_x,a_y,a_z] x [b_x,b_y,b_z]=[a_yb_z-a_zb_y , a_zb_x-a_xb_z , a_xb_y-a_yb_x].[a]

In ***Fig.76*** a_x=2 and b_y=4, the others are zero, so the normal **a** x **b** = [0,0,8] or $\begin{bmatrix} 0 \\ 0 \\ 8 \end{bmatrix}^T$.

Its length 8 equals the surface of the parallelogram[b] spanned by **a** and **b**.

Fig. 77 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 ½ , but ½², because the new surface is ½ a times ½ b.

So, the normal is the crossproduct of halved a *and* b: [1 0 0] x [0 2 0]=[0 0 2].

Sequence.wxmx

Rotating 3D requires extended transformation matrices:

Turn x

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(angle) & -\sin(angle) \\ 0 & \sin(angle) & \cos(angle) \end{bmatrix}$$

79 ↺x-axis

Turn y

$$\begin{bmatrix} \cos(angle) & 0 & \sin(angle) \\ 0 & 1 & 0 \\ -\sin(angle) & 0 & \cos(angle) \end{bmatrix}$$

80 ↺y-axis

Turn z

$$\begin{bmatrix} \cos(angle) & -\sin(angle) & 0 \\ \sin(angle) & \cos(angle) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

81 ↺z-axis

rotate first: $$\begin{bmatrix} 0.866 & 0 & 0.5 \\ 0 & 1 & 0 \\ -0.5 & 0 & 0.866 \end{bmatrix} \bullet \begin{bmatrix} 2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1.73 \\ 0 \\ 1 \end{bmatrix}^T$$

and then displace: $$\begin{bmatrix} 1.73 \\ 0 \\ 1 \end{bmatrix} + \begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix} = \begin{bmatrix} 6.73 \\ 5 \\ 6 \end{bmatrix}$$

82 Sequence of transformations

You cannot reduce and rotate ***Fig.76*** immediately into ***Fig.78***.

The *displacement itself* then would also be reduced and rotated.

Instead, first reduce a, b and calculate the new normal in ***Fig.76*** (with the origin as a starting point), then rotate them around the y-axis (- 30°), and finally displace the result into ***Fig.78***.

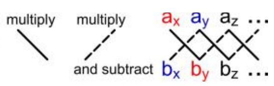
Note that in ***Fig.78*** a new xy plane of a and b has been drawn.

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 64 and next.

Crossproduct.xar

a Its logic: [a_xb_y-b_xa_y , ..-.. , ..-..] means 

. The cross product is also known as 'vector product'.

b Here, the parallelogram is a rectangle at the origin $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$ with two zero's: a=$\begin{bmatrix} 2 \\ 0 \end{bmatrix}$ and b=$\begin{bmatrix} 0 \\ 4 \end{bmatrix}$.

If they move in the xy-plane (z=0) into somewhere without zero's: **a**=$\begin{bmatrix} a_x \\ a_y \end{bmatrix}$ and **b**=$\begin{bmatrix} b_x \\ b_y \end{bmatrix}$, then the formula would be

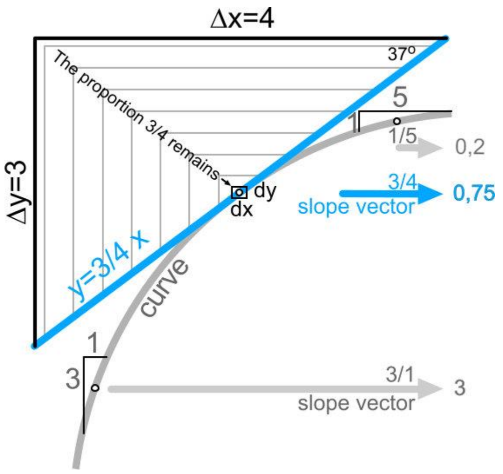
a × **b**=[a_x,a_y] × [b_x,b_y]=[a_xb_y-a_yb_x] (the sequence is important).

Its absolute |value| is called the 2D 'determinant' of **a** and **b**, the surface of a parallelogram (not necessarily ⊥).

A *volume*, spanned by three vectors **a**, **b** and **c**, equals the 3D determinant=c•(a×b), even if it is crooked.

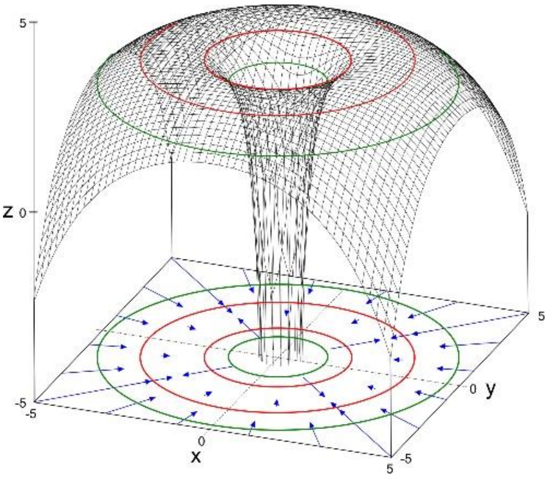
VECTORS REPRESENTING SLOPES, DIFFERENTIATION

Derivatives.xar
74.xar
contour2.wxm
Fields.xar



83 Derivatives as slope vectors

An angle is determined by a ratio of lengths Δy/Δx (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.

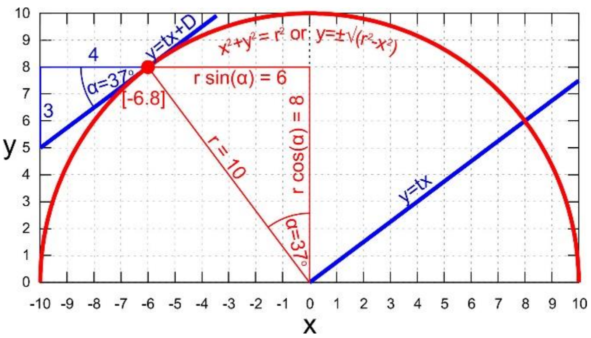


84 2D vector field of 3D derivatives

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.83*** an angle of 37° is defined by two ⊥ lengths: Δx=4 and Δy=3 (atan(3/4)*180/π=37°).
Their ratio Δy/Δx=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.84*** describes the (steepness of) the overarching 3D object as a 2D vector field.

LineCircle.xar
LineCircle.wxmx

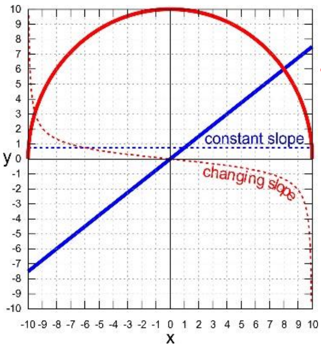


85 A line touching a circle

In ***Fig.83*** and ***Fig.85***, 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 $\alpha = \arctan(3/4) = 37°$ (***Fig.85***).

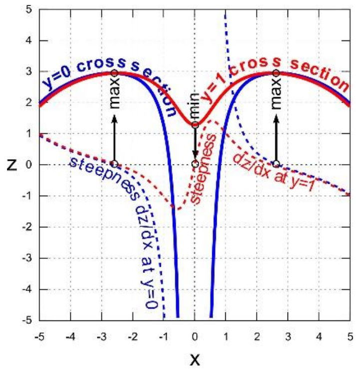
If r=10, then a similar rectangular triangle within the circle is fully determined.
So, x=-6 and $y = {}^3/_4(-6) + D = \sqrt{10^2 - (-6)^2} = 8$.
So, D = 12.5, and the point of contact is [-6 8].

Circle derivative.xar
Circle derivative.wxmx
contour.xar



< a constant positive slope dy/dx = 0.75,
and one rising and falling from y=∞ to -∞.
'differentiated' into derivatives dz/dx

Cross sections y=0 and y=1of ***Fig. 84***, with derivatives ±dz/dx of rising and falling slopes. >
Note o, the max, min, max 'extremes' at dz/dx = 0.



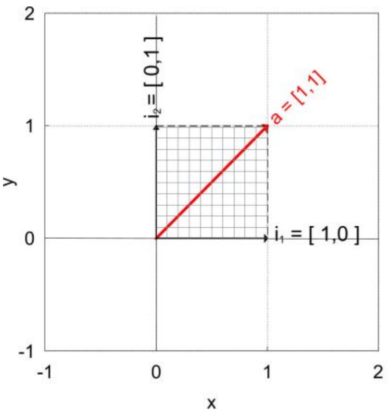
86 Line and circle derivatives

87 Two slices of Fig.84 and their derivatives

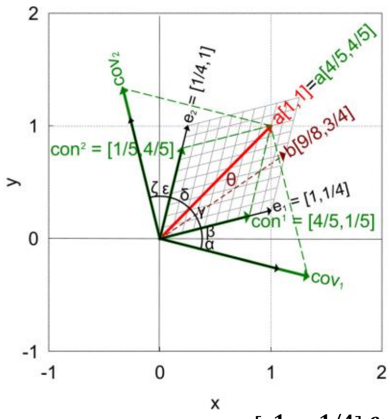
THE SAME VECTOR HAS DIFFERENT COORDINATES IN DIFFERENT GRIDS

78-80.wxm

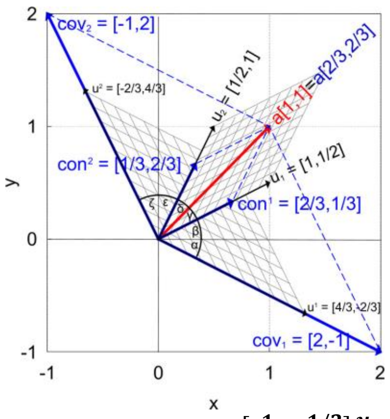
CoCon.xar



88 ***a*** ***on basis*** $i_k = \begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{matrix}i_1\\ i_2\end{matrix}$



89 ***on basis*** $e_k = \begin{bmatrix}1 & 1/4\\ 1/4 & 1\end{bmatrix}\begin{matrix}e_1\\ e_2\end{matrix}$



90 ***on basis*** $u_k = \begin{bmatrix}1 & 1/2\\ 1/2 & 1\end{bmatrix}\begin{matrix}u_1\\ u_2\end{matrix}$

In ***Fig.88***, a vector **a**=[1,1] is the sum of its components [1,0] and [0,1] coinciding with their units **i**. In ***Fig.89***, **a**=a=[4/5,4/5] defined by 'contravariant' components[a] con^1 and con^2 (*decreasing* compared to ***Fig.88***, if their units *increase*) or 'covariant' cov_1 and cov_2 (if both increase).[b]

The ratio $con^1/e_1 = 4/5$ is called α^1, and $con^2/e_2 = 4/5$ is called α^2, or write $\alpha^k = \begin{bmatrix}\frac{4}{5} & \frac{4}{5}\end{bmatrix}$, where k= 1 or 2:

081-082 ConCo.wxmx

$\alpha^k \begin{bmatrix}\frac{4}{5} & \frac{4}{5}\end{bmatrix} e_k \begin{bmatrix}1 & \frac{1}{4}\\ \frac{1}{4} & 1\end{bmatrix} =$ contravariant $\begin{bmatrix}\frac{4}{5} & \frac{1}{5}\\ \frac{1}{5} & \frac{4}{5}\end{bmatrix}\begin{matrix}con^1\\ con^2\end{matrix}$; sum: a [1 1]

$\alpha^k \begin{bmatrix}\frac{2}{3} & \frac{2}{3}\end{bmatrix} u_k \begin{bmatrix}1 & \frac{1}{2}\\ \frac{1}{2} & 1\end{bmatrix} =$ contravariant $\begin{bmatrix}\frac{2}{3} & \frac{1}{3}\\ \frac{1}{3} & \frac{2}{3}\end{bmatrix}\begin{matrix}con^1\\ con^2\end{matrix}$; sum: a [1 1]

$\alpha_k = 1/\alpha^k$ e^k=invert$(e_k)^T$ [c] $\qquad$ $\alpha_k = 1/\alpha^k$ u^k=invert$(u_k)^T$

$\alpha_k \begin{bmatrix}\frac{5}{4} & \frac{5}{4}\end{bmatrix} e^k \begin{bmatrix}\frac{16}{15} & -\frac{4}{15}\\ -\frac{4}{15} & \frac{16}{15}\end{bmatrix} =$ covariant $\begin{bmatrix}\frac{4}{3} & -\frac{1}{3}\\ -\frac{1}{3} & \frac{4}{3}\end{bmatrix}\begin{matrix}cov_1\\ cov_2\end{matrix}$; sum: a [1 1]

$\alpha_k \begin{bmatrix}\frac{3}{2} & \frac{3}{2}\end{bmatrix} u^k \begin{bmatrix}\frac{4}{3} & -\frac{2}{3}\\ -\frac{2}{3} & \frac{4}{3}\end{bmatrix} =$ covariant $\begin{bmatrix}2 & -1\\ -1 & 2\end{bmatrix}\begin{matrix}cov_1\\ cov_2\end{matrix}$; sum: a [1 1]

91 ***Contra- and covariants in Fig.89*** $\qquad$ **92** ***Contra- and covariants in Fig.90***

The contravariant sum Σcon^k=a[1,1], and the covariant sum Σcov_k= a[1,1]. Also under another basis u_k $\Sigma\alpha^k u_k = \Sigma\alpha_k u^k$ = a[1,1]. The vector a is 'invariant' under a change of basis.

Any angle[d] can be calculated:

Hoeken.wxmx

082b Angles.xlsx

$e_k = \begin{bmatrix}1 & \frac{1}{4}\\ \frac{1}{4} & 1\end{bmatrix}$ e^k=invert(e_k) in ***Fig.89***

α = -atan$(e^{1,2}/e^{1,1})$ = 14.04° $\qquad$ δ= atan$(e_{2,2}/e_{2,1})$-β-γ = 30.96°
β = atan$(e_{1,2}/e_{1,1})$ = 14.04° $\qquad$ ε= 90°-β-γ-δ) = 14.04°
γ = atan$(a_2)/(a_1)$-β = 30.96° $\qquad$ ζ= atan$(e^{2,2}/e^{2,1})$+(π/2) = 14.04°

$u_k = \begin{bmatrix}1 & \frac{1}{2}\\ \frac{1}{2} & 1\end{bmatrix}$ u^k=invert(u_k) in ***Fig.90***

α = -atan$(u^{1,2}/u^{1,1})$ = 26.57° $\qquad$ δ = atan$(u_{2,2}/u_{2,1})$-β-γ = 18.43°
β = atan$(u_{1,2}/u_{1,1})$ = 26.57° $\qquad$ ε = π/2-β-γ-δ) = 26.57°
γ = atan$(a_2)/(a_1)$-β = 18.43° $\qquad$ ζ= atan$(u^{2,2}/u^{2,1})$+ 90° = 26.57°

Note that α=β and ε=ζ (symmetry), α+β+γ+δ = 90° ($cov_1 \perp con^2$) and γ+δ+ε+ζ=90° ($con^1 \perp cov_2$).

Another vector **b** in ***Fig.89***, also based on **e**, has coordinates $\beta^1 e_1 + \beta^2 e_2 = 1*[1,\frac{1}{4}] + ½*[\frac{1}{4},1]$ = [9/8 3/4].

Metric.pdf

The cyclic dotproduct $g_{jk} = e_j \bullet e_k = \begin{bmatrix}e_1\bullet e_1 & e_1\bullet e_2\\ e_2\bullet e_1 & e_2\bullet e_2\end{bmatrix} = \begin{bmatrix}\frac{17}{16} & \frac{1}{2}\\ \frac{1}{2} & \frac{17}{16}\end{bmatrix} = \begin{bmatrix}E & F\\ F & G\end{bmatrix}$ (the '**metric**') fully characterises **e**.

Then $[\alpha^1, \alpha^2] \bullet \begin{bmatrix}E & F\\ F & G\end{bmatrix} \bullet \begin{bmatrix}\beta^1\\ \beta^2\end{bmatrix}$ implies a *function* $g(\alpha,\beta) = \alpha^1\beta^1E + \alpha^1\beta^2F + \alpha^2\beta^1F + \alpha^2\beta^2G$ calculating the lengths

Metric_tensor5.wxmx

$\|\mathbf{a}\| = \sqrt{g(\alpha,\alpha)} = \sqrt{2}$ = 1.41, $\|\mathbf{b}\| = \sqrt{g(\beta,\beta)}$ = 1.35, and the mutual angle **θ** = arccos$\left(\frac{g(a,b)}{\|a\|\,\|b\|}\right)$ = 0.119rad or 6.84°

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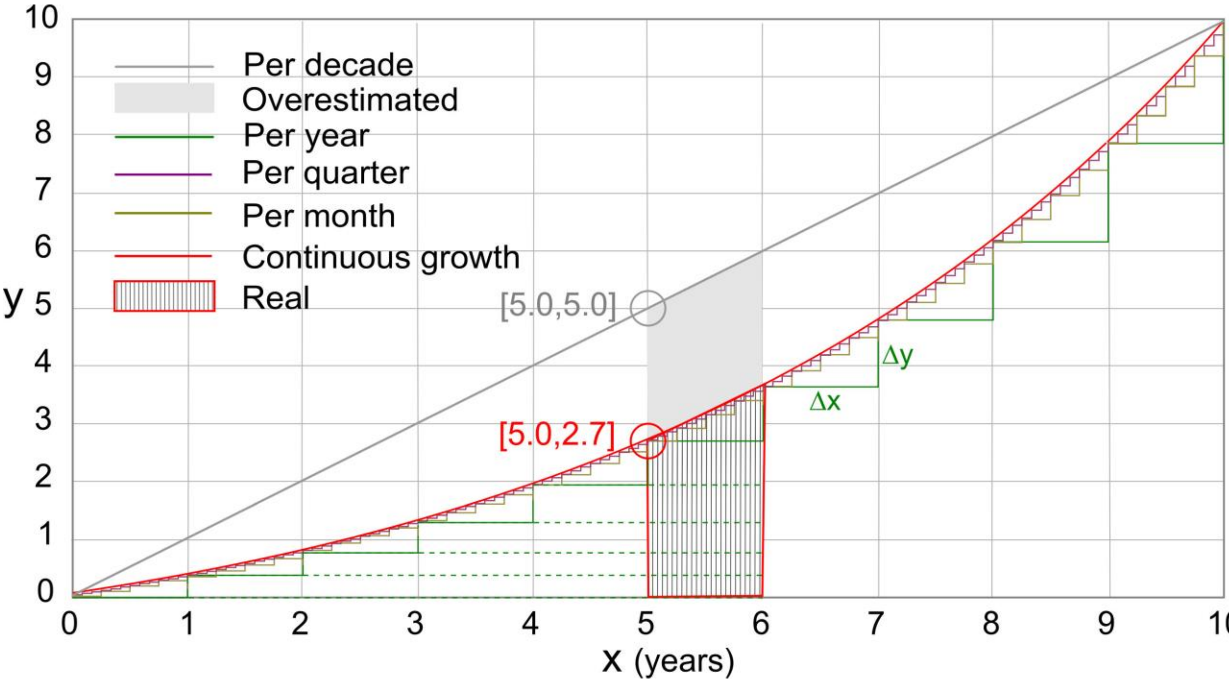
a The superscripts [1] and [2] as in con^1 and con^2 are here and further meant as indices ('tensor notation'), not as exponents e.g. in a quadrat x^2.
b Distinguished by Sylvester(1853)On a Theory of the Syzygetic Relations ...(Philosop.Trans.Royal Soc.London)143 407–548.
c The 'inverse' of $e^k \begin{bmatrix}a & b\\ c & d\end{bmatrix}$ is $e^k \begin{bmatrix}\frac{d}{ad-bc} & -\frac{b}{ad-bc}\\ -\frac{c}{ad-bc} & \frac{a}{ad-bc}\end{bmatrix}$. Their dot product, e.g.: $\begin{bmatrix}1 & \frac{1}{4}\\ \frac{1}{4} & 1\end{bmatrix} \bullet \begin{bmatrix}\frac{16}{15} & -\frac{4}{15}\\ -\frac{4}{15} & \frac{16}{15}\end{bmatrix} = \begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$ 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.

§ 20 CALCULUS DIVIDES AND SUMS INFINITELY SMALL QUANTITIES



93 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.93*** 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.85***p63), 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.93*** 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 $\frac{d}{dx}x^1 = 1x^0 (= 1)$, $\frac{d}{dx}x^2 = 2x^1$, $\frac{d}{dx}x^3 \to 3x^2$ 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 $y = x^1, x^2, \ldots$ are $\int x^1 * dx = \frac{x^2}{2} + c$, $\int x^2 * dx = \frac{x^3}{3} + c, \ldots$, where c is a constant. So, an integration has many possible results, depending on c.

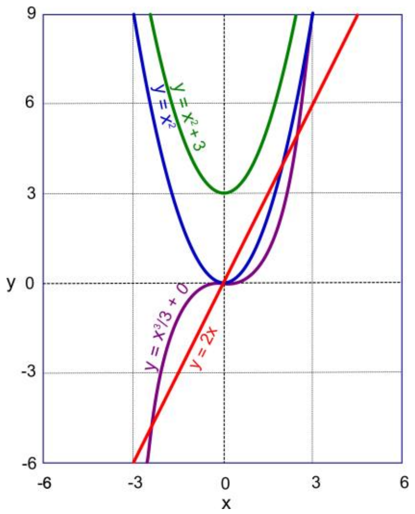
An integral may become infinite, but you may set boundaries to x ('definite integral'). For example, in ***Fig.93***, $\int_5^6 y\, dx$ (= 3.3) sums y*dx between x=5 and 6.

a The original drawing of Jelson25: https://commons.wikimedia.org/wiki/File:Compound_Interest_with_Varying_Frequencies.svg (edited here).
b **Newton(1671)**De Methodis Serierum et Fluxionum **(unpublished during his lifetime)** and **Leibniz(1684)Nova Methodus pro maximis et minimis, itemque tangentibus(Leibzig)Acta Eruditorum Octobris 467-473+Tab. xii** invented the method almost simultaneously, but Leibniz published it earlier and his notation is now common.

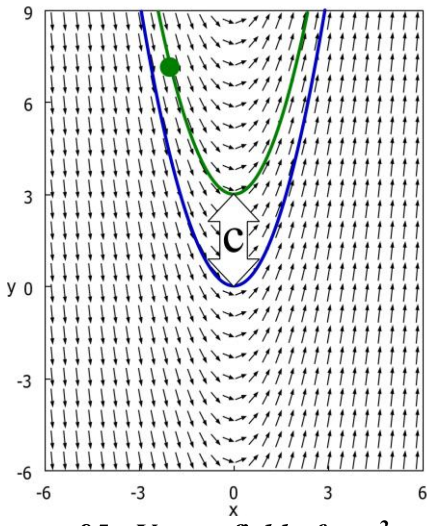
84-85.wxmx

84-85.xar

DIFFERENTIATING AND INTEGRATING ARE RECIPROQUE OPERATIONS



94 Differentiating and integrating



95 Vector field of $y=x^2+c$

Fig.94 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.95***). The original $y=x^2 + 0$ is one of them, but $y = x^2 + 3$ has also a derivative $y'=2x$.

Fig.95 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:	**Example:**
the original formula	$y=x^2$
its ***derivative***	$\frac{d}{dx}x^2 = 2x$ (the derivative of $x^a = ax^{a-1}$)
the backwards ***integral*** thereof	$\int 2x\, dx = x^2+c$ (c shifts the parabola vertically)
an ***ordinary differential equation (ODE)***	$\frac{d}{dx}y = x^2$ (if you know the slopes of y, then what is y?)
solving y in the ODE	$y = \frac{x^3}{3} + c$ (in ***Fig.94*** c=0)

ode.wxmx

'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.

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)Method of Fluxions(London 1736)Nourse formed the foundation for solving ODEs in mechanics.
Leibniz(1684)Nova Methodus pro maximis et minimis, itemque tangentibus(Leibzig)Acta Eruditorum Octobris 467-473+Tab. xii , provided tools and notation that made solving ODEs more accessible and generalizable.
Bernoulli, Johann (1695)Principia Calculi Exponentialium Seu Percurrentium(Acta Eruditorum 1697)125 Studied separable and homogeneous equations.
Alembert(1743)Traité de dynamique(Paris)David Applied ODE's to mechanics systematically.
Euler(1744)Methodus inveniendi lineas curvas maximi minimive proprietate gaudentes(Lausanne, Geneve)Bousquet and Euler(1755)Institutiones Calculi Differentialis(Petropolitanae)Academiae Imperialis Scientiarum greatly expanded the theory and solution techniques of ODE's.
Lagrange(1788)Mécanique analytique(Paris 1811)Courcier Unified differential equations and mechanics in a systematic mathematical framework.

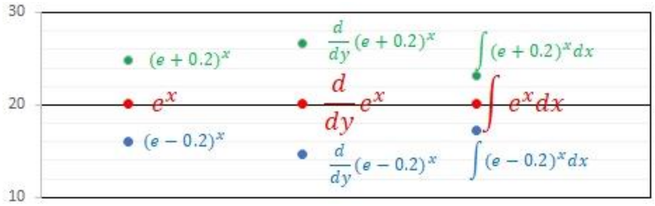
Differentiating and integrating e^x equals e^x
You may be used to logarithms based on 10: log(1)=0, log(10)=1, log(100)=2, and so on.
Calculus, however, uses the 'natural logarithm' ln(x) based on e= 2.718. . . ('Euler's number'[a]).
So, 10^3=1000 , but e^3=20. The exponential function 10^x, its derivative $\frac{d}{dx}10^x = 2.30 * 10^x$ and its integral $\int 10^x dx = 0.43 * 10.0^x$ differ. With base e, however, they are *equal*: $\frac{d}{dx}e^x = \int e^x dx = e^x$.

Fig 96 shows e^x, its derivative, and its integral as the same (20 for x=3).
That simplifies calculations.

88.xlsx

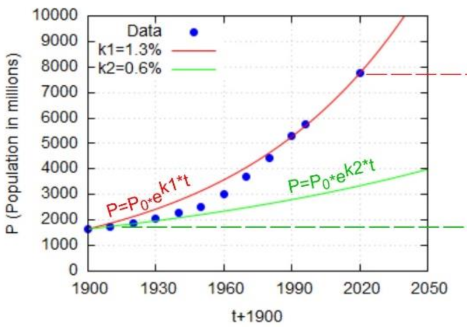
A little difference, e.g. (e+0.2) or (e-0.2) instead of e, already causes *different* outcomes. Any other base such as 10 produces a difference.

Eulers number.wxmx



96 The middle: small differences of e already produce different derivatives and integrals

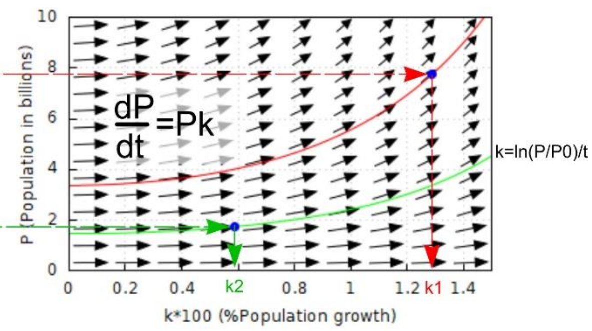
CALCULATING POPULATION GROWTH REQUIRES CALCULUS
Estimating the world population of 2050, you should use historical data (***Fig.97***).
The world population of 1650million in 1900 (P_{1900}) became 1750million in 1910 (P_{1910}).
That is 6% growth 'k' in a decade. You may first suppose that a population P_0 will grow with a growth factor k=0.06 in a time period (decade) t: $P(t)= P_{1900} + P_{1900}*k*t$.



86-87.wxmx

86-87.xar

97 Population data and models [b]



98 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.97***) 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.98***.

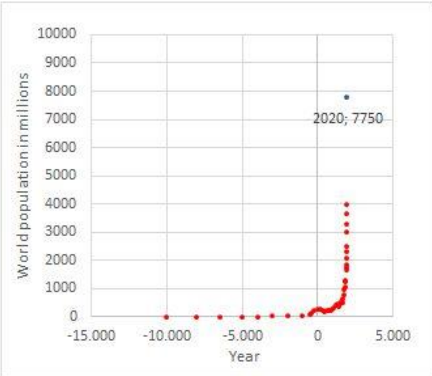
A known point (- - or - -) defines the curve. Solving $\frac{dP}{dt} = Pk$ gives $P = P_0 e^{kt}$, where $k = \ln(P_1/P_0)/t$.
If $P_0=P_{1900}=1650$million, $P_1=P_{2020} =7750$million, and t=2020-1900=120, then $k1 = \ln(7750/1650)/120 = 0.013$.
Once knowing k, you can calculate any population from 1990 and further:
$P_{1990}(= P_0e^{k1*t})=1650*e^{0.013*90} = 5\ 316$, or $P_{2050}(= P_0e^{k*t})=1650*e^{0.013*120}= 11\ 597$ million people.
That fits rather well with the known populations of 1990-2020 in ***Fig.97***.

---

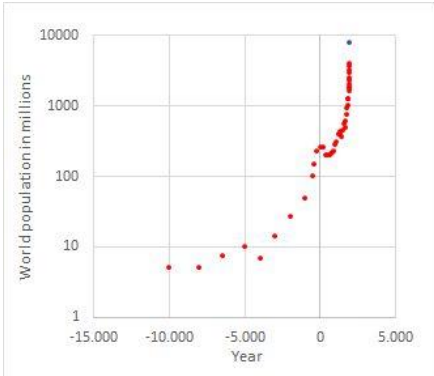
a **Napier(1614)Mirifici logarithmorum canonis descriptio(Edinburgh)Hart** discovered the 'right middle'. **Euler(1728) Meditatio in Experimenta explosione tormentorum nuper instituta**, called it 'e' and described its amazing properties for calculus and trigonometry in detail. It is finally called 'Euler's number'.
Translation in English: **Smith(1929)A source book in mathematics(New York)McGraw Hill p95**
b **Steward(1998)Calculus Concepts and Contexts(Pacific Grove)Cole Publishing Company p527-531**

AN OTHER TIME SCALE MAY REQUIRE A DIFFERENT FORMULA

The future world population (***Fig.99***p68) frightens me. ***Fig.100***p68 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.

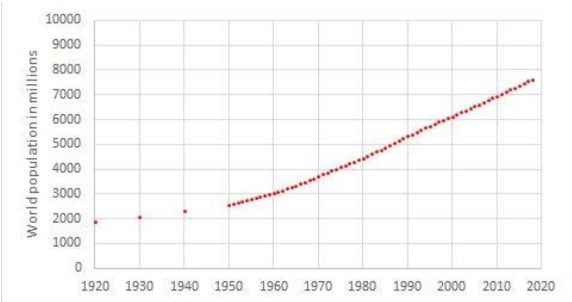


99 World population in 20 000 years[a]



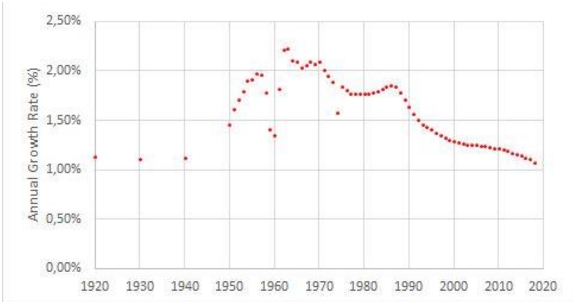
100 on a logarithmic$_{10}$ scale

Fig.101 shows a recent century in ***Fig.99*** : a world population doubling in 40 years.



101 World population P in a century [b]

91-92.xlsx



102 Growth rates k per year

Fig.102, 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.97***p67).

Verhulst(1845) included a carrying capacity as K in his 'logistic equation':
$\frac{d}{dt}P = P\left(1-\frac{P}{K}\right)k$, solved as $P = \frac{K}{1-e^{-ck}e^{-kt}}$, 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
$P(t) = \frac{K}{1+Ae^{-kt}}$. Solving A for an initial population P_0, delivers $A= (K-P_0)/P_0$.[d]

Fig.103p69 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.97***p67.

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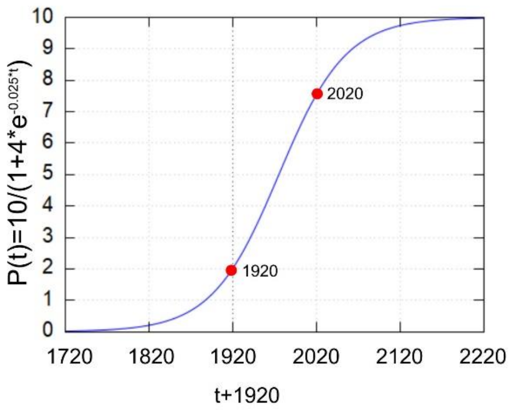
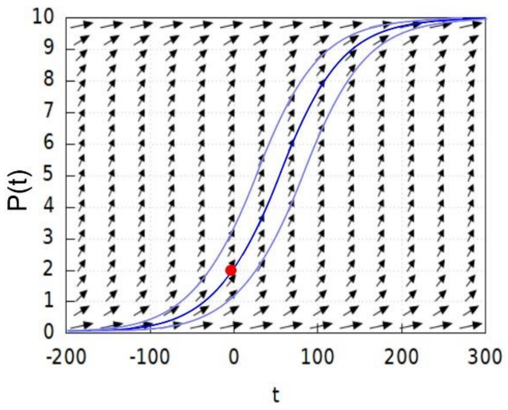
a Average of different sources from https://nl.wikipedia.org/wiki/Wereldbevolking .
b From 1975: https://www.worldometers.info/world-population/world-population-by-year/ up to 1975:
https://web.archive.org/web/20150426165332/http:/www.census.gov/population/international/data/worldpop/table_population.php .
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)An Essay on the Principle of Population, or a View of Its Past and Present Effects on Human Happiness, with An Enquiry into Our Prospects Respecting the Future Removal or Mitigation of the Evils Which It Occasions(London)Johnson**
d **Steward(1998)Calculus Concepts and Contexts(Pacific Grove)Cole Publishing Company** p540-541 shows this derivation in more detail.

93-94.wxmx
93-94.xar



103 A logistic Model 1720-2220



104 Vector field of $\frac{d}{dt}P = P\left(1-\frac{P}{K}\right)k$

Fig.103 predicts, that the world population should be stable in 2220.
The growth rate in ***Fig.102***p68 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.102***p68 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 ***100***p68 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

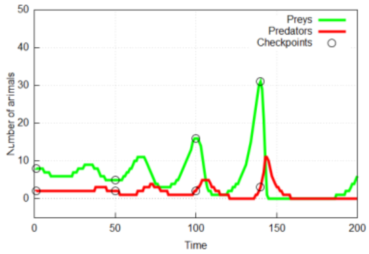
The growth of prey populations followed by those of predators eating them, depends on at least 6 supposed values ('parameters'), resulting in very different predictions, for example:

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

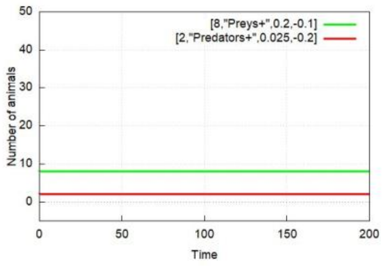
The 'Lotke-Volterra model'[a] with such parameters, predicts for time t:

the next population	=the previous population	+the same	∗(their growth rate	minus their decline):
$preys_t$	$=preys_{t-1}$	$+(preys_{t-1}$	$*(Gpreys$	$-Dpreys*predators_{t-1})$
$predators_t$	$=predators_{t-1}$	$+(predators_{t-1}$	$*(Gpreds*preys_{t-1}$	$-Dpreds)$.

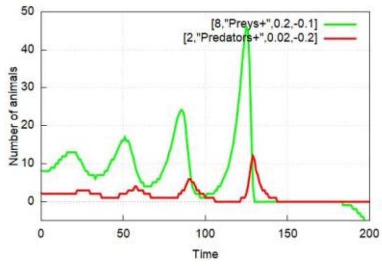
95-100.wxmx



105 Survival (Gpreds=0.029)



106 Equilibrium (Gpreds=0.025)



107 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.107*** shows after t=150 even imaginary negative numbers of prey, a clear message of extinction. At Gpreds=0.025 in ***Fig.106***, both seem stable.

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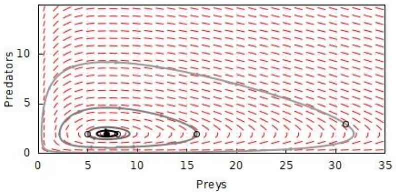
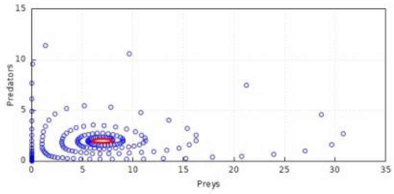
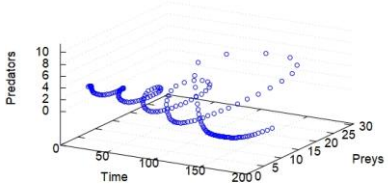
a Volterra(1926)Fluctuations in the abundance of a species considered mathematically(Nature)118: 558 – 560



108 A vector field around ● [6.9,2] with initial points○ [5,2], [8,2], [16,2], and [31,3]



109 Repeated jumping to the next cycle



110 Extruded in time

Fig.106p69, 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.108*** around ● [6.9,2], follows the vector directions.

The second part of Volterra's formula at page 69 describes the *change* of preys and predators as $preys*(Gpreys-Dpreys*predators_{t-1})$, and $predators*(Gpreds*preys_{t-1}-Dpreds)$. If they do *not* change, then the terms between the brackets are 0. That is the case if the number of $preys = \frac{Dpreds}{Gpreds} = \frac{0.2}{0.029} = 6.9$, and the number of $predators = \frac{Gpreys}{Dpreys} = \frac{0.2}{0{,}1} = 2$, together the 'equilibrium point' ● [6.9,2] in ***Fig.108***.

The other cycles in ***Fig.108*** apply the 'checkpoints' o of ***Fig.105***p69 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.108***. 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 harrased 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 69 systemativally change themselves, then the system may jump every time interval (Δt) into a larger cycle, resulting in a spiral (***Fig.70***). 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.109 shows a repeated jumping to a next larger cycle in the vector field of ***Fig.108***p70.
Fig.110 adds the dimension of time in 3D:
project the curve on the floor (the Preys-Time plane) to get the prey curve of ***Fig.107***p69;
project it on the front (the Predator-Time plane) to get the predator curve of ***Fig.107***p69.

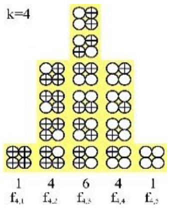
The values are not continuous as it is supposed in ***Fig.108***p70. So, calculus does not apply. The spiral has gaps $\Delta t=1$ instead of $dt \to 0$. The points, however, still do not represent individuals, but moments in time with imaginary fractions of animals.

§ 21 PROBABILITY REDUCES DIFFERENCES INTO DEVIATIONS

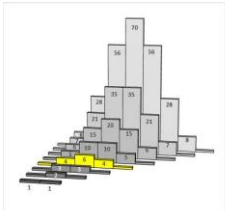
BINOMIAL CHANCE DETERMINES HOW OFTEN YOU CAN EXPECT A YES OR NO

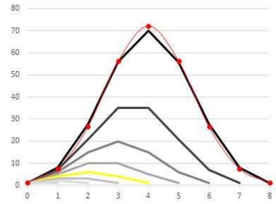
101 Frequences.xar

103-106.xlsx



k	f	Triangle	$\sum f_k = N$	=
1	f_1	1 • 1		
2	f_2	1 • 2 • 1	2^2	4
3	f_3	1 • 3 • 3 • 1	2^3	8
4	f_4	1 4 6 4 1	2^4	16
5	f_5	1 5 10 + 10 5 1	2^5	32
6	f_6	1 6 15 20 15 6 1	2^6	64
7	f_7	1 7 21 35 35 21 7 1	2^7	128
8	f_8	1 8 28 56 70 56 28 8 1	2^8	256





111 ***Frequencies*** ***112*** ***Triangle of Pascal*** ***113*** ***114*** ***The frequencies: roughly a clock shape***

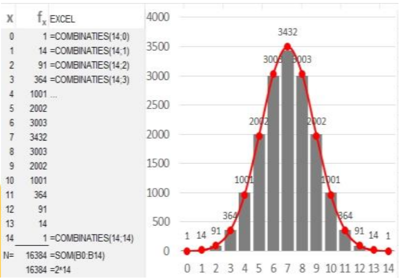
Tossing a coin, cross ⊕ or coin ○ both (bi-nomial) have equal chance or 'probability' $p = ½$ (50%).
Tossing twice (c=2), there are 4 possibilities (N=4): ⊕⊕, ⊕○, ○⊕, ○○ with each $p = ¼$ (25%).
After three times (c=3) it is one of N=8 combinations: ⊕⊕⊕, ⊕⊕○, ⊕○⊕, ○⊕⊕, ⊕○○, ○⊕○, ○○⊕ or ○○○.
With four 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.111***). 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.112***: for example 10 + 10 = 20). The sum of each row $N= \sum f_{0 \text{ to } c} = 2^c$. In row f_8 (c = 8 throws) there are already $N = 2^8 = 256$ possibilities in 9 frequencies. ***Fig.114*** suggests intermediate values, but the 'binomial distribution' itself is 'discrete'.

Galton[b] invented a board (***Fig.115***) 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 $f_0, f_1, f_2 \ldots f_{14}$. 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.

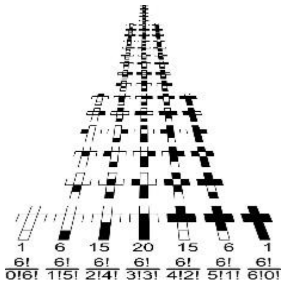
Probability.xlsm



$$\binom{N}{f_x} = \frac{N!}{f_x!\,(N-f_x)!}$$

$\binom{4}{1} = 4$ possibilities $\qquad \binom{4}{2} = 6$ possibilities $\qquad \binom{4}{3} = 4$ possibilities

$$\frac{1*2*3*4}{1*(1*2*3)} \qquad \frac{1*2*3*4}{1*2*(1*2)} \qquad \frac{1*2*3*4}{1*2*3*(1)}$$



115 ***Galton-board*** [c] ***116*** ***2^{14} = 16384 paths distributed over 15 columns*** ***117*** ***Binomium of Newton: f_x distributions in N*** [d] ***118*** ***64 possibilities to build on 6 locations***

There are 3432/16386 paths (21% chance) to end up in the middle (f_7, ***Fig.116***). Newton[e] invented a formula for all possibilities of any f_x in N (***Fig.117***), or for f_x elements on N plots (***Fig.118***). 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)Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière(Paris1665)Desprez** described the properties and applications of the arithmetical triangle, including binomial coefficients, combinatorial identities and probability applications.

b **Galton(1889)Natural Inheritance(London)Macmillan** 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.

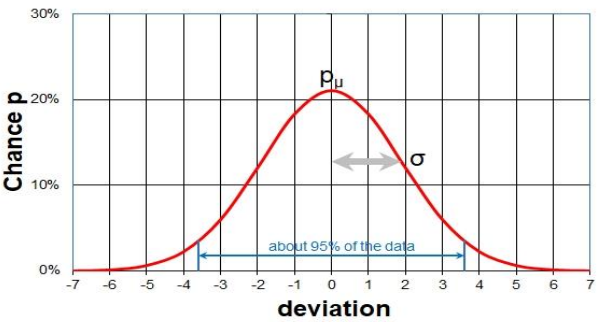
e **Katz(1993)A history of mathematics(New York)HarperCollinsCollegePublishers** p463 describes how Newton generalised Pascal's triangle and formula. He found a method to include broken integers studying infinit series.

A NORMAL DISTRIBUTION DETERMINES ANYTHING IN BETWEEN

Normal distribuition accordi

case	x	f	$u=x-\mu$	$(x-\mu)^2$	$f(x-\mu)^2$	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	$\Sigma(x-\mu)^2=$	280	57344	$=\Sigma f(x-\mu)^2$		
					16384	=N		
				variance	3,5	$=\Sigma f(x-\mu)^2/N$		
	$\mu = 7$			$\sigma=$	**1,870829**	$=\Sigma f(x-\mu)^2/N$		

119 Calculating σ from the frequencies of Fig.116p71 and…



120 , …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.114***p71, and ***Fig.116***p71. The average of all deviations x-μ determines how 'flat' the Gauss' formula (***Fig.120***) is, but if - and + deviations compensate eachother, then you cannot calculate that average. Squaring them makes all positive.

The square sum of all deviations $\Sigma(x-\mu)^2$ is therefore a positive measure for the total of all deviations from μ. That is on average $\Sigma(x-\mu)^2/N$ ('variance'). The root of the variance $\sqrt{(\Sigma(x-\mu)^2/N)}$ is the 'standard deviation' σ. If you measure the lengths of people in cm, then you get that variance in cm^2. That is a surface. Then, the square root $\sqrt{(\Sigma(x-\mu)^2/N)} = \sigma$ 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: $\sigma=\sqrt{(\Sigma f_*(k-\mu)^2/n)}$, 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.

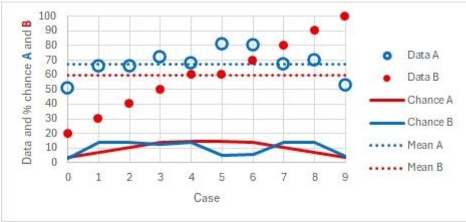
With the results of a sample n from a much larger mass N you may already estimate μ and σ quite nicely. You then instead of μ, σ, x write m, s, z. Gauss(m, s) predicts all outcomes within 'confidence limits'. Comparing your outcomes with that prediction, you may find deviations that require further explanation.

---

a That formula $\frac{1}{\sigma\sqrt{2\pi}}\cdot e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$ gives the chance of outcome x.
In Excel: NORMDIST(x;μ;σ;FALSE). With TRUE the cumulative version is calculated.

b **Gauss(1809)Theoria motus corporum coelestium(Hamburg)Perthes;Besser page 212** (latin) p259 (english) formulated least squares and normal distribution as $\varphi(x) := \frac{h}{\sqrt{\pi}} e^{-hhxx}$.. Gauss(1809)Theoria motus corporum coelestium(Hamburg)Perthes;Besser page 212

SAMPLES ALLOW CORRELATING 2 DATA SETS BY PROBABILITY TESTS



121 Data and normal chances

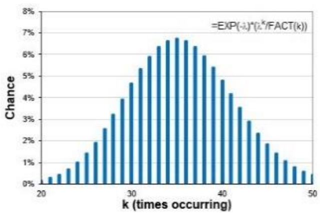
COUNTA(B2:B11)	10	10	n		number of cases
MODE.SNGL(B2:B11)	66	60	mode		most common result
MEDIAN(B2:B11)	67,5	60	median		middle result
AVERAGE(B2:B11)	67,4	60	μ ≈ m	$\Sigma_i z_i/n$	average
AVEDEV(B2:B11)	6,8	20,0	ū	$\Sigma_i(z_i\text{-}m) / n$	average deviation
VARP(B2:B11)	85,24	600,0	s^2	$\Sigma i\ (zi\text{-}m)^2 / n$	variance
	9,23	24,49	s	$\sqrt{\Sigma i\ (z_i\text{-}m)^2 / n}$	sample standard deviation
STDEV.P(B2:B11)	9,23	24,49	σ	$\sqrt{\Sigma i\ (x_i\text{-}m)^2 / N}$	standard deviation n = N mass
CHISQ.TEST(B2:C11;expected)	0,0%		χ^2	A and B still run a 0% chance of being dependent	
CORREL(B2:B11;C2:C11)	13,3%		r	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	
FTEST(B2:B11;C2:C11)	0,8%		F	insofar as independent, the variances differ considerably	

122 Comparative tests of Fig.121 in Excel

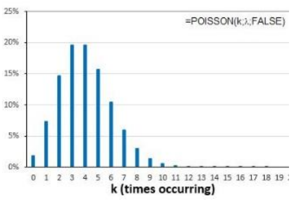
You may compare *two* different sets of data A and B. For example, ***Fig.121*** shows two data sets. ***Fig.122*** shows the differences, and 'tests' of relations between A and B.

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.121***, but these tests convince in case of many more data.

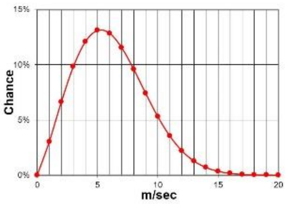
FEW FROM COUNTLESS CASES STILL HAVE A CHANCE TO OCCUR



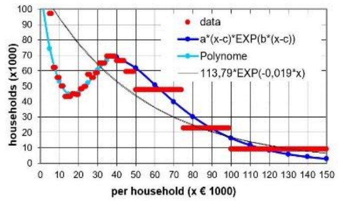
123 Poisson at λ=35,5



124 Poisson at λ=4



125 Weibull[b]



126 An income distribution[c]

A year counts 365*24*60*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.123***).

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.124***p73), then the Poisson distribution becomes skewed.

---

a Pearson(1900)On the Criterion That a Given System of Deviations from the Probable in the Case of a Correlated System of Variables is Such That It Can Be Reasonably Supposed to Have Arisen from Random Sampling(Philosophical Magazine)5 50 **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)Recherches sur la probabilité des jugements en matière criminelle et en matière civile(Paris)Bachelier

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 ASYMMETRICAL DEVIATIONS

There are other skewed probability distributions that start at 0, such as the continuous 'Weibull distribution' (***Fig.125***p73), e.g. used for wind velocities (≧0, in a given direction).

The distribution of incomes (***Fig.126***p73) is also distorted, but a bureau for statistics may provide data per 'class' (from .. to). In ***Fig.126***p73 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.96***p67).
In Excel you write e^x as 'EXP (x)'. If you click on an exponential 'trend line' in Excel for the data of ***Fig.126***p73, 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.126***p73 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.126***p73 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.126***p73 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.127***)[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.127*** goes to zero (extrapolate to the top left), then the shopkeeper would get a turnover = 40 if he gives away everything for free.

127 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.127***), 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)Statistiek om mee te werken(Groningen)Stenfert Kroese** 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 turnover = -4.33*price + 0.17*advertising + 33.63. That shows that a price reduction weights much heavier (-4.33) (a steeper slope in ***Fig.127*** p74) 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 p27).

Graunt(1662) studied human mortality statistically for the first time, but Snow(1855)[d] found the cause of cholera deads, 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 § 23p86).
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’ (§ 22).

---

a **Slotboom(2001)Statistiek in woorden(Groningen)Wolters Noordhoff** 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)Natural and Political Observations Made upon the Bills of Mortality(London)** made early demographic statistics laying the foundation for population statistics and epidemiology.
Quetelet(1835)**Sur l'homme et le développement de ses facultés**(Paris)Bachelier applied statistics in social sciences and criminology

d Discovered by **Snow(1855)On the mode of transmission of cholera(London)Churchill**

§ 22 ITERATION PRODUCES DETERMINED DIVERSITY


128 Weierstrass[a]


129 Koch[b]


130 Julia[c]


131 Mandelbrot[d]

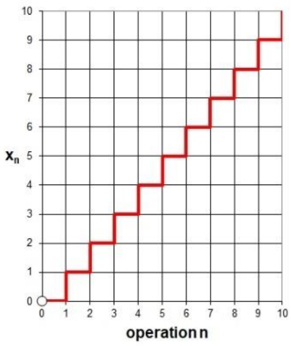
Leading designers of this paragraph

ITERATION HAPPENS EVERYWHERE

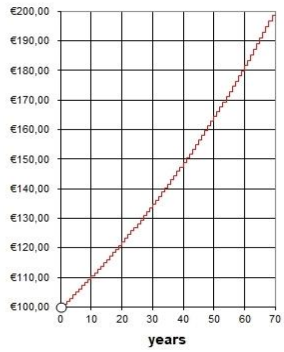
If you change a number with a formula and then change *the result* with the same formula, then such a 'feedback' on each previous result is called 'iteration'. The simplest example is *counting*. Its formula is $x_{n+1}=x_n+1$. If x_n is the previous number, then x_{n+1} is the next one.

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.132***).

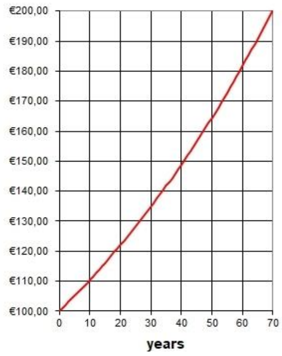
Iteration.xlsm



132 Counting



133 $x_{n+1} = x_n*1,01$



134 $y = 100*1,01^n$

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.133***).

You may also write the result after n years as a 'continuous' formula with an exponent n: $y=100*1,01^n$ (***Fig.134***). 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.

RieWei.wxmx
Koch.wxmx

a Weierstrass(1872)Mathematische werke II(Berlin1895)Mayer&Muller **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.

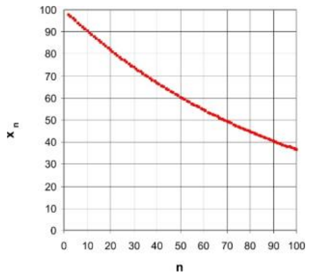
b Koch(1904)Sur une courbe continue sans tangente, obtenue par une construction géométrique élémentaire(Arkiv för matematik, astronomi och fysik)1 **681–704.** Koch found another fractal function known as Koch's snowflake.

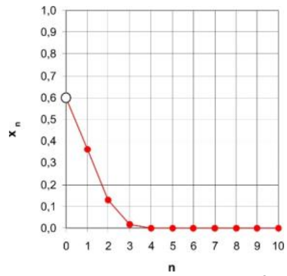
c Julia(1918)Mémoire sur l'itération des fonctions rationnelles(Journal de Mathématiques Pures et Appliquées)8 **1 47-245** based a set of fractals on iterative functions.

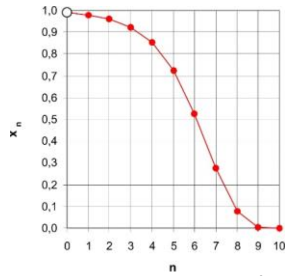
d **Mandelbrot(1967)How Long Is the Coast of Britain(Science)156 p636** studied broken curves. In 1975 he coined the term 'fractal': **Mandelbrot(1975)Les objets fractals(Paris)Flammarion.** He studied and plotted the Julia sets, and in 1979 he introduced the Mandelbrot set: **Mandelbrot(1982)The Fractal Geometry of Nature(New York)Freeman**

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 $1/1.01\approx0.99$.







135 $x_{n+1}=x_n*0,99;\ x_0=100$ ***136*** $x_{n+1}=x_n^2;\ x_0=0,6$ ***137*** $x_{n+1}=x_n^2;\ x_0=0,99$

By iteration, the result, $x_{n+1}=x_n*0,99$, will *approach* zero, (***Fig.135***). 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.136*** 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 ⤥ (***Fig.137***).

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.103***p69) in order to get a more realistic ∫ 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 ($x_{n+1} = x_n^2$-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.136***). Starting with $x_0=0.99$ (***Fig.137***), however, it looks like a mirrored (⤥) logistic function (***Fig.137***). But, what if the constant > 0?

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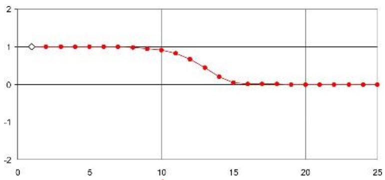
a This conclusion is not always valid, but that restriction leads into the specialized mathematical field of transfinite numbers I will not further explore.

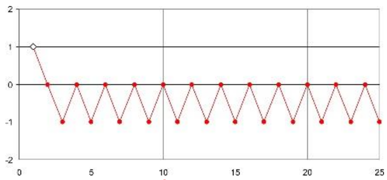
b The result of the iteration $x_{n+1}=x_n^2$ is actually something else than the function $y=x^2$, because that results in a parabola.

c **Malthus(1826)An Essay on the Principle of Population, or a View of Its Past and Present Effects on Human Happiness, with An Enquiry into Our Prospects Respecting the Future Removal or Mitigation of the Evils Which It Occasions(London)Johnson**

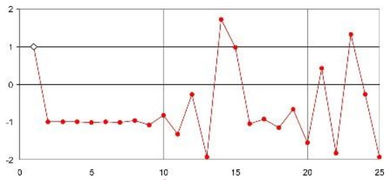
d **Verhulst(1845)Recherches mathématiques sur la loi d'accroissement de la population(Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles)18 1–42**; **Verhulst(1847)Deuxième mémoire sur la loi d'accroissement de la population(Mémoires de l'Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique)20 1–32.**



138 $x_n^2 - 0$; $x_0=0,9999$



139 $x_n^2 - 1$; $x_0=0,9999$



140 $x_n^2 - 2$; $x_0=0,9999$

Fig.138 resembles ***Fig.137***p77, but in ***Fig.138*** 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.

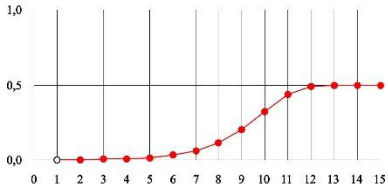
Until constant=0.2 it remains ʅ, but if constant=1 (***Fig.139***), then x *fluctuates* between 2 values.
Beyond 1.2, that first becomes 4, then 8 different values, but after 1.3 all values seem to differ.
In ***Fig.140*** the constant is 2, the function has become 'chaos'.
Then it is no longer a smooth function. It has become broken ('fractal') and unpredictable.

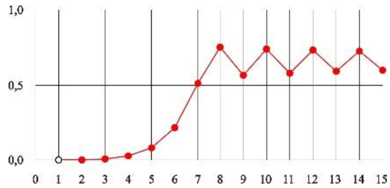
So, a very small change of the initial value x_0 or other parameters may yield a very different graph. Your computer may even draw another graph than mine by different rounding offs.
Squaring makes any negative number positive, but the subtraction may make it also negative.

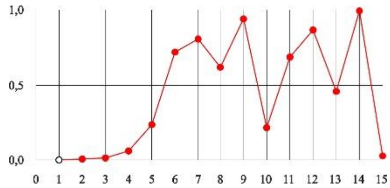
Comparing neighboring values or differentiating and integrating then does not make sense.
The jumping curve is 'not integrable', and rather frustrating for classical mathematicians.[a]
I limit myself to iterations with x_0 between zero and one, because then squaring may produce perceptible chaos instead 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 ʅ-shape with the same factor, but it remains a ʅ form. At an initial value=1/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 ʃ 'logistic' curve (***Fig.141***). In ***Fig.141- Fig.143***, appear the effect of factors 2, 3 and 4. A factor=3 (***Fig.142***) results in fluctuations, a factor 4 in chaos (***Fig.143***).







X_0 = 0,001

141 $x_{n+1}=2*x_n-2*x_n^2$ ***142*** $x_{n+1}=3*x_n-3*x_n^2$ ***143*** $x_{n+1}=4*x_n-4*x_n^2$

This formula is not the logistic function of Verhulst (***Fig.103***p69). 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.

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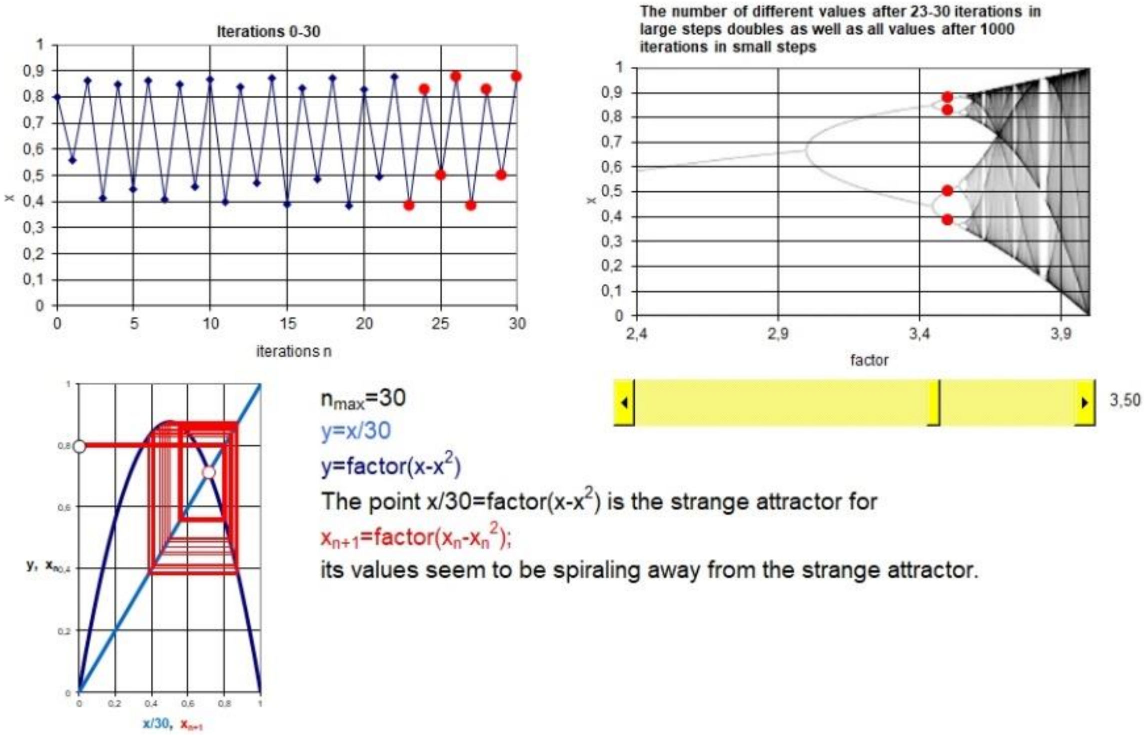
a **Peitgen(1986)The beauty of fractals(Berlin)Springer**; **Steward(1989)Does God Play Dice? The Mathematics of chaos(London)Penguin Books** and **Tennekes(1990)De vlinder van Lorenz(Bloemendaal)Aramith**; **Gleick(1987)Chaos:making a new science(New York)Viking**

CHAOS HAS SOME ORDER



144 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.144***). 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 eachother, has been appropriately called 'fig tree' honouring Feigenbaum.

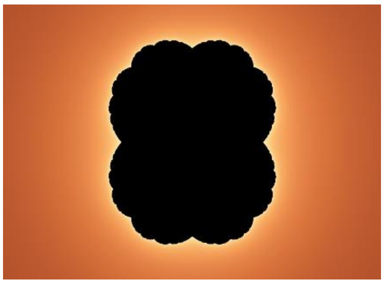
That 'Feigenbaum number' occurs in many iterations. This is, for example, useful to understand population fluctuations at the edge of chaos, or if a flow is distributed into ever smaller waves ('turbulence'), such as fluid in pipelines and wind on the earth's surface.

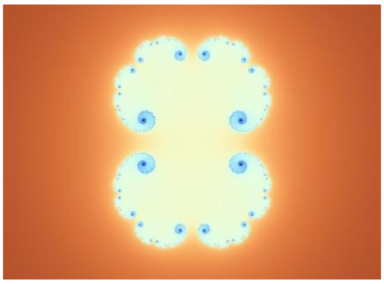
TWO VARIABLES PRODUCE A JULIA SET

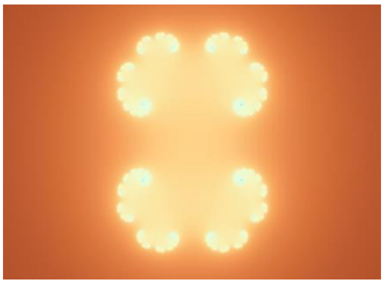
Already in 1918, France, Julia[c] invented the brilliant formulas $x_{n+1}=x_n^2-y_n^2+p$ and $y_{+1}=2*x_n*y_n+q$, as x and y coordinates in a plane. If you choose combinations of x_0, y_0 initial values, p and q, then fascinating figures ('fractals') may emerge (***Fig.145***p80 - ***Fig.153***p80)[d].
Any enlargement shows new patterns, sometimes similar to the enlarged.

Julia did not draw his formulas in 1918, but Mandelbrot (p76 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)Quantitative Universality for a Class of Non-Linear Transformations(J Stat Phys)19 25–52**
b **Smale(1974)Sufficient conditions for an optimum((Proc Sympos Appl Topology and Dynamical Systems, Univ Warwick, Coventry)p 287-292**
c **Julia(1918)Mémoire sur l'itération des fonctions rationnelles(Journal de Mathématiques Pures et Appliquées)8 1 47-245**
d For these figures I use http://fraqtive.mimec.org/downloads







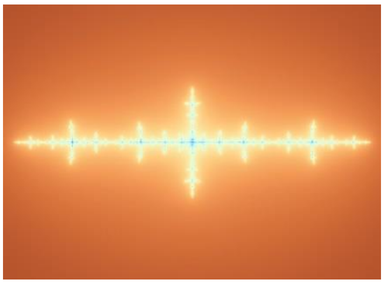
145 Julia p=0.2; q=0 ***146 Julia p=0.3; q=0*** ***147 Julia p=0.4; q=0***

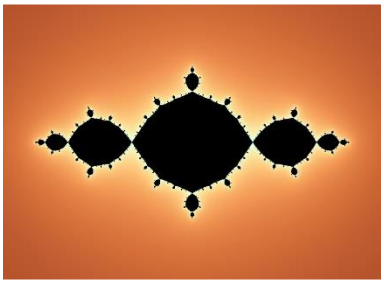
Julia's x and y coordinates: $x_{n+1}=x_n^2-y_n^2+p$ ***and*** $y_{+1}=2*x_n*y_n+q$.

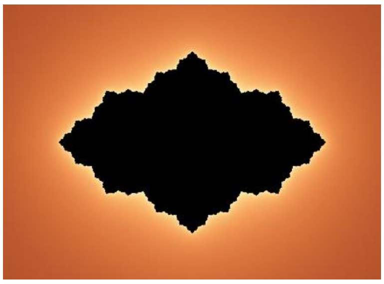
If p and q are both zero, then you get a clean, filled circle, a disk with all points connected to each other. The simulator gives different colors at different degrees of connection.
Black usually means that all pixels are filled and connected without gaps.
Let's first only vary p and keep q zero.

If you choose p = 0.2, then that circle distorts to ***Fig.145***. In ***Fig.146***, 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.147***, 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.

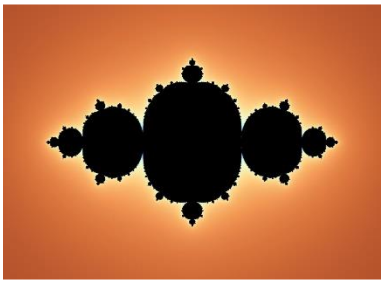


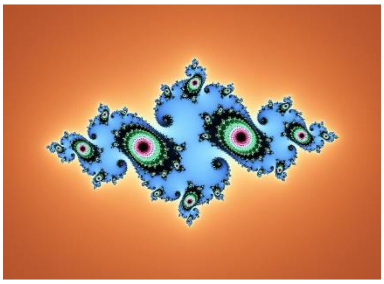


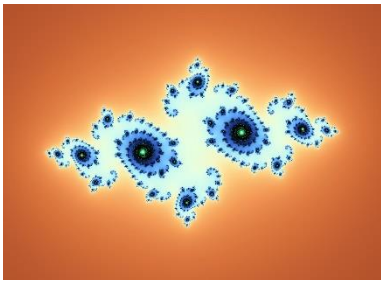


148 Julia p=-1.5; q=0 ***149 Julia p=-1; q=0*** ***150 Julia p=-0.5; q=0***

I leave interpreting these differences between positive and negative values of p to the reader.
Concerning p, ***Fig.151*** (p=-0.75) is exactly between ***Fig.149*** (p=-1) and ***Fig.150*** (p=-0.5).
Let us now vary q with a constant value p=-0.75 (***Fig.151*** – ***Fig.152***).







151 Julia p=-0.75; q=0 ***152 Julia p=-0.75; q=0,1*** ***153 Julia p=-0.75; q=0,2***

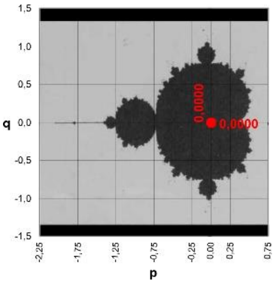
If q varies between 0 and 0.2, q appears to skew the symmetry axes, but at even higher values they also fall apart. The negative values of q fall apart exactly as the positive ones.
They also produce the same figures with their negative values, but their symmetry is mirrored by the minus sign.

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 infinit, but limited to pure repetition.

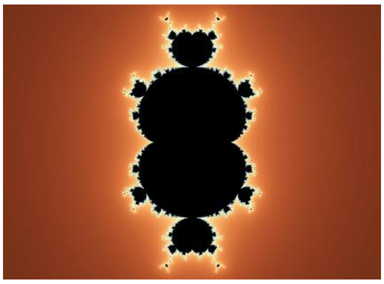
THE MANDELBROT SET IS A CATALOGUE OF COHERENT JULIA-IMAGES

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.154***). It became the famous Mandelbrot set (***Fig.154***) and Julia was back in the spotlight again, but he died in 1978.

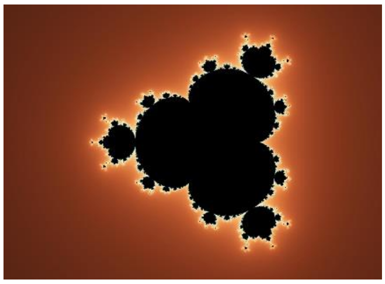
Each point in this set is a combination of p and q, producing a different Julia fractal.
The black area represents solid shapes. At the edge you will find the most fascinating fractals.
You can endlessly enlarge any fractal by taking smaller steps.



154 p and q in the Mandelbrot set

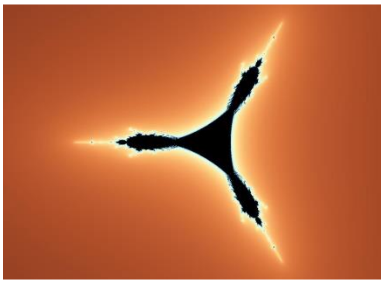


155 Mandelbrot set for third powers

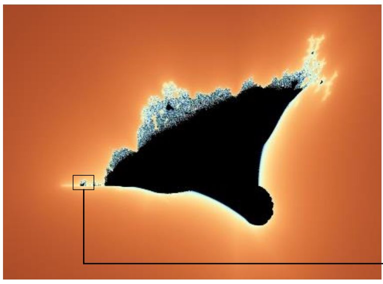


156 Mandelbrot set for forth powers

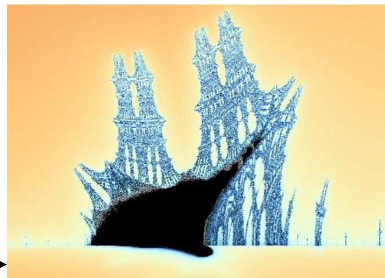
This revolution stimulated the investigation of chaotic formulas. Now there were not only formulas with squares, but also with higher powers for which you could make Mandelbrot sets (***Fig.155*** and ***Fig.156***). Several additions to the first formula brought other variants of the original Mandelbrot set (***Fig.157 - Fig.159***).



157 Conjugate Mandelbrot set



158 Burning ship Mandelbrot set



159 Enlargement of the extreme left part of Fig.158

This yields other images such as ***Fig.158***. 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.

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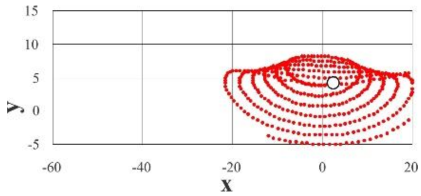
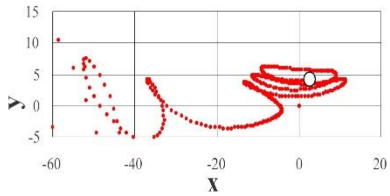
[a] **Mandelbrot(1977)Fractals: Form, Chance and Dimension(New York)Freeman**
Mandelbrot(1982)The Fractal Geometry of Nature(New York)Freeman

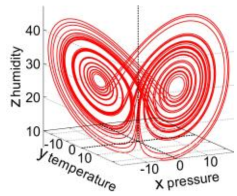
THREE VARIABLES PRODUCE A LORENZ SET



160 Lorenz s=30,r=0,b=0



161 s=30,r=3,b=0



162 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:

$$x_{n+1} = x_n - s * (x_n - y_n)$$
$$y_{n+1} = y_n + x*(r - z_n - y_n)$$
$$z_{n+1} = z_n + (x*y - b*z_n)$$

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.160*** - ***Fig.161***), 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.160***), you will see a spiral that seems to revolve appoaching 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.161***) 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.162***[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.

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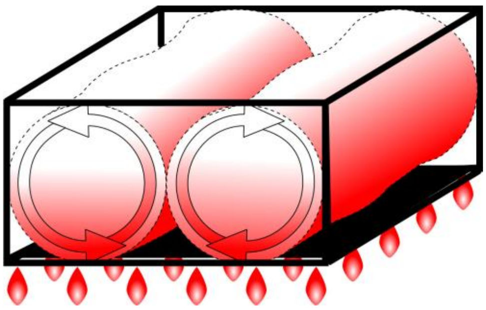
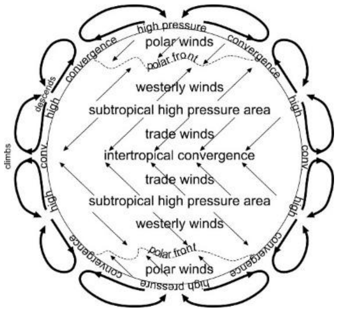
a **Lorenz(1963)Deterministic nonperiodic flow(J Atmospheric of the Sciences)20 130-141**
b Rayleigh number is the property of a fluid that determines how heat is transferred throughout the fluid.
c How that works is beautifully explained in https://blogs.mathworks.com/cleve/2014/04/28/periodic-solutions-to-the-lorenz-equations/

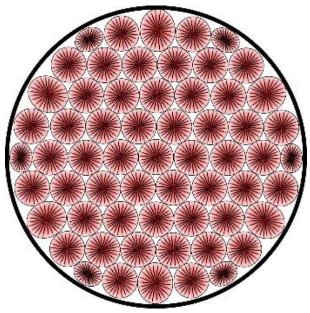
BÉNARD CELLS SHOW EMERGING ORDER IN CHAOS



163 Cylindric convection



164 The atmosphere



165 Bénard cells

Lorenz was inspired by a round bowl of water that Bénard[a] in 1908 (***Fig.165***) heated slowly and very evenly. If you heat up a *rectangular* bowl of water (***Fig.163***), 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.163***).

Such cylinders can also be found on a much larger scale in the atmosphere (***Fig.164***).
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.160***p82), 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.161***p82). 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.165***p83).

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 risinging 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.164***p83). 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.

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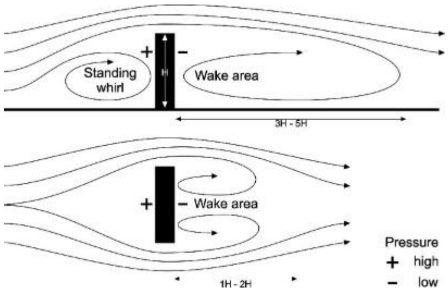
a **Bénard(1900)Les tourbillons cellulaires dans une nappe liquide(Rev Gen Sci pures et appl)11 1261-1271 & 1309-1328**

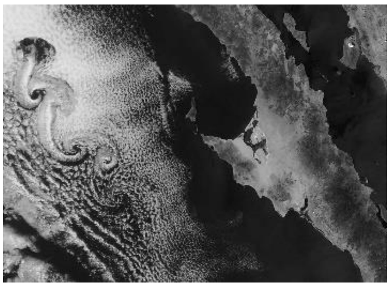
In a northern latitude the dominant wind towards the pole is deviated by its higher speed from the equator to the east. The wind then comes from southwest due to its eastward velocity impulse from the larger equator circle. South of the subtropics, on the other hand, it comes from the northeast.

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.164***p83). 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



166 Whirls behind obstacles



167 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.166***). 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.167***).

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 context. 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.

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a From http://fuckyeahfluiddynamics.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)De vlinder van Lorenz(Bloemendaal)Aramith**
d **Wolfram(2002)A new kind of science(Champaign)Wolfram media**

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).

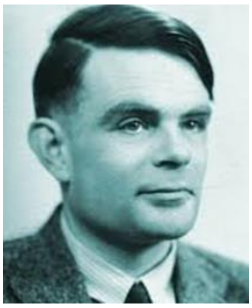
It is at most pattern formation. Self-uniformity on different levels of scale such as spirals and whirls are rare in living organisms. In the society of different organisms, studied in ecology, it sometimes *looks* like that. There is much repetition, but it is never *exactly* the same.

Between the scale levels with a nomial 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.9***p10): 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)Diversifying environments through design(Delft)TU
b Nes;Zijp(2000) Scale factor 3 for hierarchical road networks a natural phenomenon?(Delft)Trail Research School.

§ 23 A NEURAL NETWORK CORRECTS ITS SUPPOSITIONS



168 Turing[a]

169 Simon[b]

170 Minsky[c]

171 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 ⅓⅓⅓000111000⅓⅓⅓ (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.

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.

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a Turing(1936)On computable numbers(Proc Lond Math Soc)2 42p230-265 43p544-546 Alan Turing laid the theoretical foundation for AI and raised substantial questions about machine intelligence.

b **Simon(1966)Thinking by computers(Pittsburgh)University Press.** 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)The Society Of Mind(NewYork 1988)Simon Schuster** Marvin Minsky, one of the founders of AI had a major influence on the direction of AI research.

d **Rosenblatt(1962)Principles of Neurodynamics(WashingtonDC)Spartan Books** 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.

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;
- 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.

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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.

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 assumptions about our functioning. It appears to be a barely comprehensible alternative to current mathematical optimization techniques or multivariate analysis (p75 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.127*** p127, you first have to convert that list (***Fig.172*** colums **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)					

172 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 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.172 and ***Fig.173***p89 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.172***).
Fig.173 p89 shows a list of random weights, two hidden layers (AC Hidden 1 and AD Hidden 2) and one Output column AK.

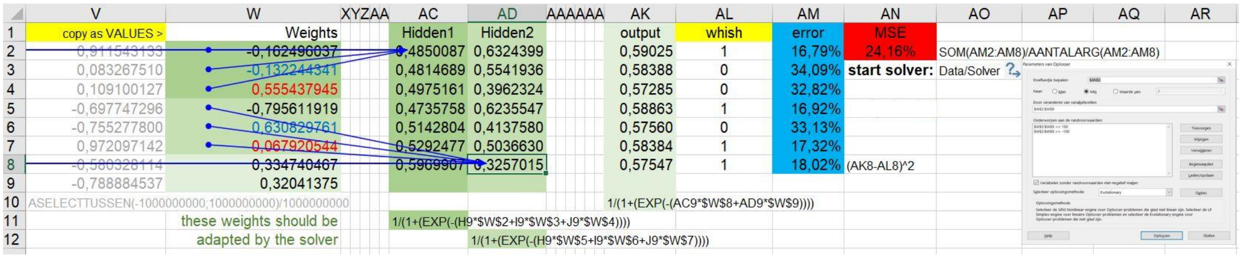
a Choong(2009)Build Neural Network with Excel(WWW)XLPert Enterprise provides a clear explanation for some operating ANN-applications in Excel.

Hidden 1 and 2 (in ***Fig.173***p89 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.

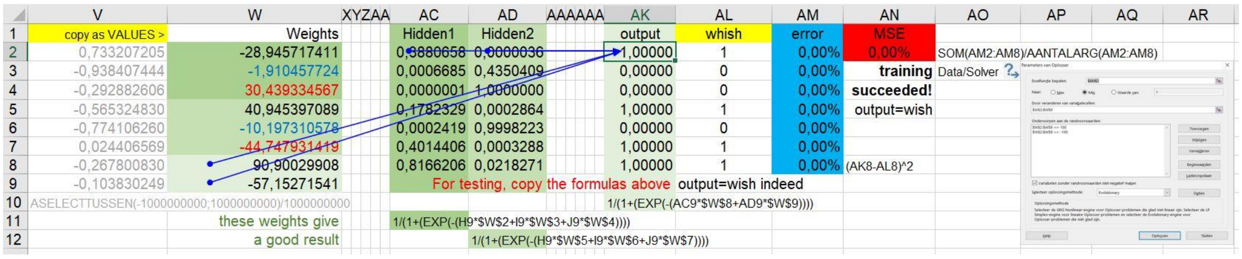


173 ANN does not know anything yet; she has still 25% chance to make mistakes

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.174***).

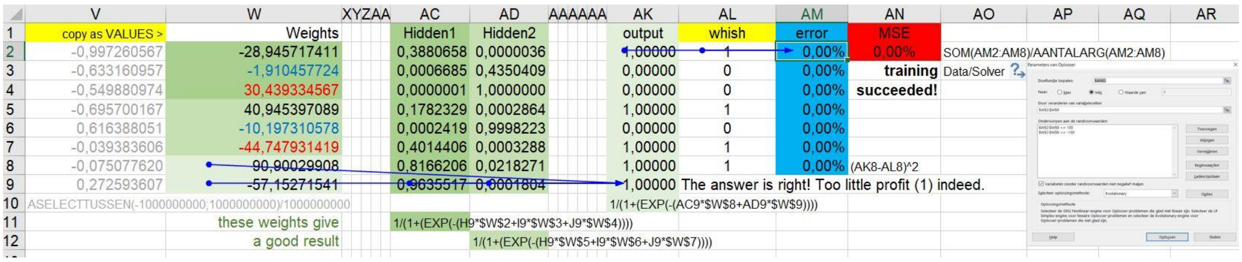
The solver stops with the announcement that he has found a solution. If MSE is not yet less than 1%, then let him do the same again. If the *training* is successful, then you may *test* ANN.



174 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.175***). Hidden 1, Hidden 2 and the Output column then should display the values of that row as a result of the data in ***Fig.172***p88 (H9, I9, J9), produced by the new weights.
ANN now gives the correct opinion (1 : 'too little profit') about the unknown eighth pattern!



175 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 assumptions (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.126*** p73.

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.
'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.

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a Sarle(1994)Neural Networks and Statistical Models(SAS Users Group)Nineteenth Annual

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, assumptions 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.

§ 24 MINIMAL SUPPOSITIONS ENABLE MATHEMATICS

Abiotic :	difference	⥣ change	⥣ object[a]	⥣ separation	⥣ combination	⥣ B
Biotic :	metabolism	⥣ regulation	⥣ organization	⥣ specialization	⥣ reproduction	⥣ C
Conceptual :	imagination	⥣ safety	⥣ attachment	⥣ identity	⥣ influence	*(individual)*
Cultural :	empathy	security	loyalty	publicity	power	*(social)*

A Mathematics ⇓ an external *difference* of variables mutually, but an internal *equality* (equal intervals, units). *Change* ⇓ difference. Repetition ⇓ equal change. Time ⇓ equal repetition.
The '=' sign means *Equality*. It makes sense if the expressions at both sides are *different*.
The *separation* (analysis) into different variables supposes a coherent *object*.
Then, variables may be *combined* by operations such as +, -, *, /, Σ, ∫.

B Different combinations may produce ('metabolise') *the same* output by equation.
Regulation supposes changing the *metabolism* from input into output by 'parameters'.
Coherent regulation enables *organization* in subsequent equations ('algorithm').
Separation of algorithms enables *specialisation* for a special task ('applied mathematics').
Combining specialisations produce a system that may be *reproduced*.

C It may be reproduced in a report ⥣ *imagination* ⥣ safety (reliability) ⥣ attachment ⥣ identity.
A patent or copyright connects that sequence to an *identifiable* creator. That is why groundbreaking results in mathematics still bear the name of *influential* mathematicians.
Honor where honor is due.

Mathematics extends imaginability beyond probability or even possibility and desirability.
As a counterculture in a predominantly causal-analytical culture, it tends to holism and suicausality. It releases blocking suppositions. It attacks commonly shared suppositions intending total freedom of mind and imagination without conditions, except … *difference*.

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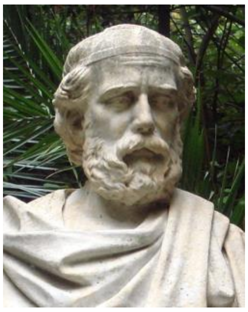
a Here, 'object' may be read as 'coherence' remaining *different* from the rest and resisting *change*.

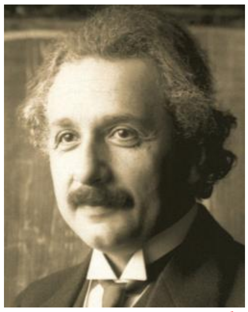
5. ABIOTIC CONDITIONS ARE PROBABLE



176 Archimedes[a]

177 Galilei[b]

178 Maxwell[c]



179 Einstein[d]

With Newton (Fig.37p25**) leading designers of the contents of this chapter.**

a **Archimedes sculptured by Luciano Campisi (1885) in the Latomia dei Cappuccini municipal park Syracuse.** Archimedes introduced *rigorous mathematics* in physics, see **Heath(1897)The works of Archimedes(London)Clay and Sons**.

b **Galilei(1635)painted by Sustermans, Uffizi Florence. Galilei(1632)Dialogue Concerning the Two Chief World Systems(Berkeley1967)University of California Press.** 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.37**p28.

c **Maxwell(ca.1870)photograph ETH Library Zurich. Maxwell(1865)A Dynamical Theory of the Electromagnetic Field (PhilTransRSocLondon)155 459-512** incorporated all observations and theories on electricity, magnetism and light in 20 formulae, reduced to 4 by Heaviside(1885), inspiring Einstein.

d **Einstein(1921)photographed during a lecture in Vienna by Schmutzer. Einstein(190506)Zur Elektrodynamik bewegter Körper(Annalen der Physik)17 p 891-921,** and **Einstein(1916)Die Grundlage der allgemeinen Relativitätstheorie(Annalen der Physik)IV 49 p769-822.** Einstein relativized Newtons absolute space and time.

What is the designerly content of physics? Which discoveries are acually inventions, designs of a model? Does physics cover a broader field of possibility beyond probability?
This chapter explores some disciplines of physics until 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 *shape* of a cylinder, filled with gas at fluctuating temperature.

A stable shape is in-formed. Technology is the information about stable forms, enabling directed movement. 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 explanion.

There are different probabilities, expectations, conditioned at layers and levels (***Fig.14***p14).
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.

§ 25 RELATIVE MOVEMENT IS THE CORE OF PHYSICS

GRAVITY ATTRACTS; ELECTRIC CHARGE ATTRACTS *AND* REPELS

A summary of classical mechanics since Newton[a] reads (without derivatives):

Velocity '**v**'(*m/sec*)[b] is a traveled distance '**s**' divided by the required time '**t**': **v=s/t**
Momentum '**p**' quantifies the movement of a mass 'm' (*kg∗m/sec*): **p=m∗v**
Acceleration '**a**'(m/sec^2) is **v**, again divided by the time **t**, required to reach that speed: **a=s/t²**
Force '**F**'($kg{*}m/sec^2$, *newton, N*) is the acceleration '**a**', times the accelerated mass 'm': **F=m∗a**
Energy '**E**'(*joule, J*) is a force **F** exerted on a mass m over a distance s[c]: **E=m∗v²**
Power '**P**'*(watt, W)* is energy '**E**' per unit of time: **P=E/t**

Two masses m_1 and m_2 of 1*kg* at s=1*meter* between their centers of gravity attract each other by $G = 0.0000000000667428 = 6.67428 * 10^{-11}$ *newton* (*N*). G is used in Newton's gravity formula[d]: $F = G{*}m_1{*}m_2/s^2$, the mutual gravity force F of two masses m_1, m_2 at a distance s between their centers of gravity.
So, F is larger with *larger* masses m_1 or m_2 *and* at a *smaller* distance s.[e]

Zwaartekracht.wxmx

Similar to Newton's gravitational formula, Coulomb (1785)[f] found that two opposite (+ and -) *electric charges* Q_1 and Q_2 attract each other also with a force proportional to the product of both (but absolute, without minus signs: $|Q_1|$ and $|Q_2|$), divided by s^2).
This resulted in the analogous 'Coulomb's Law': $F=k{*}|Q_1|{*}|Q_2|/s^2$, where $k \approx 9{*}10^9$ in vacuum.[g]

If both charges are positive (or negative), this also applies to their mutually *repelling* force.

The smallest charge is the 'elemental charge' of an electron (-) or proton (+).
If you imagine an electron as a small body, then two contiguous electrons may *attract* each other by **gravity** with $F=G{*}m_1{*}m_2/s^2 \approx 7{*}10^{-42}N$ force, but their **charge** *repels* them with a force of no less than $F=k{*}|Q_1|{*}|Q_2|/s^2 \approx 7N$[h]. At this level, the force of **gravity** is insignificant compared to that of **charge**.

Positively charged protons in the nucleus of an atom attract the surrounding *negative* electrons by their charge, but these are kept at a limited distance by centrifugal force.
That is also an indication of the velocity of the electrons.

Within the nucleus, two equally +protons *repel* each other with a comparable force, but at such a short distance, this force is on its turn inferior to a third 'fundamental natural force': the 'strong nuclear force'. For that force you should not divide by s^2, but by s^7.
That increases the force substantially. It prevents the nucleus from exploding.[i]

A coulomb (*C*) is the charge unit of 6241509074460762607.776 ($\approx 6.24{*}10^{18}$) electrons.
At 1 meter, two charges Q of 1*C* repel each other with $F=k \approx 9{*}10^9$ *newton*.
So, 1*C* is a very large charge with a very large force between charged objects.
Therefore, the charge is often expressed in picocoulombs *pC* ($1pC=10^{-12}C$).

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a **Newton(1687)Philosophiae naturalis principia Mathematica(London)** defined in Book 1: mass in Definition I, velocity as a component of motion in Definition IV, acceleration in Law (or axiom) II, force in Definition II. Energy and power played a role, but they were defined later based on Newton e.g. by Leibniz and Watt. https://openlibrary.org/books/OL25646536M/Philosophiae_naturalis_principia_mathematica
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 Usually work $W = \int_0^{v_e} mv \cdot dv = \frac{1}{2} m{v_e}^2$, but that is half the required energy E. If you push a car to that speed v_{ear}, then the ground surface also undergoes the same force in the opposite direction. This should bring about an immeasurably small movement of the earth 'at rest' to v_{earth}. That 'reacting mass' then receives the same kinetic energy in opposite direction, an unnoticed other half of your work, in total $E=mv^2$.
d **Newton(1687) Book 1, Proposition 75, the law of gravity.**
e For example, the Earth (m_1=5.97×1024 kg) and I (m_2=75kg), attract each other at a distance s= 6371km (the Earth's radius) with F=G*m1*m2/s2=735.15newton.
If I jump from a springboard, then the Earth gets a negligible acceleration a=735.15/5.97*1024=0.00000000000000000000123*meters/sec²*, but my much smaller mass is set in motion with an acceleration a=F/m=735.15/75=9.8 (*m/sec2*).
f **Coulomb(1785) Second mémoire sur l'électricité et le magnétisme (Histoire de l'Académie Royale des Sciences)** p578-611, p597
g For the ones who want to know exactly: the 'Coulomb's constant' $k = 8.9875517873681764{*}10^9 N{*}m^2/C^2$.
h For the mutual centre of gravity between connected electrons I have assumed $s \approx 5{,}6{*}10^{-15}$ *meters*. So, $1/s^2=3{,}1{*}10^{28}$.
As a result, $F \approx 9{*}10^9{*}|1{,}6{*}10^{-19}|{*}|1{,}6{*}10^{-19}|{*}3{,}1{*}10^{28} \approx 7N$ becomes so large.
i I will not consider the fourth natural force ('weak nuclear force'). See https://en.wikipedia.org/wiki/Fundamental_interaction

ELECTRIC CURRENT MEETS RESISTANCE

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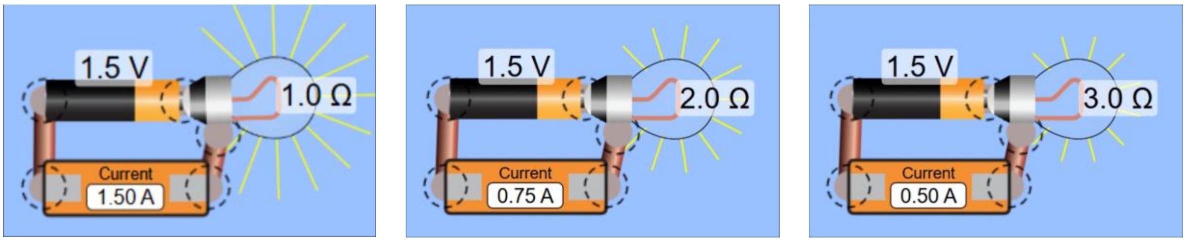

$1.5V=1.5A*1\Omega$ $1.5V=0.75A*2\Omega$ $1.5V=0.5A*3\Omega$

180 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 $V=A*\Omega$, their *quantity* provides Ohm's law[e] U=I*R (the tension U in *volts V*, the current I in *amperes* A, and the resistance R in *ohms Ω*).
Fig.180 is an example of Ohm's law in a flashlight, with increasing resistance R(*Ω*) 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 ↺ in ***Fig.180***). So, '+' indicates an electron *shortage* ('minus is more').

The resistance R(*Ω*) differs per material and temperature. For example, the 'resistivity' of copper at 20^oC is $1{,}7*10^{-8}\ \Omega*m^2/m$. So, a copper wire of 1*m* with an intersection of $10^{-6}m^2$ ($1mm^2$) has a resistance $R=resistivity*length/diameter=1.7*10^{-2}=0.017\Omega$.

My low-voltage light bulb with its very thin wire measures 2*Ω*.
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 5.65 *Ω* per *meter* at 20^oC. That is 1.13*Ω* for 20*cm*.
But resistance is temperature-sensitive. At 1000^oC, the resistance will rise into 1.5*Ω*.

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*)*I (*ampères*). (Remember it as '*Wa* is *VA*'.)
A person at rest uses about 100*watt*, but running 12*km/hour* takes 1000*watt* (1*kilowatt*, *kW*).
in 1 hour you then have used 1 *kilowatt-hour* (*kWh*) or 1000*60*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*24*60*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 $F=k*|Q_1|*|Q_2|/s^2$.

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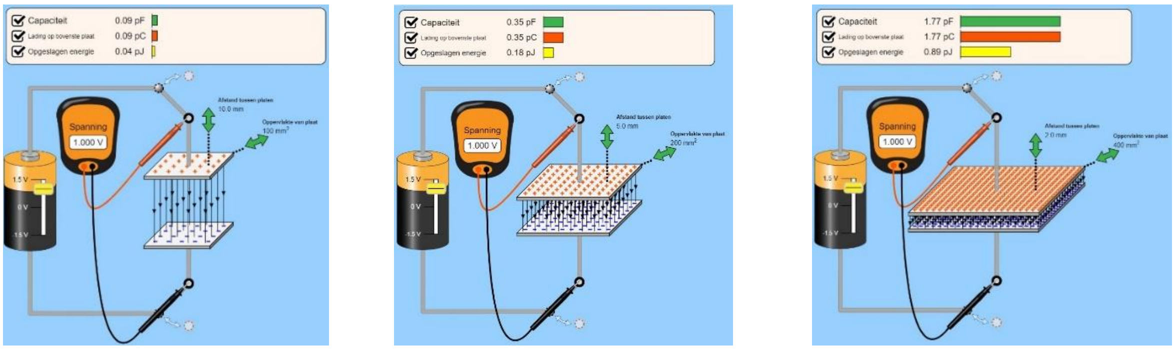
a From phet.
b **Ampère(1826)Théorie des phénomènes électrodynamiques, uniquement déduite de l'expérience(Paris)Méquignon-Marvis.**
c **Volta(1800)On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds(Philosophical Transactions of the Royal Society of London)90 403–431.**
d After **De la Rue(1820),Swann(1878)** and others, **Edison(1880)** designed a commercially successful bulb.
e **Ohm(1827)Die galvanische Kette(Berlin) Riemann** p178
f https://nl.wikipedia.org/wiki/Batterij_(elektrisch)



Condensator.wxmx

A=0,0001m^2, s=0,01m, U=1V A=0,0002m^2, s=0,005m, U=1V A=0,0004m^2, s=0,002m, U=1V

181 A capacitor stores the applied voltage, depending on surface and distance[a]

If you put two conductive plates of 1∗1*cm* (surface A=0.0001m^2) at 1*cm* distance (s=0.01*m*) under 1*volt* (***Fig.181***), then the 'capacitance' of the capacitor is: ε∗A/s=0.09*pF* [b], where ε is the 'permittivity'[c] of the medium between the plates. If you multiply that capacitance ε∗A/s by tension U(*volt*), then you know also the charge Q=ε∗A∗U/s=0.09∗U(*pC*).

With the charge Q and the voltage U, you know also the stored energy: E=Q∗U/2=0.04 (*pJ*).[d]
So, this *energy storage* of the capacitor E=Q∗U/2=0.04 (*pJ*) is something else than its *capacitance* ε∗A/s=0.09(*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 ε s^2=0.73 (*pN*).
This force increases when the distance s in the denominator decreases (see the third ***Fig.181***).
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(=capacity∗voltage U) and the energy storage W(=Q∗U/2).

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.104***p69), and it is called **E**.

Such a field exists also around one ore 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.182***p98). 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.

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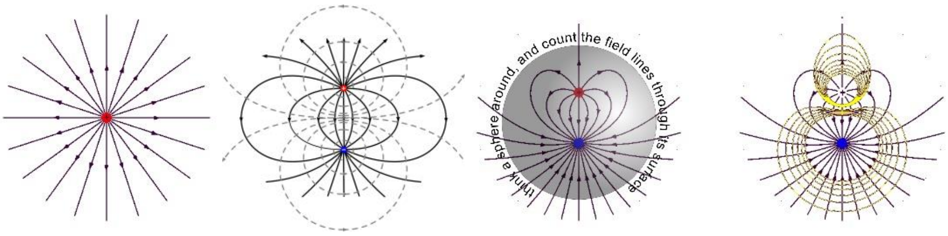
a From phet
b The unit of capacitance is farad (*F=C/V*), but 1F is a very large capacitance, so I will continue using picofarad=*pF*=$10^{-12}F$.
c The "permittivity" ε=ε_0∗ε_r determines the degree to which not the electric current, but electromagnetic force is transmitted.
In this, ε_0=8.854187818∗10-12(*C2/N∗m²*), 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∗π∗ε)=8.9876∗10^9(N*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*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)Essay sur l'electricité des corps(Paris)Guerin**.

160 Tweepolig elektromagnetisch vel



A point charge, two *equal* opposite, a *smaller* +. The ⊥ magnetic field added

182 Electric force fields and perpendicular (⊥) to them a magnetic field [a]

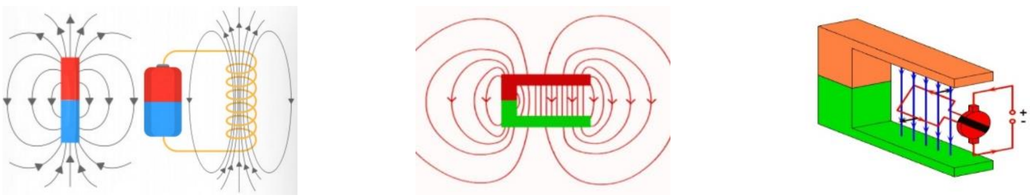
Q/volume is called 'charge density' ρ. Q/surface is reduced by the permittivity of the medium ε. It is called 'flux' $\Theta_E = Q/\varepsilon$ (Gauss's law 1813).[b] With more point charges you may think a sphere or any closed surface around it where the lines pass. The volume of a sphere is $\frac{4}{3}\pi r^3$, 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 ⊥ of these lines a *magnetic* field (the ***Fig.182*** right).

Ampère(1820) amplified magnetism around a current wire by winding it on a coil (***Fig183***). 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 ⊥ 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 (***Fig183*** right).[e]



183 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* ⊥ through a magnetic field, then it will experience a force $F=1$ *N(newton)*, and the 'field strength' $\mathbf{B} = \mathbf{F_B}/(Q*\mathbf{v}) = 1\ N * 1\ sec\ /\ (1\ C * 1\ m) = 1\ T$ (*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: $B=4000*n/l$. 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) Theoria attractionis corporum sphaeroidicorum ellipticorum homogeneorum methodo nova tractata(Commentationes Societatis Regiae Scientiarum Gottingensis Recentiores) 3 293–306**
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)Experimental researches in electricity II(London)Taylor**.
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 $H = N*m/A^2$.
h See Wikipedia

Magnetic field lines *outside* the magnet spread out (***Fig. 183***p98) 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 (⊥) 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 ⊥ *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 $F_E=k*|Q_1|*|Q_2|/s^2$.

Crossing ⊥ 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 $\mathbf{F}_E=Q*\mathbf{E}_F$ can be deflected by magnetic forces $\mathbf{F}_B=Q*(\mathbf{v}\times\mathbf{B})$, 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 derivates (δ)[e] with respect to three dimensions x,y,z : **E**/δx+**E**/δy+**E**/δz and **B**/δx+**B**/δy+**B**/δz, briefly represented by the 'nabla-operator' ∇ as ∇·**E** and ∇·**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 $\nabla\cdot\mathbf{E} = \rho/\varepsilon$ (Gauss, 1813). You will loose or gain **ρ/ε** voltage on each step.
2 $\nabla\cdot\mathbf{B} = 0$ (Gauss, 1813). In the magnetic field you have equal velocities back and forth.
3 $\nabla\times\mathbf{E} = -\partial\mathbf{B}/\partial t$ (Faraday,1831). **E** changes when **B** *moves* ⊥ E_F or ×$\mathbf{E}_F$ ('induction').
4 $\nabla\times\mathbf{B} = \mu*\rho*\mathbf{v} + \mu*\varepsilon*\partial\mathbf{E}/\partial t$ (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.

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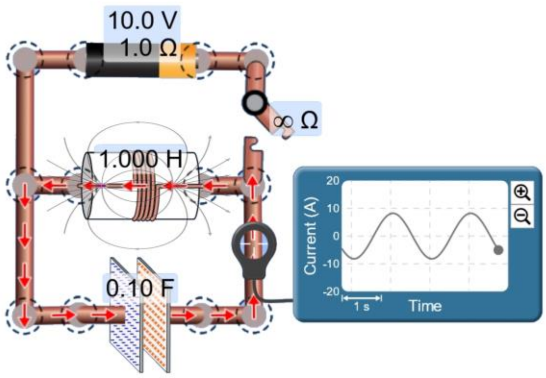
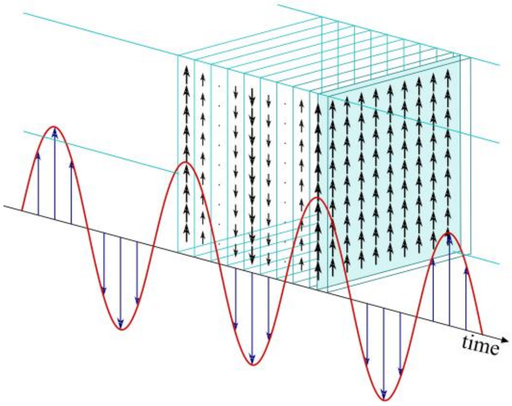
a Gauss's law (1813) and Maxwell's first equation (1865).
b This is simulated nicely in https://bruningonline.nl/applets/inductie/inductie.htm
c The 'resultant' is a vector sum (a diagonal in the parallelogram of vectors). A vector is a number with a direction, further shown in bold. For vectors, '+' means a "vectorial addition". The sign '×' is the 'cross-product' between both direction-bearing vectors v and B. It is the matrix operation that formulates the difference of perpendicular (⊥) direction between the two. See p108.
d https://nl.wikipedia.org/wiki/LorentzkrachtThis is simulated nicely in https://bruningonline.nl/applets/lorentzkracht-afbuigen/lorentzkracht-afbuigen.htm
e dB/dt, would deduce all variables in B=Fb/(Q*v) into t, but ∂B/∂t is a 'partial derivative', keeping any variable constant except speed v.
f **Maxwell(1865)A Dynamical Theory of the Electromagnetic Field(PhilTransRSocLondon)155** 459-512 predicted the existence of electromagnetic fields and **Hertz(1887)** proved their existence at the speed of light.
g See Wikipedia

RADIATON SUPPOSES *CHANGING* MAGNETIC FIELDS

oscillatorB.xar

Changing polarities.xar





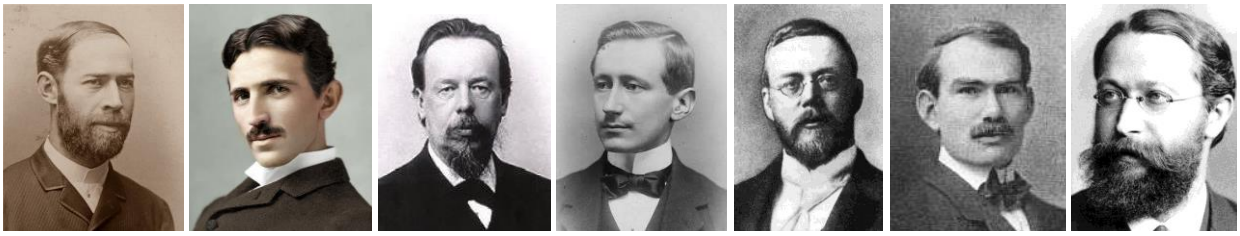
184 An electric oscillator[a] causes … ***185 … changing polarities of the field.***

Fig. 184 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. 185***).

wavelength and frequency.xlsx

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. 187***p101). It transforms radiation again into a current for a speaker by a coil (***Fig. 184*** without a battery fed by radiation[d]).



Hertz (waves) | *Tesla (signals)* | *Popov (detecting)* | *Marconi (telegraphy)* | *Fessenden (broadcast)* | *Forest (amplifying)* | *Braun (tuning)*

186 Founders of radio transmission

Higher frequencies may be obstructed by the atmosphere. From numerous frequences a variable capacitor may select (tune) a proper one: the single frequency of the sender you want to receive.

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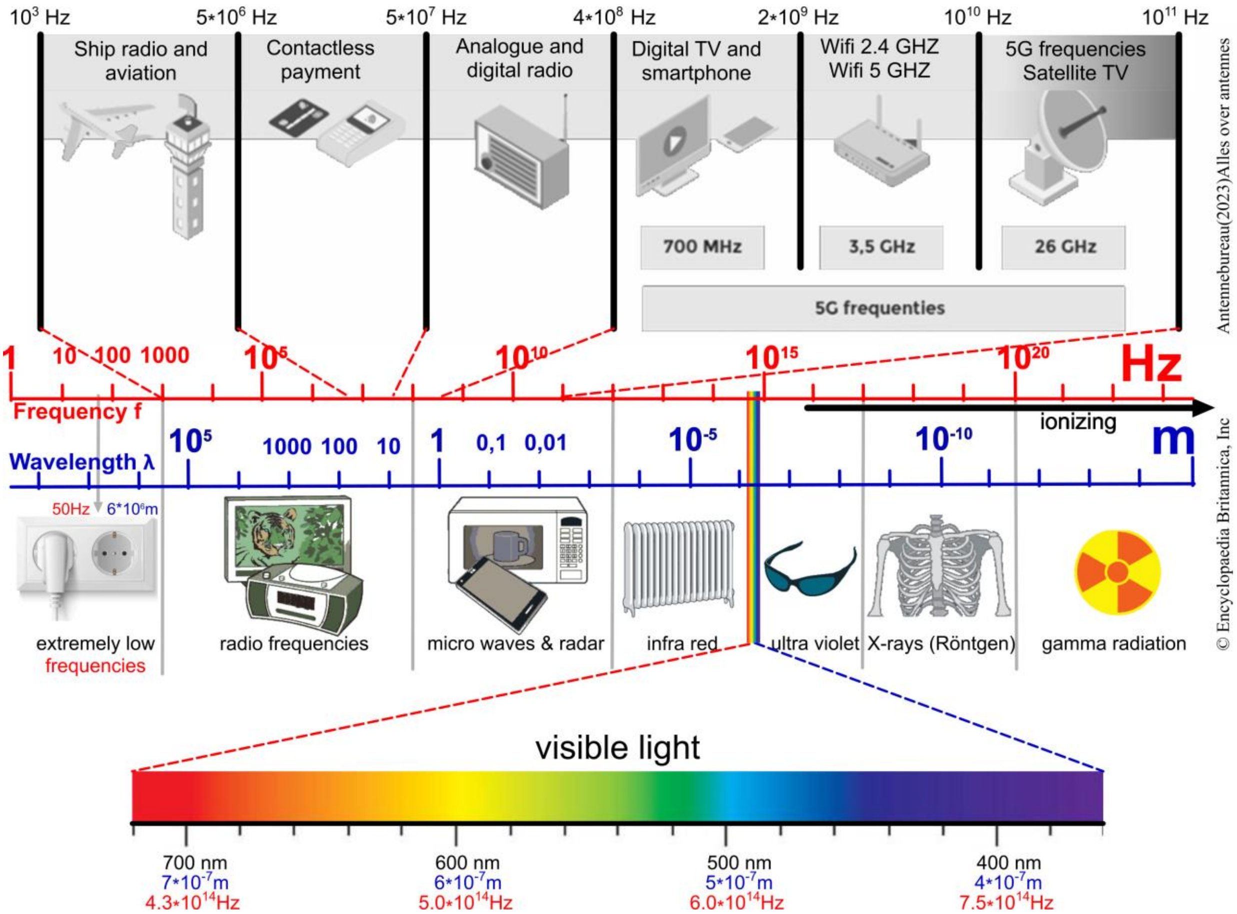
a From phet
b Explanation by Houten
c See for a general overview Esaulov(2019).
Tesla(>1891)) developed systems for alternating current, wireless energy transmission and radio signals.
Marconi(1895) developed the first usable wireless telegraphy system and Founded the Wireless Telegraph and Signal Company in 1897. He was the first to send a radio signal across the Atlantic Ocean in 1901. (Nobel Prize 1909)
Popov(1895) On the Relation of Metallic Powders to Electric Oscillations 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.

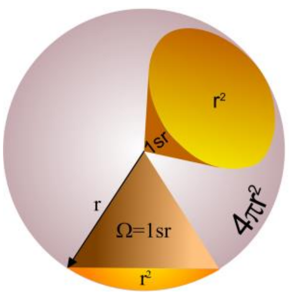


187 Frequences and wave lengths of radiation [a]

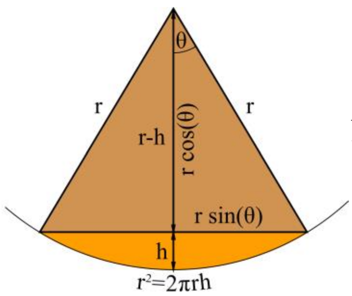
Fig. 187 shows the available frequences f, their corresponding wave lengths λ=c/f and their use. The energy of waves is roughly proportional to their frequence until 10^{14} Hz. Beyond 10^{16} Hz they may damage living tissues. A small part is the spectrum of visible light.

LIGHT ON A SURROUNDING SPHERE WEAKENS BY INCREASING DISTANCE OF ITS RADIUS²

The surface of a sphere is $4\pi r^2$. If r = 1m, then the surface of the sphere = 4π = 12.6m². A *curved surface* $r^2 = 1m^2$ on the sphere determines an angle θ. Rotated 3D, θ becomes a 'solid angle' $\Omega = 2*\pi*(1-\cos(\theta))$ = 1sr, a unit called 'steradian'[b]. A total sphere counts $4\pi*sr \approx 12.6$sr.



188 A sphere divided in solid angles of 1sr [d]



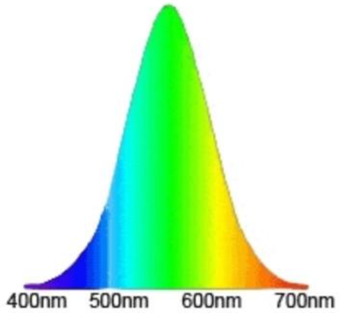
189 A cross section (⦰) of 1sr

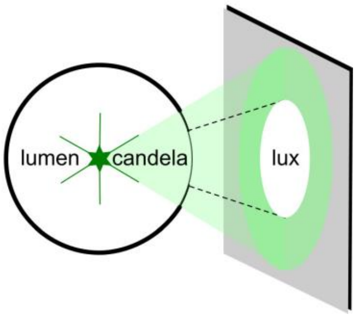
The unit *surface* $r^2 = 2\pi hr$[c]. So you may solve $h = \frac{r}{2\pi}$ = 0.159m and r−h = 0.841m.

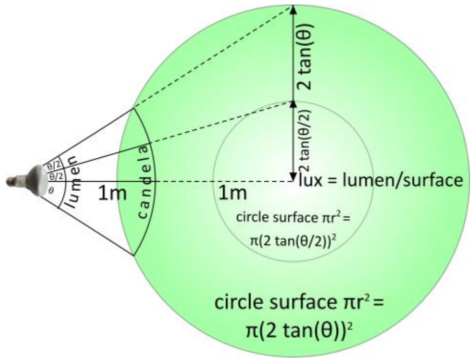
Now you may calculate θ = arccos $\frac{r-h}{r}$ = 0.572 radians = 32.75°, and (⦰ sr) 2θ =1.14 radians = 65.5°.

Note that the brown triangle is not equilateral. Its basis is not r = 1m , but 2 r sin(θ) = 2 * 0.541m = 1.08m.

a From **Antennebureau(2023)Alles over antennes(Groningen)**; https://www.britannica.com/science/electromagnetic-spectrum
b https://en.wikipedia.org/wiki/Steradian
c **Gieck(1969)Technische formules(Amsterdam)Agon Elsevier** pC3
d Edited after Steradian By Andy Anderson - Own work, CC BY-SA 4.0, https://en.m.wikipedia.org/wiki/File:Steradian_cone_and_cap.svg







190 Human light sensitivity at daylight ***191 Lumen, candela, lux***[a] ***192 Deriving Lux***

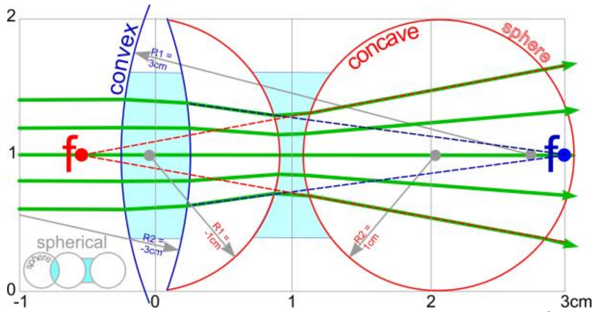
The surface 12.6m^2 of sphere with a radius r =1m is $4\pi r^2$. A green[b] (***Fig. 190***) lamp, emitting 12.6 'lumen' in all directions emits 1 *lumen per sr* (2θ = 65.5°) or 1 'candela' (≈ a candle light). If 1 lumen in a 2θ = 32.75° *beam* is projected on a flat screen at r ≈ 2m distance of the lamp, then the illuminated *flat* surface will be 1 m^2, and its 'illuminance' is 1 lumen/m^2 ('lux').

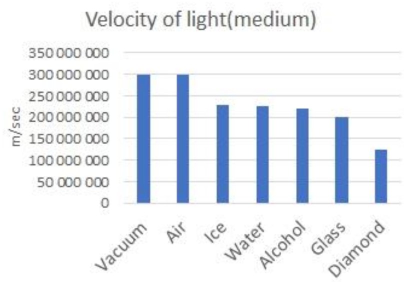
Delivering *500* lux (lumen/m^2) at r = *2 meter* distance from a bulb (internally illuminating a sphere of $4{*}\pi{*}r^2$ ≈ 50m^2 in all directons) requires 500lux*50m^2 = **25000 lumen**.
Concentrating light on a desk in a *beam* reduces that number.

A 1sr beam (2θ = 65.5°) illuminates at 2m from the lamp a flat surface of $\pi(2\tan(\theta))^2$ = 5.21 m^2.
In order to get 500 lux on 5.21 m^2, then requires 500*5,21 = **2610 lumen**.
A ½sr beam (2θ = 32.75 °) illuminates at 2m from the lamp a flat surface of 1.09 m^2.
In order to get 500 lux on 1.09 m^2, then requires 500*1,09 = **543 lumen**.

One lumen has a power of 1/683 = 0.00146 watt. So, 683 lumen requires *at least*[c] 1watt.
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





193 Two spherical glass lenses [d] ***194 Velocities of light(medium)***

In ***Fig. 193*** 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. 194***).

The **v**elocity 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. 193*** any $R_2 = - R_1$ and **n**=1.5.

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a 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/

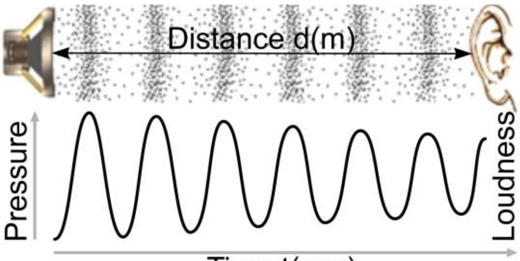
b The most visible green light has a wavelength λ= 555 nanometer, implying a frequency f=540 terahertz: f = c/λ and λ = c/f, where c=299792458m/sec, the velocity of light in vacuum.

c 'At least', because a lamp also produces heat.

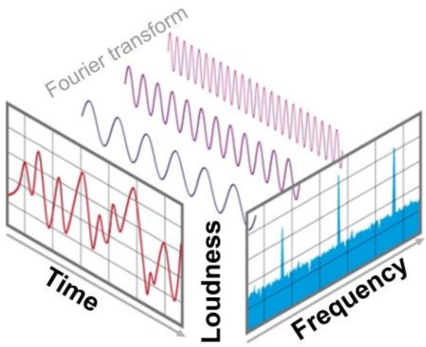
d The figure is constructed with the optical simulator https://phydemo.app/ray-optics/simulator/ .

R1 and R2 are related to **f** by a 'lens makers formula' (Snellius' law): $\frac{1}{f} = (n-1)\left(\frac{1}{R1} - \frac{1}{R2}\right)$.
For the convex lens R_1 = 3cm and R_2 = -3cm, so f_1 = 3 in ***Fig. 193***p102.
For the concave lens R_1 = -1cm and R_2 = 1cm, so f_2 = -1.
But together $\frac{1}{f_{total}} = \frac{1}{f_1} + \frac{1}{f_2} = -\frac{2}{3}cm$. So, in ***Fig. 193***p102 f_{total} is at -1.5cm from the second lens.

SOUNDS DISPERSE AS WAVES

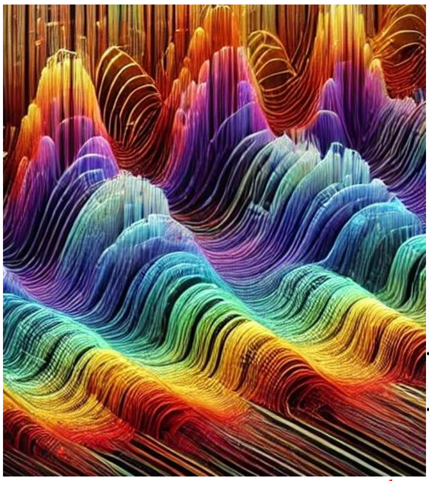


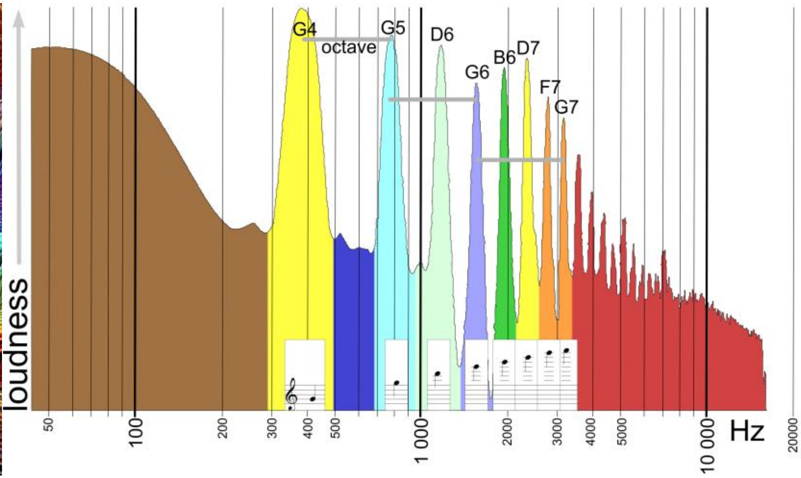
The velocity d/t varies from 300m/sec(-50°C) to 360m/sec(50°C)



195 Sound(pressure)[a] ***196 Mixed and untangled wavelengths***[b]

Sounds reach our ear by changing loudness(air pressure) propagated like waves(***Fig. 195***).
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 irragular pattern (***Fig. 196***), untangled by our mind or mathematically ('Fourier transform').





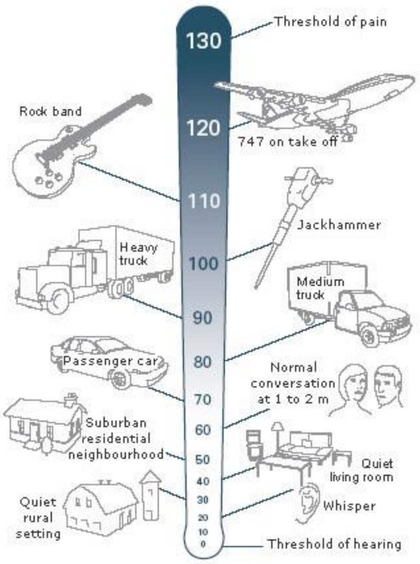
197 Sounds of a violin[d] ***198 Such peaks of a Stradivarius violin***[e]

In ***Fig. 197*** many undertones and overtones surround the loudest ground tone of a violin.
In ***Fig. 198*** 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. 200***p104).
The least Δpressure registrated by ears is approximately 0.00002Pa = 0 'decibel' (dBA[g]).
A decibel (see ***Fig. 199***p104) 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)Klankanalyse vioolbouw(Sneek)
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/m^2, where N(newton) ≈ 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 (log_{10} or log_e).

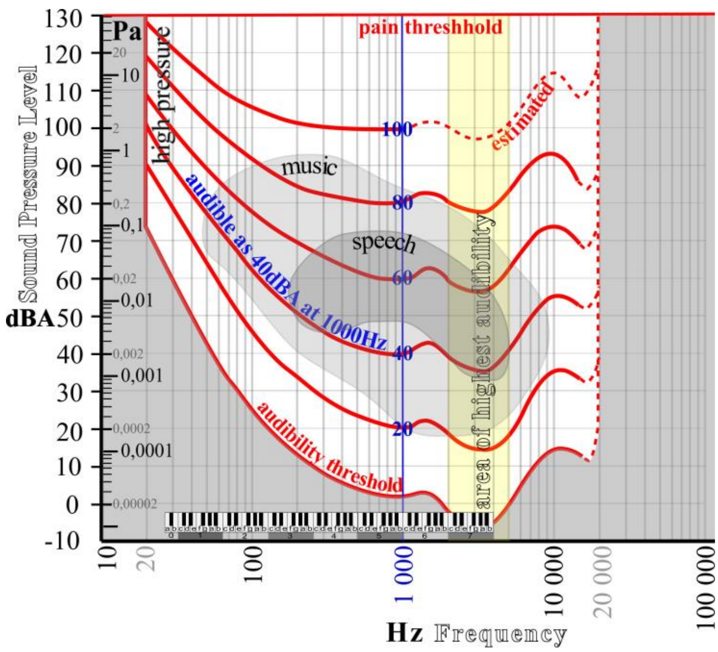
Audible frequencies.xar



dBA-Pascal.xlsx

$$dBA = 0{,}00002 * e^{(0{,}11512926*Pa)}$$

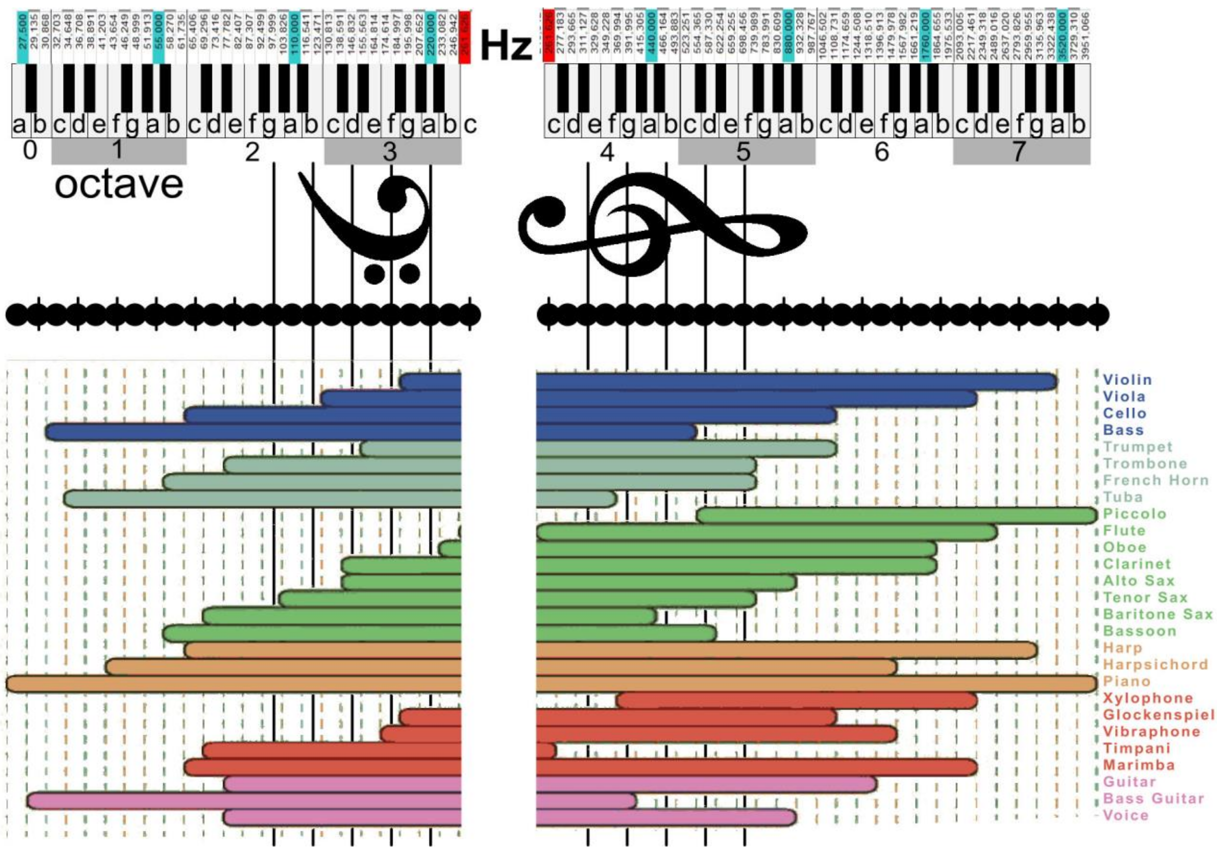
$$Pa = 8{,}6859\ln(dBA) + 93{,}979$$



199 dBA loudness [a] ***200 Audible frequences*** [b]

Low frequences are tempered by our ear (***Fig. 200***, with the piano inserted as a reference). Compare the piano with the audible range of other musical instruments (***Fig. 201***).

NootNamen.xar



201 Musical names of notes and the available range in different instruments [c]

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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. 202***) 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.

Traffic noise.xlsx

The horizontal distance and the altitude where the noise is heard are important suppositions of any specified 'dBA'. In the example of ***Fig. 202*** the maximum noise is heard at the 7th floor, 20m altitude (73dBA, ***Fig. 203***).

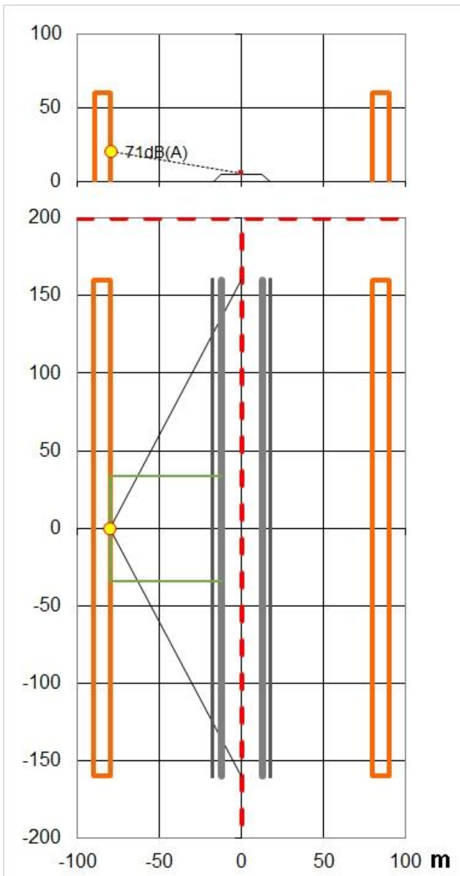
... If nothing is done to reduce it.

A proper asphalt surface[a] (***Fig. 203***) may reduce that noise by 3dBA to 70dBA. If the surface in between is not paved (***Fig. 202*** the square), then the noise is again reduced by 1 dBA (***Fig. 203***), due to less noise reflection from the floor.

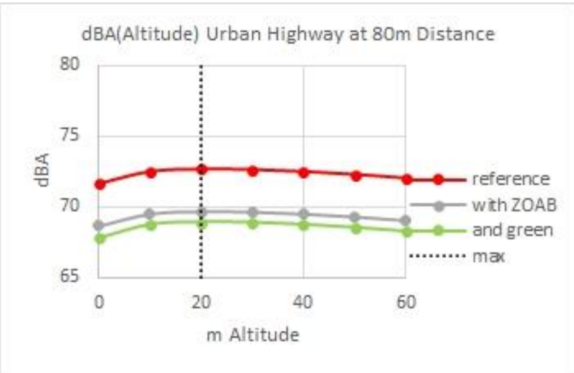
Supposing these conditions, a 30km/hr *increase* of the velocity of vehicles (classes light and medium) may cause 2 dBA *more* noise (***Fig. 204***). For heavy vehicles a velocity of 80km/hr is supposed in both cases.

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.

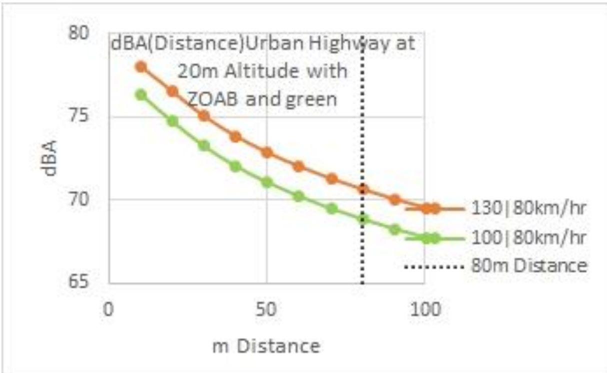
There are, however, more suppositions not mentioned here: the distance, altitude and width of the opposite noise reflecting surface, the distance to eventual obstacles, a nearest crossing and a number of reduction factors.



202 An urban highway between high buildings



203 Some reductions of traffic noise



204 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.

§ 26 MECHANICS RELATIVATES SPACE AND TIME

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 exacly 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.[a]

Half a century before Einstein, 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.[b] With the rise of quantum physics, however, this again became a problem at an even smaller scale.

E=MC² IS THE LIMIT OF E=MV² DUE TO THE MAXIMUM SPEED C OF MASSES M AND LIGHT

Remember the classical mechanics since Newton[c] (p95, without derivatives):

Velocity '**v**' is a traveled distance '**s**' divided by the required time '**t**'(*m/sec*)[d]: **v**=s/**t**
Momentum '**p**' quantifies the movement of a mass 'm' (*kg∗m/sec*): **p**=m∗**v**
Acceleration '**a**' is **v**, again divided by the time **t**, required to reach that speed (*m/sec²*): **a**=s/**t²**
Force '**F**' is the acceleration '**a**', times the accelerated mass 'm' (*kg∗m/sec², newton, N*): **F**=m∗**a**
Energy 'E' required is a force **F** exerted on masses m over a distance s (*joule, J*)[e]: **E**=m∗**v²**

Masses, however, appear to have a maximum mutual speed c ≈ 300 000km/sec (also the velocity of light).[f] At that maximum, more energy added cannot end up in a higher speed v (being at its maximum c). So, it must result in increasing mass m, according to: **E**=m**c²**.

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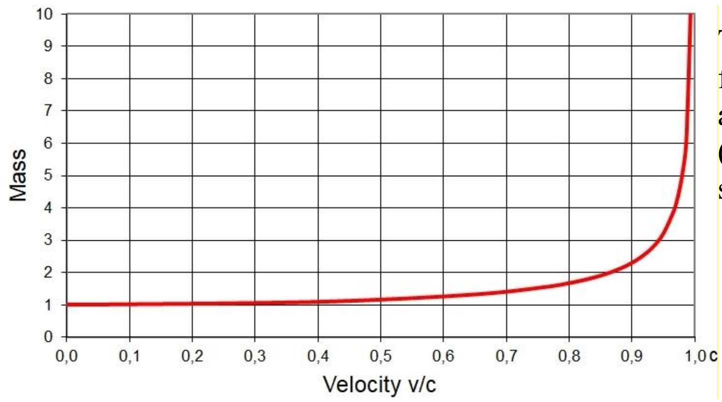
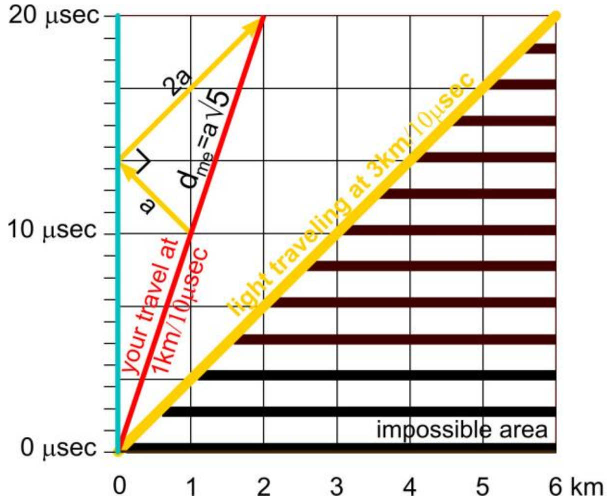


205 Lorentz' mass increase by velocity

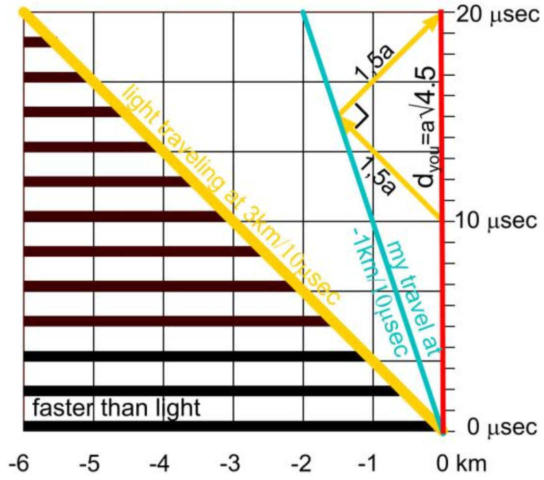
This mass building-up already starts from 0*m/sec* onwards by any acceleration, but at low v compared to c (v/c) the mass increase is immeasurably small (***Fig.205***)[g].

a Einstein(190506)Zur Elektrodynamik bewegter Körper(Annalen der Physik)17 p 891-921 and Einstein(190509)Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?(Annalen der Physik)18, p 639–641
b See for example **Young(1964)Fundamentals of Mechanics and Heat(New York)McGraw-Hill**
c Newton(1687)Philosophiae naturalis principia Mathematica(London)
d 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*).
e Usually work $W = \int_0^{v_e} mv \cdot dv = \frac{1}{2} m v_e^2$, but that is half the 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 an immeasurably small movement of the earth 'at rest'. That 'reacting mass' then receives the same kinetic energy in opposite direction, an unnoticed other half of your work, in total $E=mv^2$.
f Beeckman(1634)Journal tenu par Isaac Beeckman de 1604 à 1634 Tome III already invented a method to calculate c (in Dutch: http://adcs.home.xs4all.nl/beeckman/III/1634.html#lumen,) but Rømer (1676) "A Demonstration concerning the Motion of Light". Philosophical Transactions of the Royal Society 12 (136): 893–4. 1677 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 Lorentz(1895)Versuch einer Theorie der electrischen und optischen Erscheinungen in bewegten Körpern(Leiden)Brill proved that a mass m increases moving by a factor $\lambda = (1-(v/c)^2)^{-½}$. This 'Lorentz factor' λ and therefore the moving mass, would become infinite if it would approach the speed of light c. Close to c you then have to use an infinite amount of energy to speed up. So, c is a maximum speed for masses. Acceleration beyond light speed is imaginary, because it requires more than infinite energy. As a thought experiment, however, it is a simple shortcut into the complicated mathematics of the special relativity theory of Einstein(1905).

MASS INCREASES, BUT TIME AND SPACE SHRINK BY INCREASING VELOCITY



206 Your travel in my world



207 My travel in your world

In both figures, the **diagonal** represents the **maximum speed** c ≈ 3km/10µsec[a] as a constant.
The grids show 1km and 3⅓µsec as interchangeable 'space-time' units in 4 dimensions.[b]
In ***Fig.206*** I see you moving away from me with a velocity ⅓c ≈ 1km/10µsec.
We both start at the origin (0, 0), but I travel only in time (vertical axis), not in space (km).

In ***Fig.207***, however, you see *me* disappearing behind you, supposing that *you* don't move.
At 10µsec, 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.207*** seems shorter.

In ***Fig.206*** 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 $d_{me}=\sqrt{(a^2+(2a)^2)}=\mathbf{a\sqrt{5}}$.

In ***Fig.207***, 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 $\sqrt{((1{,}5a)^2+(1{,}5a)^2)}=\mathbf{a\sqrt{4.5}}$.
So d_{you} is $\sqrt{4.5}$ / $a\sqrt{5}$ ≈ 95% smaller than 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)Die Grundgleichungen für die elektromagnetischen Vorgänge in bewegten Körpern(Nachrichten der Gesellschaft der Wissenschaften zu Göttingen)Mathematisch-Physikalische Klasse p53–111 introduced time as a fourth dimension with equal units.

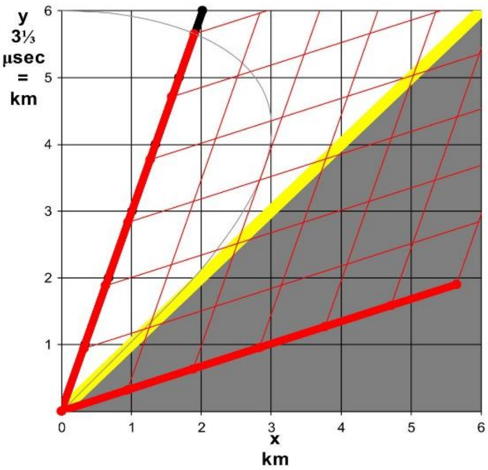
c The **thick yellow** diagonals represent the speed of light c (3km/10µsec), also being the maximum velocity of masses. Each slope parallel to that yellow line (or back perpendicular to it) equals that speed. It is the same for you and me. Even with a moving light source, c remains the same forwards and backwards, proven by the experiments of Michelson;Morley(1887)On the relative Motion of the Earth and the Luminiferous Ether(American Journal of Science)XXXIV p883-845

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. Exacly 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(your speed)*r/c. Now $p/r=\sqrt{(1-v^2r^2/r^2c^2)}=\sqrt{1v^2/c^2}$, or simply $p/r=\sqrt{(1-(v/c)^2)}$. That is the *shrink* factor 1/γ! In this, γ is the famous Lorenz factor, with which your mass *grows*.

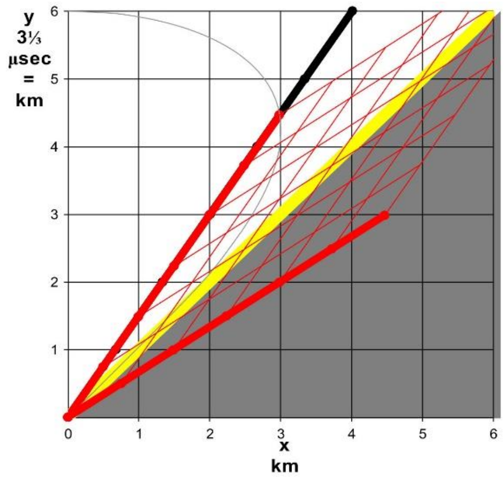
166-169
Jong(2015)Relativiteit

ACCELERATION DRAWS YOUR SPACE-TIME CROOKED COMPARED TO MINE

In ***Fig.208*** 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*.



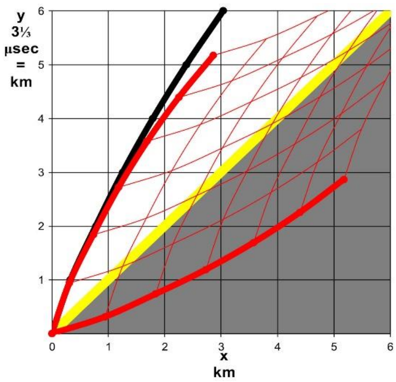
208 My projection of your world



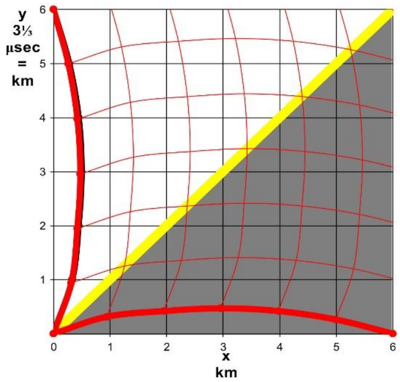
209 The same with double speed

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.210*** show curved lines (more and more kilometers are made per µsec). Time and space themselves are curved.
In ***Fig.210*** acceleration is positive, retardation is a 'negative acceleration' (***Fig.211***).



210 Acceleration



211 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.205*** p106) 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.

a **Einstein(1916)Die Grundlage der allgemeinen Relativitätstheorie(Annalen der Physik)IV 49 p769-822**

Then you should be able to see a galaxy behind the sun where you expect it to be hidden.
That is what Eddington[a] demonstrated for the first time during the solar eclipse on 29 May 1919.

§ 27 QUANTUM MECHANICS SUPPOSES UNCERTAINTY

Quantum mechanics is already briefly introduced on page 33.

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[b], there are other field forces than gravity[c]. 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.[d]
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').

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. 48***p33).

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.205***p106) 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 p33) has been Plancks constant h predicting the observed energy of light E = h∗frequency=h∗c/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=mass∗velocity (p106) then has to be redefined as p=h/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.

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a **Eddington(1920)Space time and gravitation An outline of the General Relativity Theory(Cambridge)University Press**
http://www.gutenberg.org/files/29782/29782-pdf.pdf?session_id=a60a38a8e2635a9ee437a880211f4b09acb4dd27
b Quarks (from which protons and neutrons are composed), leptomes (like the electron) and bosons (like the photon).
c Electromagnetic forces (transferred by photons), strong nuclear forces (gluons), weak nuclear forces and other (bosons).
d **Heisenberg(1927)Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik(Zeitschrift für Physik) 43 3–4 172–198**

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 (↻ 'upward spin' or ↺ '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)Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres(Nature) 526, 682-686**; **Wayenburg(2015)Quantummechanica De werkelijkheid is nu bewezen spookachtig(NRC)0828** and a comic strip that gives an exciting account of that evidence: Kriek;Calmthout(2015)Het spook van Delft Quantumfysica(Volkskrant)1024

§ 28 THERMODYNAMICS CONNECTS TWO LEVELS OF SCALE




212 Boyle[a] *213 Watt*[b] *214 Carnot*[c] *215 Boltzmann*[d]

Leading designers of the contents of this paragraph

WORK AND HEAT SUPPOSE ENERGY AT DIFFERENT LEVELS OF SCALE

Boyle-Gay-Lussac.xlsx

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} = 20*cm* downwards, then you feel an counterforce increasing from s = 0*m* into 0.2*m*. If your final force f_{max} matches 1*kg* weight, then your force f increases from 0 to 1*kgforce (=* 9.8*newton* = 9.8*N)*.

The *energy* you delivered (your work W) is force times distance, f∗s *Nm (= joule = J)*, but f and s both increase stepwise (***Fig.93***p65), 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*°C*.
The units of *celcius* and *kelvin* are the same, but their zero-point differs.

Now take $6.022141*10^{23}$ equal molecules of gas (a '*mole*' see page 129), at temperature T.
Then the number of *moles* n = 1. Their heat energy pV appears to be n∗R∗T joule, where R = 8,314 462 618 *J/(K∗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 ca.1*kgf* on 1cm^2, or approximately 10N/cm^2=100 000N/m^2*(Pa)*=1*bar*[f].
Suppose your bicycle pump has a working length of 54 cm and an inside diameter ('bore') of 3.57 cm. So, it contains $54*\pi*1.78^2 = 540\ cm^3$ of air (that is 0.7 *gram* or 0.024046 *mole* at 25°C).

---

a Boyle(1660,1662)New experiments physico-mechanical(Oxford)Hall. Robert Boyle invented the model P*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)Patent 913 Method of Lessening the Consumption of Steam & Fuel in Fire Engines(London1855)Eyre
James Watt improved the steam engines of Savery and Newcomen, clearing the way for the Industrial Revolution.

c Carnot(1824)Réflexions sur la puissance motrice du feu(Paris)Bachelier
Sadi Carnot clarified the efficiency of steam engines. This has been the foundation of thermodynamics as a science

d Boltzmann(1877)Über die Beziehung zwischen dem zweiten Hauptsatz der mechanischen Wärmetheorie und der Wahrscheinlichkeitsrechnung respektive den Sätzen über das Wärmegleichgewicht(Wien)Ber 76 373-435.
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=1*mole*.

f Our air pressure is approximately 100 000N/m^2, 100 000 *pascal*, '*Pa* ', 1000 *hectopascal* '*hPa*' or 1'*bar* '.

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*kgf*/1*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*cm*^{3} (540/340 is called the 'compression ratio').

You have *increased* pressure from the atmosphere p_1=100 000*N/m*^{2} into p_2=200 000*N/m*^{2}.
You have *decreased* the original volume from V_1=0.00054*m*^{3} into V_2=0.00034*m*^{3}.
The increase of energy in the pump is $V_2p_2-V_1p_1$=14*J*, but 'stepwise' (∫) 7*J*.

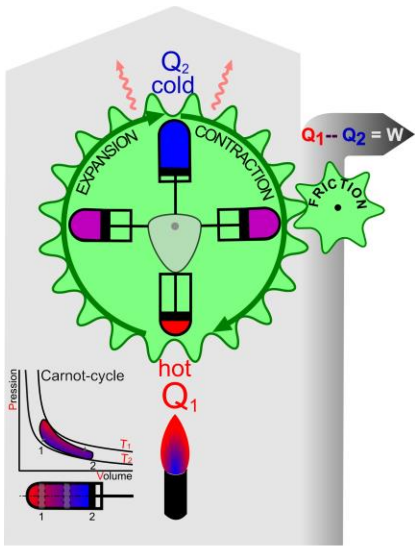
Let us for the time being forget stepwise integration (∫). According to Boyle-Gay-Lussac pV/T is constant, so $p_1V_1/T_1=p_2V_2/T_2$. The initial temperature T_1 was 298.15*K* = 25°*C*. Then the new temperature must be $T_2=T_1*p_2V_2/p_1V_1$=298.15∗(200000∗0.00034)/(100000∗0.00054)= 375*K*.
That is 375-273,15=102°*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.216***).



216 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=ΔQ (minus a part lost by friction).
Work or heat is Boyle's pV in pV/T=nR=constant[c].

The absolute temperature T_{hot} cooles –ΔT into T_{cold}, delivering W and then the reverse heats again +ΔT.
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:
$W = \int_{Vmin}^{Vmax} p\, dV = \int_{Vmin}^{Vmax} nRT/V\, dV = nRT \cdot \int_{Vmin}^{Vmax} 1/V\, dV.$

In the cycle as a whole R, n, and T (=T+ΔT-ΔT) are constants. So, they can be put outside the integration.

One '*mole*' of gas contains 6,022∗10^{23} molecules (Avogadro's number N_A).
If n=1*mole*, R=8.31 (gas constant), overall T is also constant, and V_{max} is $2V_{min}$, then
$\Delta Q = W = nRT \cdot \int_{Vmin}^{Vmax} 1/V\, dV = 1*8.31*T*\int_1^2 \frac{1}{V} dV = 8.31*T*\ln(2/1) = 8.31*T*0.693 = 5.76T$. ΔQ/T (=5.76) is called entropy.

---

a If you take a more realistic normal air pressure of 1011,3*hPa*, then it is 94°*C*.
b **Carnot(1824)Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance(Paris)Bachelier** .
c Law Boyle-**Gay-Lussac(1802)Recherches sur la dilatation des gaz et des vapeurs(Annales de Chimie)43 137–175** See Magie(1935)p165

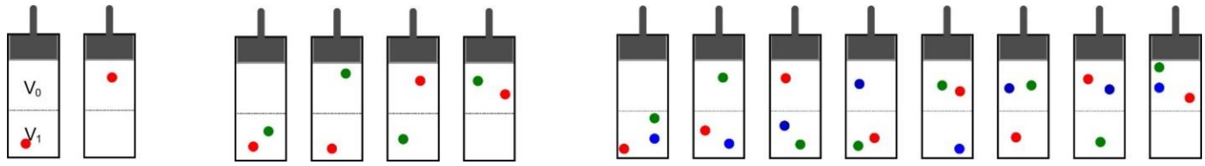
ENTROPY SUPPOSES A PROBABILITY OF DISTRIBUTION

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 ½ (50%).
With two molecules that probability is $½^2=¼$, with three molecules $½^3$ (***Fig.217***).

173 verdeling moleculen in een cilin



217 All possible distributions of 1, 2 or 3 molecules over two equal halves of a cylinder

173 Clausius.wxmx

With m molecules that probability then is $½^m$. The chance that all molecules of one *mole* ($m=6{,}022*10^{23}$) happen to be in V_1 of ***Fig.217***. 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 ½V, but up to ⅓V or even 1/22V (as in some diesel engines), then that probability is even smaller (not $½^m$, but $⅓^m$, $1/22^m$ 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.67

Entropy S based on probabilities, compares two chances: $S=R/m*\ln(chance_{all\ in V0+V1}/chance_{all\ in\ V1}) = R/m*\ln(2^m/1^m) = mR/m*\ln(2/1) = R*\ln(2) = 8.31*0.693 = 5.76$ (in fact ΔS, but the second chance is practically zero).
So, the *chance theoretic* $S= R/m *\ln(chance_1/chance_0)$, 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= 0*K*) 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 → ← changes necessarily into a divergent ← → (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)Ueber eine veränderte Form des zweiten Hauptsatzes der mechanischen Wärmetheorieein(Annalen der Physik und Chemie)93 12** p481–506.

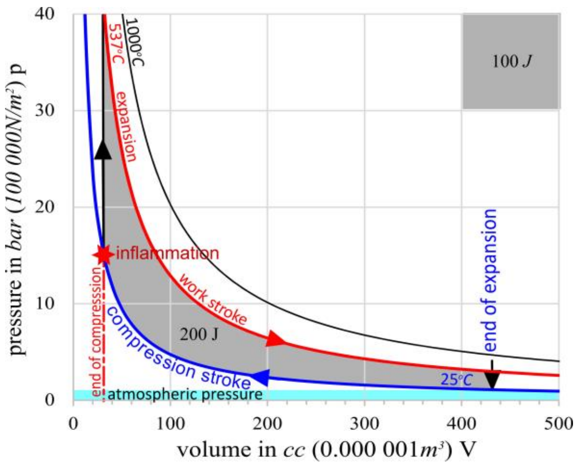
WORK OUT OF HEAT SUPPOSES LOSS OF ENERGY

A steam engine brings water to a boil in a closed boiler.
The saturated steam can reach a temperature of 190^oC 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.



218 pV graph (Boyle-Gay-Lussac) in a passenger car

Fig.218 (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∗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 $100*200J = 20\,000J/sec = 20\ watt$.

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 $0.0004m^3$ takes about 6% petrol mixed with the necessary air.
It has a calorific value (heat production) of $Q_1 = 872J$, but only $200J$ is used for work.
The return (efficiency) $\eta = W/\Delta Q$ then is 200/872=23%.
The remainder, $Q_2 = 672J$, is lost as heat (see also ***Fig.216*** p112).

The left vertical arrow in ***Fig.218*** represents the moment after ignition where suddenly 872J of heat (Q_1) 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)Arbeitsweise und Ausführung eines Gaskraft- oder Petroleum-Motors(patent Germany)DRP 532**

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; $V_{max}=0{,}034m^3$; $V_{min}=0{,}0031m^3$.

If the volume would not change ('isochore'), the temperature should rise to 537 ºC. That is unlikely to happen, if the volume increases immediately thereafter (expansion in ***Fig.218***p114).

Since 1892, gas mixtures have been used that spontaneously ignite in a 'diesel engine' at 256ºC 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.218p114 shows that a passenger car requires a temperature difference ΔT of 527-25 ≈ 500ºC to yield enough work and power. A racing car may require more than 1000ºC.
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 ΔQ/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 $E=mc^2$ (p106) as potential energy, the potential decomposition energy of all molecules (bondings represent potential energy, see p131), 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 ΔQ+ΔW.
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 ∫d can still produce higher or lower values (***Fig.93*** p65).

THE HEAT REQUIRED TO RAISE THE TEMPERATURE OF 1 KG BY 1 ºC MAY BE DIFFERENT.
If you heat 1*kg* of air (34.5*mol* or 1.2m^3) at 20*ºC* (293.15*K*) into 21*ºC*, without a change of *pressure* ('**isobar**') you have added 1003*J* of heat Q. That 1003*J* per *ºC* or *ºK* and *kg* is the 'specific heat at equal pressure' ('$\mathbf{c_p}$') 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: 715*J*.
That 715*J*/(º*K*∗*kg*) is called 'specific heat at equal *volume*' ('$\mathbf{c_v}$') 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.218***p114 I used c_p to add up the work the engine had to do first: 'lifting the atmosphere'.

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a The first Diesel engine has been invented by **Diesel(1886)Theorie und Konstruktion eines rationellen Wärmemotors zum Ersatz der Dampfmaschine und der heute bekannten Verbrennungsmotoren(Düsseldorf 1991)VDI Verlag**. 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.

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.

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 4187*J* per *degree* and *kilogram*, dry brick only 880*J*/(*K*∗*kg*).

Heating up a brick of 1.75*kg* (5∗10∗15*cm*) one degree costs 1470*J*. 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 INFORMATION SUPPOSES FORMATION

INFORMATION SUPPOSES PHYSICS

00000	00001	00010	00011	00100	00101	00110	00111	01000	01001	01010	01011	01100	01101	01110	01111	10000	10001	10010	10011	10100	10101	10110	10111	11000	11001	11010	11011	11100	11101	11110	11111
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	[	\	]	^	_

219 Binary ASCII codes for 26 capitals and 6 other signs out of 256 possible codes [a]

Information can be physically stored, 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. 219***).

Logarithmen.wxmx

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 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.219*** 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=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 lb(16)= 4 bits/pixel, and that 25 times per second, yields 500 000∗4∗25=50 000 000bits/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.

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a https://www.rapidtables.com/code/text/ascii-table.html
b $\log_{10}(256) = 2.41$ $ln(256) = 5.55$ $lb(256) = 8.0$
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?

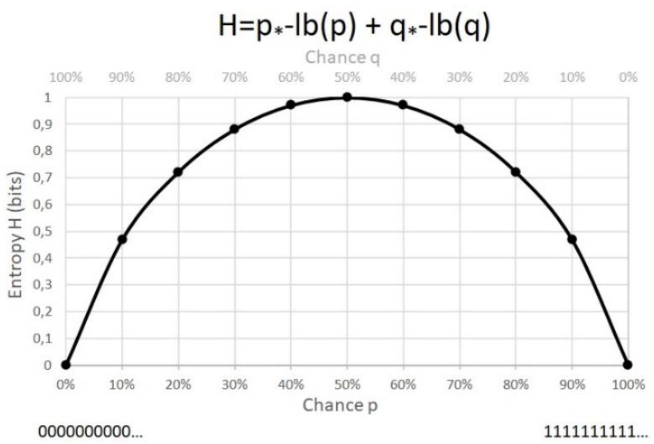
In ***Fig.217***p113 all possible distributions of 1, 2 or 3 molecules are represented on two equal halves of a cylinder. You can call those halves 0 and 1 and n molecules can be located in a list of 2^n locations.

The position of one molecule (n=1) in volume V_0 or V_1 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, V_1 or V_2 (ordered, low entropy). On p113 entropy has been defined as $S=k*\ln(chance_{V \text{ or } V_1})$, a measure for disorder, the opposite of 'value' or 'quality'.

176 Shannon2.xlsx

175 Breuer(1995) Buchstaben.xlsx



220 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 time100%, 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=lb(2) is one bit, but its SI is less.

You may reduce I by the chance p: $p*I$ ($p*lb(2)$bits), but then, if p=1 (100% certainty) it would also be 1bit ($p*lb(2)=1*1$) 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)A Mathematical Theory of Communication(Bell Systems Technical Journal)27 379-423, 623-656 p21**
c https://en.wikipedia.org/wiki/Self-information

This should be the point that Shannon remembered entropy $S=k*\ln(chance)$ as an energy-value. It does, however, not concern gas. Use k=1.443 to change the kind of logarithm $lb(x)=1.443*\ln(x)$.

If you take SI=lb(p), then $p*lb(p)$ is the chance you may receive *relevant* information (SI). Since lb(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 $lb(1/p)=-lb(p)$ make his final formula for information-entropy (***Fig.220***p118) 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 $q*-lb(q)$, and q is nothing else than 1-p.
So, the information entropy H is a function of only p: H(p).

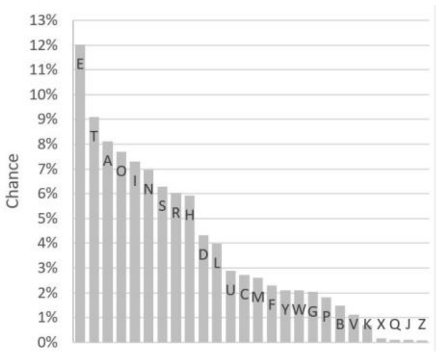
According to this function the texts '000 ...' and '111 ...' do have an information entropy H=0, and a random text such as '110100111000' may have offered total uncertainty and thus the highest relevance H=1.

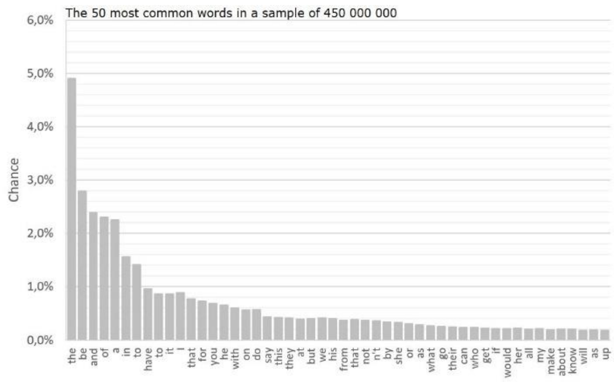
The chance to get '1' equals the chance to get '0'. Instead of '1' and '0', you may also choose 'E' and 'any other character' ('not E'). You can even split 'not E' into 'M' and 'not E or M', adding terms with p_E, p_M and $p_{\text{not E or M}}$.

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=lb(26)=4.7 bits.
Any character, however, has its own probability to appear in a text.

Fig.221 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 $SI_E=-lb(p_E)$=3.06bits self-information, and M has $SI_M=-lb(p_M)$= 5.27bits.
The chance that you will actually *receive* this self-information is again p_E or p_M, producing $p_E*-lb(p_E)$, $p_M*-lb(p_M)$ and $p_{\text{not E or M}}*-lb(p_{\text{not E or M}})$. Add all, and you have Shannons entropy of the signal. Note that the *sequence* (ME or EM) does not yet play a role.





221 Characterfrequency [a] ***222 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.

a http://pi.math.cornell.edu/~mec/2003-2004/cryptography/subs/frequencies.html **Broecke(1988)Ter sprake, Spraak als betekenisvol geluid in 36 thematische hoofdstukken(Leiden)Foris**

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*1/26=3.8%*3.8%=0.15%. That is much less predictable.

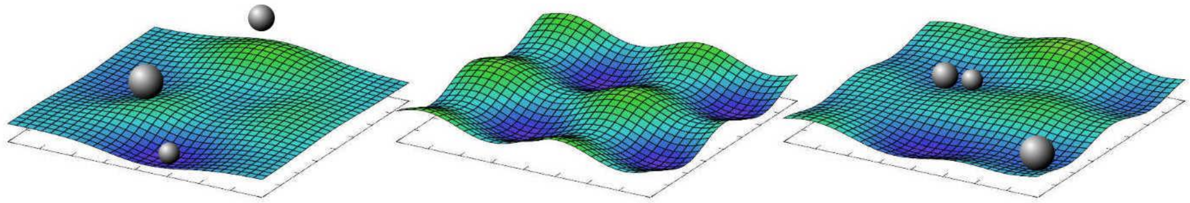
Based on the character frequency in English (***Fig.221***p119), however, the probability of ME is 3%*12%=0.4%. ***Fig.222***p119 is based on a word list of 60 000 words in a sample of more than 450 million words. In an alphabet with 60 000 'characters' the probability of ME would be 1/60 000=0.0017%, 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.223***). 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.



223 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.223***). 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),α)+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.

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a **Haken(2006)Information and Self-Organization(Berlin)Springer** 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.

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. Haken[a] quantifies that as follows (***Fig.224***). To keep it simple: take 3 mail messages p_0, p_1, p_2.

179 Haken(2006)Informat

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			
j'			k	0	1	2	
0	p'_0	$L_{jk} = \frac{M_{jk}}{\sum_{j'} M_{j'k} + \varepsilon}$	L_{jk}	-	0,53	0,13	
1	p'_1			-	0,33	0,33	
2	p'_2			-	0,13	0,53	
ε=	0,0001	$\left(\sum_j \frac{M_{jk}}{\sum_{j'} M_{j'k} + \varepsilon}\right)$		-	1,00	1,00	$\sum_j p'_j = 1$

224 Weight of messages received ***225 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} ***Fig224***). 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 $-p'_k * \ln p'_k$) 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.225***). 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 dentrites and transmits it to other neurons via an axon with a different weight (see ***Fig.174*** p89 and onwards).

a **Haken(2006)Information and Self-Organization(Berlin)Springer** p21

§ 30 COMPLEXITY ⇓ SURVIVAL AT A 'FITTEST' CONTEXT AND SCALE

COMPLEXITY IS NOT PROPERLY DEFINED

Open systems are usually in a chaotic (entropic) equilibrium, but with steady or fluctuating external supply and dissipation of mass, energy or information, these can suddenly display an order (a 'phase transition' similar to freezing) 'far from equilibrium', characterised as 'complex'.

That surprised some physicists. You would expect that an open system always falls prey to increasing entropy if you do not close it off from a disordered outside world. Such an open *and* ordered complexity, however, resembles reduced entropy, which can be described by less bits.

For example, 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 a narrow directed beam of highly focused coherent light in the same phase and with the same frequency. This high energy beam escapes through a hole in the mirror (a 'laser').

Another often cited example is the appearance of pure hexagonal Bénard cells in a slowly and evenly heated fluid (***Fig.165***p83)[a], or the swivels in chaotic gases (cyclones) and liquids (***Fig.167***p84). Such order is easily associated with an 'invisible hand', as supposed in economics[b] or in suddenly directed social movements ('hypes' or 'waves' in a stadium), but both may be explained by exact repetition, simulated by mathematical iteration (0p74).

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').[c]
Without a better definition than this, it is an embarrassing concept for something the author apparently does not understand ("It is sooo complex").[d]

Haken[e] claims to capture synergetic 'complexity' in complex mathematics.
If it distinguises only order and disorder, then I would define it as 'different differences at different levels of scale', changing less than their environment.
That also appeals to designers: make a difference. Making equal is not the art of design.

If suddenly a very large number of particles become 'enslaved' and show 'self-organization', then the phenomenon 'emerges'. An emergent complex open system may

(1) differ from the external rest ('difference'),
(2) have some internal equality ('order'),
(3) remain the same, despite changes in that environment ('stability'),
(4) adapt to them ('adaptation'), or even
(5) adapt that environment to itself ('accommodation'), known from biological growth and reproduction. Finally,
(6) such a system may be divided into mutually connected subsystems with different contents, forms, structures, functions, and sometimes even intentions ('specialization').

As far as I am concerned, these characteristics define *increasing* levels of 'complexity'. Freezing, swirls, Bénard cells and lasers do not go beyond self-*ordering* by iteration (2) and some stability (3). I would speak of '*organization*' only at (6).

a **Bénard(1900)Les tourbillons cellulaires dans une nappe liquide(Rev Gen Sci pures et appl)11 1261-1271 & 1309-1328**
b Supposed in **Smith(1776)An inquiry into the nature and the wealth of nations(London)**
c **Page(2011)Diversity and complexity(Princeton)University Press** p32 See also **Prigogine;Stengers(1984)Order out of Chaos Man's new dialogue with nature(London)Flamingo**, Gleick(1987)Chaos making a new science(New York)Viking
d **Simon(1969)The Sciences Of The Artificial(CambridgeMass1982)MITPress** p3: '…complexity, correctly viewed, is only a mask for simplicity…'
e **Haken(1978)Synergetics an introduction(Berlin)Springer** and **Haken(2006)Information and Self-Organization(Berlin)Springer.**

'ORDER' IS SCALE-DEPENDENT

For example, a city as a complex system[a], 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, biotic 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 p85).

There are many more levels of scale between 'microscopic' and 'macroscopic', than to which physics (mechanics, thermodynamics,[b] and quantum mechanics) is limited per discipline. Ecology should distinguish at least 15 levels of scale e.g. in order to define biodiversity.

A change of scale may reverse the conclusion 'order' (concentration) or 'disorder' (dispersion) already by a factor 3. Without scale specification you can conclude both in the same time.
I know only one publication that divides 'complexity' into different levels of scale.[c]

Change more often destroys difference than creating it.
My footstep full of information on the beach is lost in the sea by advancing seawater, but a remaining jellyfish remains longer by protective walls and internal membranes.

In a cylinder with molecules (1) and empty spaces (0) the entropy of an unequal distribution 111000 increases into an equal distribution 101010. The first is concentration (compression), the other is dispersion (expansion). This 'equalizing', conceived as characteristic for increasing entropy, seems to contradict the Shannon entropy.

In ***Fig.220***p118, 111000 and 101010 do have the same information entropy, but from both into 111111 (equality) entropy *decreases*. In ***Fig.226*** the 'Kolmogorov complexity'[d] of 111000 is also larger than 111111. The sequence 101010, however, seems to be in between.

WHAT YOU CALL 'DIFFERENCE' IS SCALE-SENSITIVE

bit range	Shannon entropy H	Kolmogorov complexity	grain scale A 2 characters differences	grain scale B 3 characters differences	grain scale C 4 characters differences
111000	1	high	1	2	1
101010	1	medium	5	0	1
111111	0	low	0	0	0

226 Differences in a bit range differ per supposed level of grain scale

At the smallest grain scale (A) you have an alphabet of two characters (0 and 1).
You recognize one difference in 111000, five differences in 101010 and zero in 111111.
If you double that grain scale (B), you will see 11 10 00, 10 10 10, and 11 11 11 recognizing 3 characters (11, 10 and 00) and thus only 2 differences in the first bit range.

Now take a grain scale C. You see 111 000, 101 010 and 111 111. You recognize 4 characters (111, 000, 101, 010) and you recognize only 1 difference in the first two cases of ***Fig.226***.
This exercise is not intended to find any regularity in this list, but only to prove that other differences can be observed and named at a different level of scale.

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a **Portugali(1999)Self Organization And The City(Berlin)Springer**; Batty(2007)Cities and complexity(Cambridge Mass.)MIT Press
b **Young(1964)Fundamentals of Mechanics and Heat(New York)McGraw-Hill**
c **Bar-Yam(2004)Multiscale Complexity/Entropy(Cambridge, Mass)**
d **Kolmogorov(1963)On Tables of Random Numbers(Theoretical Computer Science 1998)207 (2) 387–395**

ORDER SUPPOSES SEPARATION IN MORE DIRECTIONS THAN ONE

A physical object may differ from its environment, maintain more order than its environment, and change less than its environment. The difference from the environment may be stabilised by an observable *separation* from the environment. 'Complexity' seems to maintain these characteristics *without* such separation. What replaces that separation in case of complexity?

Separation consists of two differences, more or less symmetrically mirrored, such as in walls, cell walls, membranes, but also in legal rules. Separations themselves change less than their environment by static connection ⊥ the direction of separation.
Once separated, enclosed differences may stabilize.

A different set of separations and connections ('structure') is crucial for organizations, organisms, organs, networks and devices.
Separations are required for their creation and maintenance, connections are risky.

The contradiction between the physical ('Clausius') entropy and that of Shannon (in which the one takes equality as a hallmark of disorder and the other on the contrary of order), may be solved by different resolution (grain).
There are, however, more differences in their assumptions.

With Shannon it is the chance of a next character in a linear, one-dimensional bit series.
With Clausius, macroscopic chances apply on three-dimensional states.
These chances may differ in 6 mutually ⊥ standard directions.

The macroscopic degrees of freedom may differ in those directions. This is, for example, the case in a closed cylinder with a piston allowing only freedom of expansion in one dimension.

If you build a two-dimensional screen picture by dividing a byte sequence into horizontal lines and displaying them in time one below the other, then the Shannon sequence only applies horizontally, but not vertically.

For the device, there is no vertical relationship between the pixels in the message.
That connection must be made by the spectator. A vertical streak supposes a vertical equality, but it requires a horizontal difference.

This perpendicular paradox is invisible in the tube vision of a bit sequence.
This paradoxical effect becomes the stronger with a third dimension adding more directions and perhaps also with a fourth dimension (time).
This makes the case 'complex' and difficult to 'describe' linearly.

It is therefore quite possible that you see order where another sees disorder, not only through a spatial or temporal scale shift, but also by changing direction. These are then summarized in the confusing term 'complexity'. A designers view on order, however, may look different[a]

Chaos~ and complexity theory are still deterministic, even if the emergence of a phase-transition is not fully understood. Lasers or cyclones are in principle predictable at a determined level of scale and in a well-described context.
The evolution of life, however, is based on *failures* in genes-transfer: improbable mutations.

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a **Alexander(2002)The Nature of Order Book 1-4 (Berkeley)The Centre of Environmental structure**.

§ 31 MINIMAL SUPPOSITIONS OF ABIOTIC POSSIBILITY

Abiotic : difference ⥣ change ⥣ object ⥣ separation ⥣ combination

Without a difference nothing can be observed, chosen or imagined (thought).

A1. **Difference** (e.g. adjacent black and white) enables to imagine a **place**, a **direction**, and a **sequence**. The direction and the sequence is from one side to the other. The place is in between. 'Different differences' enable to imagine different places ('space'), directions ('dimensions'), and sequences. **Equality** may appear as zero-difference ⊥ difference (***Fig.8***p10).

Equal sequences in all directions enable to distinguish an '**object**' from its '**environment**' (non-object). It enables to imagine '**not**', an outline (a boundary, a line, a shape), an '**inside**' and an '**outside**'. Different objects enable to imagine **plurality**, a '**set**', '**subsets**', a '**relation**' or a '**category**'. Different sets enable to imagine **magnitude**, and **levels of magnitude** (scale).

Quantifying 'more and less' difference encounters an inside-outside paradox of quantification. Numbers may belong to mutually *different* variables, but inside, the intervals of successive numbers (units) are supposed to be *equal*. What, then is the unit of difference?
A gradient counts an infinite number of differences. A 'larger' gradient even 'more'.

Choosing a *frame of observation* (an upper level of scale) and a *grain* (the lowest level taken into account, supposing equality inside), enables variables of finite real numbers.
Diversity then is the amount of 'different differences' (counting equal differences as one).
Note that this is not the diversity of objects, but the diversity of two-sided differences.

A2. **Change** 'takes place'. It is a special kind of difference (between before and after), including the different places, different directions, and *one* sequence, enabling a first concept of time. **Moving** (changing place) translates a passed spatial sequence to a temporal one. It enables **memory**, the imagination of **consecutive occasions** (history), changes in between, and **energy**.

Action is a change in the actor (**subject**) *and* in the intended **object** or its environment.
This enables to distinguish a subject (e.g. 'I') as the **cause**, and an affected object as an **effect**.
It also splits a childish solipsism into an own **identity** and the rest (decentralisation).

The act of grasping (***Fig.6***p8) enables a first concept (com-prehend, inter-lock) of **causation**.
The result of grasping is an appropriation (incorporation) of an object into the subject.
It is a temporary relapse into solipsism (see a child's tendency to put everything in its mouth).

A3. Grasping requires coherence of the grasped **object** as a solid (see the fascination of a child playing in the sand). An object appears as stability in the face of change. You cannot imagine an object without change or without trying to destruct (testing) a coherent object (see the fascination of a child laughing and knocking down your newly built toy tower again and again).

A4. An object enables the possibility of **separation** (supposing force).

A5. Separation enables **combination**.

Let me abbreviate the conditions A1 to A5 as
difference⥣change⥣object⥣separation⥣combination, where ⥣ means 'enables' or 'makes possible to imagine'. The chosen words are provisional[a] with a wide extension of fitting images.
The sequence, however, is strict. It gradually increases the possibilities of imagination.
The only a priori category is 'difference'. Its meaning is physically *and* mentally equivalent.

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a The term 'object', for example', may be read as **stable** external **difference** in any direction, and some internal **coherence**.

Difference may diversify any other condition: different changes, different objects, etc..
Change is also applicable to any other condition: changing objects, changing separations, etc..
The same counts for objects: coherent separations, coherent combinations and so on.
This 'recurrency' widens the still poor content of my abbreviations.

Any condition has a zero-value: zero difference (equality), zero change (stability), etc..
Equality then is not the opposite or a negation of difference, but a *value* of difference.
Nothing can be more equal than equal, but anything may be more different than a given difference. This prevents seeming contradictions. 'Different objects' may be equal.

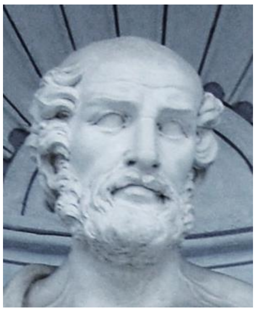
In the same way, stability is not the *opposite* or a negation of change, but a *value* of change.
Incoherence is not the opposite or a negation of coherence, but a value of coherence, and so on.
If, however, one in the series do have a zero-value, then any next condition will be impossible.
By zero difference, you cannot imagine change, with zero change no cohesion, and so on.

Just as you may *reduce* the whole series into 'difference⇈combination', you also may *expand* each element. For example: 'cohesion' may be expanded by 'substance⇈form⇈structure⇈function⇈intention'. The abiotic series then reads 'difference⇈change⇈substance⇈form⇈structure⇈function⇈intention⇈separation⇈combination.

An abiotic intention? Intentions should be human or divine. The word, however, is chosen for lack of anything better in order to include meanings such as 'propensity' or 'inclination'. In that sense you may imagine a slope or a stream inclined to separate ever finer sediments (gradient).

However that may be, rare separations emerge on Earth. An improbable combination once have opened the gateway to life. An immense diversity of possible chemical and biotic combinations became separated from the surrounding all-predominant abiotic probability (entropy).
The separation, however, is not absolute. A *selective* input and a different output enables life.

6. BIOTIC CONDITIONS ARE IMPROBABLE [a]



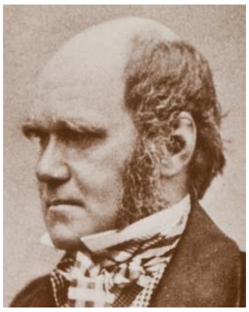
227 Theophrastus[b]

228 Leeuwenhoek[c]

229 Linnaeus[d]

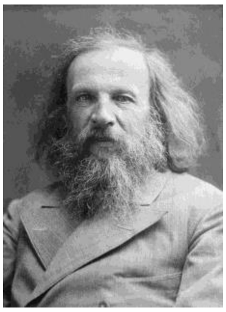
230 Lavoisier[e]

231 von Humboldt[f]



232 Darwin[g]

233 Mendel[h]



234 Mendeleev[i]

Leading designers of the contents of this chapter.

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a 'Improbable' here is meant as 'with very little probability'.

b **Theophrasus statue by Tuccio in Palermo Botanical Garden** Theophrastus(-287)Enquiry into Plants(London1916)Loeb Heinemann. Linnaeus called Theophrastus 'the father of botany'.

c **Leeuwenhoek portret by Verkolje in Rijksmuseum Amsterdam** Van Leeuwenhoek founded the science of microbiology..See Dobell(1932)Antony van Leeuwenhoek and his little animals(New York)Harcourt

d **Linnaeus portret by Roslin in Chateau de Versailles** Linnaeus(1753)Species plantarum vol 1 and 2(Stockholm)Impensis Laurentii Salvii designed the current naming of plants.

e **Lavoisier portret by David in The Metropolitan Museum of Art (the MED) New York City** Lavoisier(1789)Traité élémentaire de chimie(Paris)Cuchet 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 **Humbolt portret by Stieler, Charlottenhof Palace Potsdam.** 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)Kosmos, Entwurf einer Physischen Weltbeschreibung (Stuttgard) Cotta'scher Verlag, translated in English as Humboldt(1845)Cosmos a sketch of a physical description of the universe(New York1856)Harper.

g Darwin(1859)The origin of species(London)Murray established evolutionary biology with the concept of selection by survival of the fittest.

h Mendel(1865)Versuche über Plflanzenhybriden(Brünn)Naturforschenden Vereines IV 3–47 long unnoticed but rediscovered around 1900, translated as Mendel(1865)Experiments in Plant Hybridization(Cambridge Mass1925)Harvard University Press, founding the current science of genetics.

i Mendeleev(1870)Principles of chemistry(London1897)Longmans 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.

What is the designerly content of biology? Which discoveries are acually inventions, designs of a model? Do they cover a broader field of possibility beyond probability?
This chapter explores some disciplines of biology until 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.

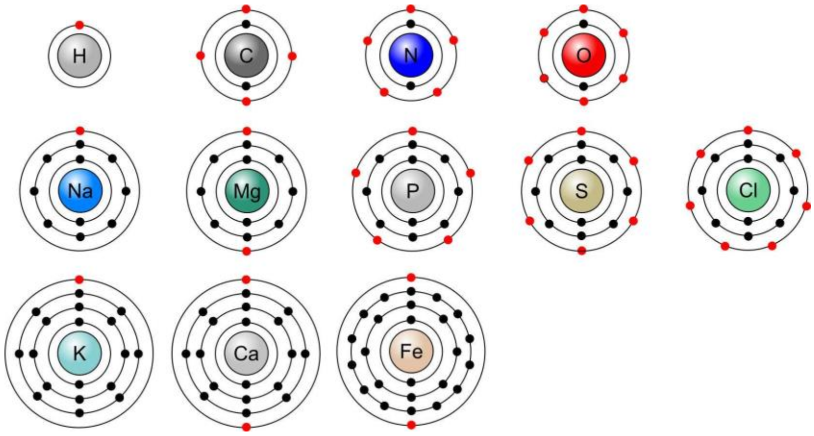
The diversity multiplies on each higher level: organelles, organs, organisms, organisations.
The rare conditions are ensured by selectively enclosing membranes. Separations in the shape of a tube may develop a *gradient* of rare conditions, where any specific reaction may find its niche.
Your intestinal 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 during 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.

§ 32 LIFE USES PREDOMINANTLY 12 OF THE 118 KNOWN ELEMENTS



235 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, all 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).

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a https://en.wikipedia.org/wiki/File:Periodic_Table_of_Elements_showing_Electron_Shells.svg
b **Lavoisier(1789)Traité élémentaire de chimie(Paris)Cuchet 1, 2** founded modern chemistry separatting 30 elements in molecules.
c **Mendeleev(1870)Principles of chemistry(London1897)Longmans**predicted undiscovered elements in his periodic system.
d **Bohr(1913)I On the constitution of atoms and molecules(Philosophical Magazine Series 6)26 151 1-25** supposed orbits of electrons,
Schrödinger(1926)An Undulatory Theory of the Mechanics of Atoms and Molecules(Physical Review)28 6 1049-70 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)Notiz über die Spectrallinien des Wasserstoffs(Annalen der Physik und Chemie)25, 80-87**, explained by **Bohr(1913)**
h **Chadwick(1932)Possible Existence of a Neutron(Nature) 129, 312**

CONNECTIONS 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 bondings 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 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.262***p143) 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^-).

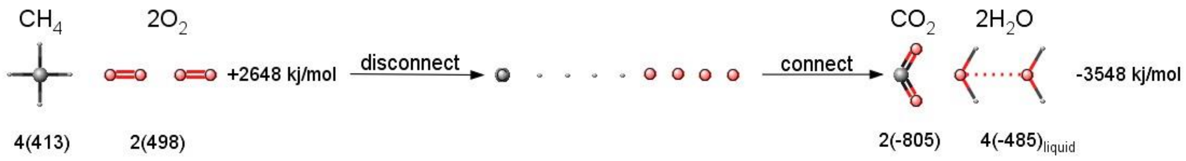
log.xlsx

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)On a New Series of Organic Bodies Containing Metals(Philosophical Transactions of the Royal Society of London)417-444, Lewis(1916)The atom and the molecule(J. Am. Chem. Soc.)38 4, Pauling(1927-1954) Pauling(1954)Nobelprize
b Faraday(1834)Experimental Researches in Electricity(Phil. Trans. R. Soc. Lond.)124 77–122
c Proposed by Sørensen(1909)Enzymstudien II: Über die Messung und die Bedeutung der Wasserstoffionenkonzentration bei enzymatischen Prozessen(Biochemische Zeitschrift)21 131-200

SEPARATING USUALLY *COSTS* ENERGY; CONNECTING *DELIVERS* ENERGY

183 Ontbinden, verbinden.mrv



236 A chemical reaction separates and connects

183a Bond energy COH and length.xlsx

If you light methane CH_4 with 2648 kJ/mole 'ignition energy', then you 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 $2(H_2O)$.

The required energy is written as positive input (+2648) and the released energy as negative output (-3548). So, you may write CH_4+2O_2+2648kj/mole → $CO_2+2H_2O-3548$kj/mole, but the loss of one is gain for the other, and outgoing 3548kj/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 'bondenergy'[b] required to separate, but also the energy released by connection (***Fig.236***).

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 collisions forcing a bond.

When all methane is burned, then 4(413)+2(498)-2(805)-4(485)=2648-3550=-908kJ/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.249***p136) ***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.

Thes 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 'mitochondrium' (p136, ***Fig.299***p156), present in any eukaryotic cell, using energetic bonds once enabled by photosynthesis elsewhere. In step by step reactions, the released energy is directly energising other reactions ('enthalpy'), with little heat.

LIFE IS BASED ON A SIMPLE ENERGY CYCLE

Plants separate C with solar energy from CO_2 (CO_2+2H_2O+solar energy → $C+4H+2O_2$). 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.236***). This 'carbon cycle' can be described simply in general, but in detail the chemical pathway is complicated by many intermediate steps.

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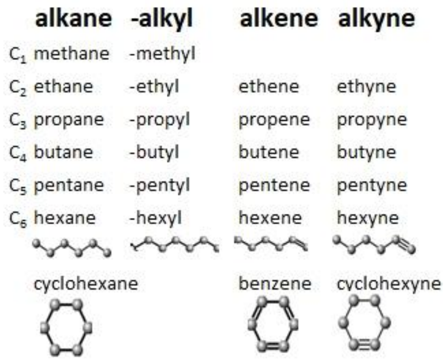
a http://www.wiredchemist.com/chemistry/data/bond_energies_lengths.html , https://labs.chem.ucsb.edu/zakarian/armen/11---bonddissociationenergy.pdf
b **Pauling (1932)The Nature of the Chemical Bond(J. Am. Chem. Soc.)Sepember** calculated bond energies based on the quantum mechanics.
c The calculation can be more complicated than it is important here for global understanding, see **Ellison(2002)Bond Dissociation Energies of Organic Molecules(Boulder)University of Colorado**

§ 33 CARBON (C) CONNECTS

CARBON[a] CONNECTS WITH HYDROGEN (H)[b]

183-184 Koolstofverbindingen

Implicit hydrogens.mrv



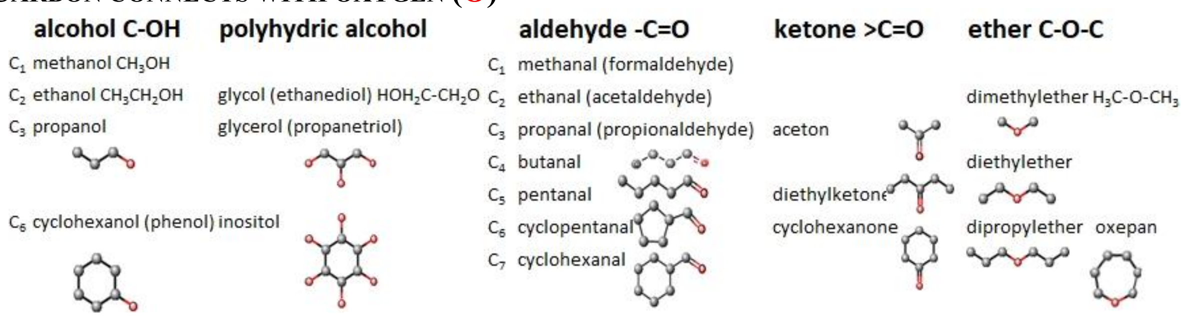
237 With hydrogen

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.237***, the chains of 1, 2, 3, 4, 5 or 6 carbon atoms are summarised as C_1, C_2, etc..

The first column contains the 'alkanes': 'methane' (CH_4) to 'hexane' (C_6H_{14}). At C_6 the chain may also form a hexagonal ring 'cyclohexane'. A hydrocarbon *rest* is called 'alkyl group'. If a ring has 3 'double' bonds,then it is called 'benzene', 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'.

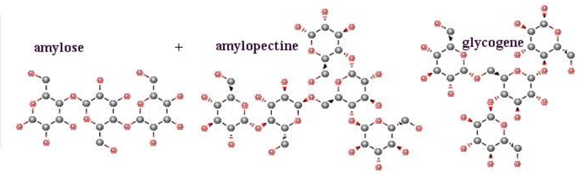
CARBON CONNECTS WITH OXYGEN (O)



238 With oxygen

In methane and other hydrocarbons, 2H can be replaced by a 'hungry' O.
Their names (***Fig.238***), end with -ol (alcohol[e], single bond) or '-al' ('aldehyde'[f], double bond).
If an intermediate C atom has a double bound =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].

185-186 Suikers.mrv



239 Sugars (saccharoses) *240 Starch and glycogen*

'Sugars'[i] (***Fig.239***) are composed of alcohols (***Fig.238***). Some sugars have the same formula,

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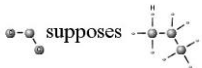
a Lavoisier(1789)Traité élémentaire de chimie(Paris)Cuchet 1, 2 separated carbon and many other particles as indivisible elements.

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 applicatiens, inventing many of the necessary instruments.
See his text in English: Liebig;Playfair ed(1842)Agriculture and physiology(Cambridge)Owen.

d The valences of C were found by Kekulé(1858)Ueber die Constitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs" (Annalen der Chemie)

e Lavoisier(1789) p139… la fermentation vineuse

f Liebig(1835)Ueber die Producte de Oxidation des Alkohols(Annalen der Pharmacie)XIV p134

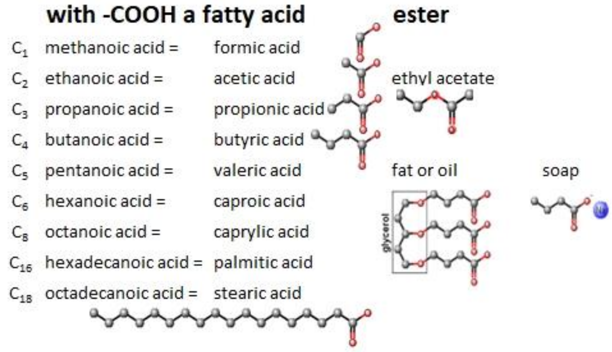
g Gmelin(1848)Handbuch der Chemie(Heidelberg)Winter

h August Sigmund Frobenius(1730)An Account of a Spiritus Vini Æthereus, Together with Several Experiments Tried(Philosophical Transactions of the Royal Society)36 283

i Lippmann(1895)Die Chemie der Zuckerarten(Braunsweich)Vieweg

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'[a] in plants, or as 'glycogen' in animals ***Fig.240***p132).

Fatty acids have a -COOH group



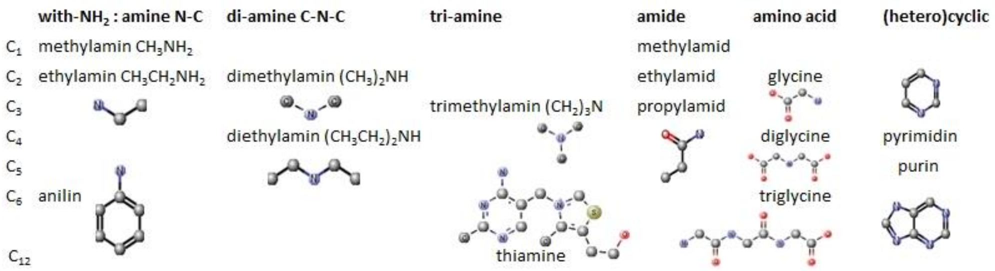
241 Fatty acids and their esters[b]

If two oxygen atoms claim all 3 valences from a C-end (-COOH), then the molecule becomes an acid. An alkyl group (***Fig.237***p132) with –COOH is a 'fatty acid' (***Fig.241***).

Three of them connected by a glycerol molecule (***Fig.238***p132) 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').

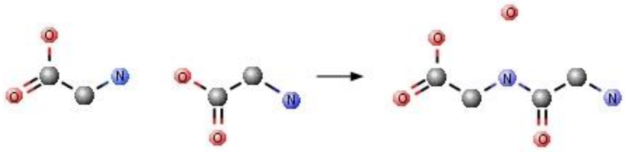
CARBON CONNECTS WITH NITROGEN (N)



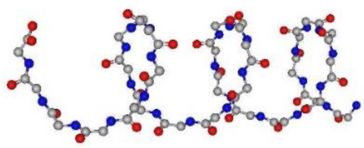
242 Amins, amids, amino acids and cyclics with N

If you replace a C by N (***Fig.242)***, then you get 'amines'[c] (such as vitamin B1 = thiamine) reacting as a base or almost neutral 'amides'[d].

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'[e]). The smallest amino acid is 'glycine'[f] . Two amino acids can be joined with head and tail to form a 'peptide' e.g. diglycine (***Fig.243***)[g].



243 Two glycine molecules → a peptide



244 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.244***).

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.[h]

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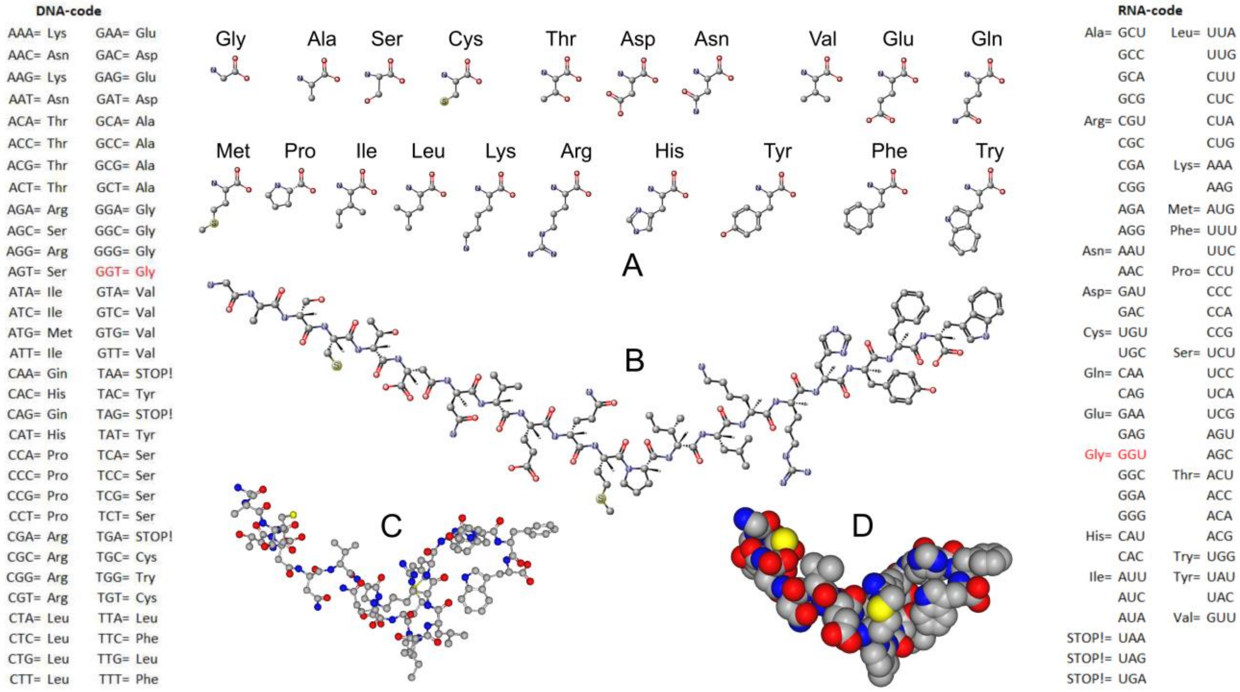
a Payen;Persoz(1833)Mémoire sur la diastase, les principaux produits de ses réactions et leurs applications aux arts industriels(Annales de Chimie et de Physique)53 73–92
b Chevreul (1823)Recherches chimiques sur les corps gras d'origine animale(Paris1889)Imprimrie nationale. Structure by Liebig(1837).
c Wurtz(1847)Sur un Série d'Alcalis Organiques Homologues Avec l'Ammoniaque(Comptes rendus hebdomadaires des séances de l'Académie des sciences 1849)28, 223 Hofmann(1865)Introduction to Modern Chemistry(London)Walton and Maberley
d Gerhardt(1844)Précis de chimie organique(Annales de chimie)
e Vauquelin;Robiquet(1806)Découverte d'un nouveau principe végétal dans les asperges (Annales de chimie)1 88 found asparagine.
f Braconnot(1820)Mémoire sur la Conversion des matières animales en nouvelles substances par le moyen de l'acide sulfurique.(Annales de chimie et de physique)
g Fischer(1899-1906)Untersuchungen über Aminosäuren, Peptide und Proteine(Berlin)Springer
h http://www.rcsb.org/pdb/home/home.do

eiwitten.mrv

191 EIWIT MET 20 AMINOZUREN 3D.xar

EIWIT MET 20 AMINOZUREN.mrv



245 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.

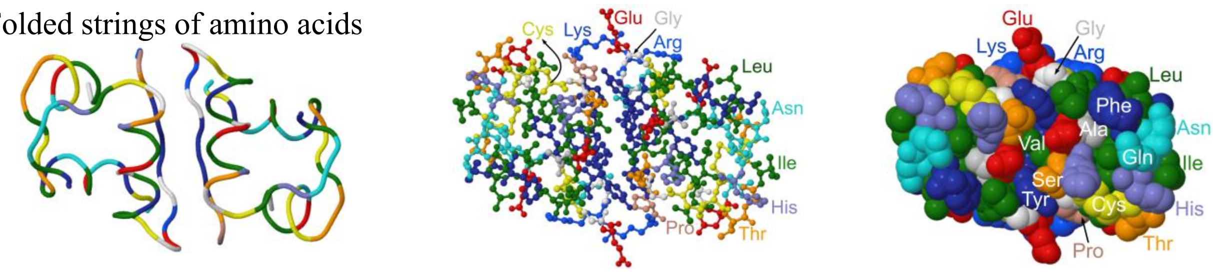
A 'protein'[a] is a chain ('polymer') of about 50 to 3000 amino acids.[b]
Fig.245A shows 20 types of amino acids present in living organisms in the order of their size.[c]
Their names are usually limited to abbreviations with 3 characters, e.g. Gly for glycine.
In ***Fig.245***B an imaginary protein 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.245C***). ***Fig.245***D 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.246***).

Folded strings of amino acids

Insuline.xar



246 An existing protein (insuline) composed of 17 different amino acids (colours)[d]

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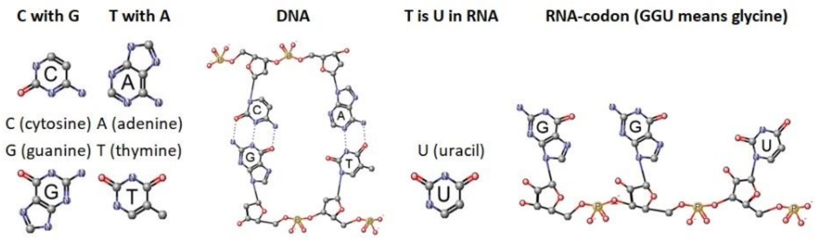
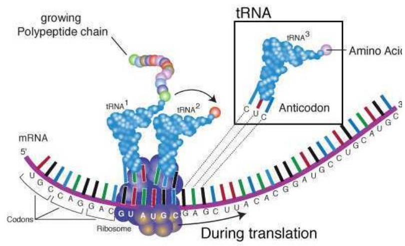
a **Berzelius (1838)** coined the Term "Protein" in his letters to Mulder:
Mulder (1838)On the composition of some animal substances(Jahresbericht über die Fortschritte der Tierchemie) ;
Fischer(1899-1906)Untersuchungen über Aminosäuren, Peptide und Proteine(Berlin)Springeran overview until 1906.
b http://proteopedia.org/wiki/index.php/Proteopedia:Table_of_Contents 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

Carbon bonds.xlsx





247 The alphabet of DNA and RNA[a] ***248 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.245***p134).
The sequence of amino acids for a substance is coded in a part of DNA between stops (‘gene’).

mRNA.pdf

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.247***).
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.284***p150)[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.248***, see also ***Fig.283***p150), located in a business park around the nucleus (a labyrinth of membranes, called 'endoplasmic reticulum' see ***Fig.299***p156).

A ribosome is a large molecule where a mRNA runs through with its codon(***Fig.248***).
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.299*** p156).

The energy for biotic processes is mainly delivered by a carbon bond with phosphorus.

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a **Miescher(1871)Über die chemische Zusammensetzung der Eiterzellen(Hoppe-Seyler’s Med. Chem. Investigations)** 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)The structure of thymonucleic acid(J. Biol. Chem.)** supposed a string of them. History by Hargittai(2009). **Chargaff** cs**(1950)Composition of deoxypentose nucleic acids(Experientia)** and **Chargaff (1952)Chemical specificity of nucleic acids and mechanism of their enzymatic degradation(Experientia)** discovered that in DNA, the amount of **A = T** and **C = G**, hinting at base-pairing rules. Chargaff’s legacy **Watson;Crick(1953)Molecular structure of nucleic acids: A structure for deoxyribose nucleic acid(Nature) 171, 737–738** finally found the double helix structure and base pairing of DNA.

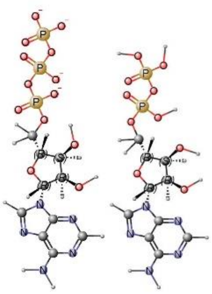
b http://aprendendogenetica.blogspot.nl/2011/03/genetica-molecular-aula-3-transcricao.html

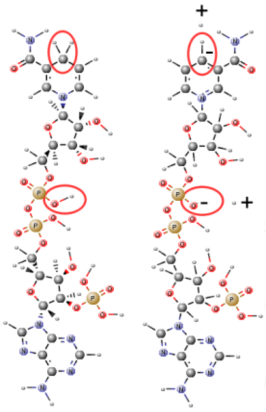
c **Wall(2016)The search for Human Chromosomes(Heidelberg)Springer** describes the quest of 88 years to translate the foundational laws of **Mendel(1865)Versuche über Plflanzenhybriden(Brünn)Naturforschenden Vereines IV 3–47**into a chemical model.

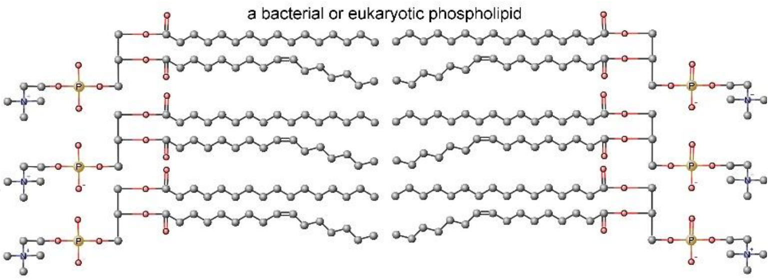
d **Brenner;Meselson (1961)An unstable intermediate carrying information from genes to ribosomes for protein synthesis(Nature)190 576–581. Jacob;Monod(1961)Genetic regulatory mechanisms in the synthesis of proteins(Journal of Molecular Biology)3 3 318–356**

e **Palade(1955)A small particulate component of the cytoplasm(Journal of Biophysical and Biochemical Cytology)1 59–68** related the ribosome to protein synthesis. Nobel prize(1974). **Zamecnik;Hoagland(1956)The Role of Soluble RNA in Protein Synthesis(Journal of Biological Chemistry)233 1535–539** found RNA and amino acids involved**. Siekevitz;Palade (1958)A Cytochemical Study on the Pancreas of the Guinea Pig: V. In vivo Incorporation of Leucine-1-C14 into the Chymotrypsinogen of Various Cell Fractions(Journal of Cell Biology then Journal of Biophysical and Biochemical Cytology)4 557–580** found biochemical evidence.

CARBON CONNECTS WITH PHOSPHORUS (P) [a]







249 ***250*** ***251***

ATP → ADP ***NADPH→ NADP*** ***A cell membrane***

Phosphorus is required for energy supply

Phosphorus has a crucial function in the energy supply for life. ***Fig.249*** 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 p136). That separation delivers 30kJ/mole of energy.[c] The battery is recharged elsewhere in a charging factory ('**mitochondrium**' ***Fig.299***p156)[d].

Something similar happens in ***Fig.250***, when NADPH offers two free $hydrogen^+$ atoms. In ***Fig.249*** and ***Fig.250***, 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.251 shows the role of phosphate (PO_4) 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.241***p133), but the third branch of the glycerol contains a PO_4-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.

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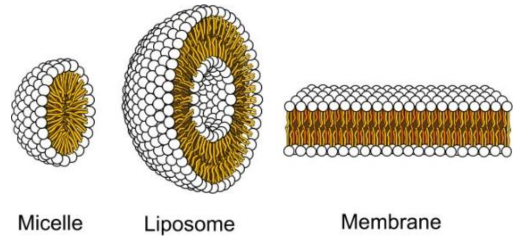
a Hennig **Brand(1669)** produced light giving phosphor from urine, Johann Daniel **Krafft** dipersed his discovery in Europe, Robert **Boyle(1677)** repeated and confirmed the experiment. He published it in English: **Boyle(1780)The aerial noctiluca(London)Nath. Ranew.** p11.

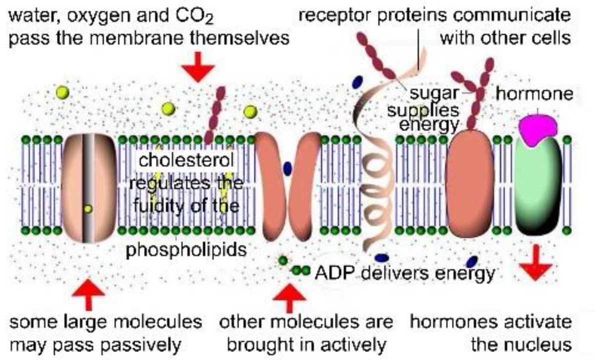
b **Lohmann(1929)Über die Pyrophosphatfraktion im Muskel(Naturwissenschaften) 17, 624** found ATP and three phosphate groups involved in energy transfer. **Lipmann(1941)Metabolic generation and utilization of phosphate bond energy(Advances in Enzymology)1 99–162** linked ATP/ADP to metabolic energy transfer. **Kalckar(1941)The nature of phosphorylation and energy exchange in biological processes(Chemical Reviews)28 71–132** created a unified theory of biological energy metabolism.

c https://en.wikipedia.org/wiki/Adenosine_triphosphate

d **Kölicker(1857)** separateted mitochondria from a cell structure. **Altmann(1890)Elementarorganismen und ihre Beziehungen zu den Zellen** observed 'bioblasts' (later identified as mitochondria). **Benda(1898)Ueber die Mitochondrien, sowie über einige andere Strukturen der Zelle(Ergebnisse der Anatomie und Entwicklungsgeschichte)** coined the name mitochondrium, but supposed individual cells within cells. **Claude(1946)The Constitution of the Cytoplasm. Isolation of Cell Components(The Journal of Experimental Medicine)** studied the chemical compositin. **Palade(1952)A study of fixation for electron microscopy(Journal of Experimental Medicine)** visualised it. **Mitchell, P. (1961). Coupling of phosphorylation to electron and hydrogen transfer by a chemi-osmotic type of mechanism(Nature)191 144–148** modelled ATP synthesis. Nobelprize(1978)

e **Overton(1896)über die osmotischen Eigenschaften der Zelle(Vierteljahrschr. Naturforsch. Ges. Zürich)41 383-406** suspected lipidoid cell walls. **Gorter;Grendel (1925)On bimolecular layers of lipoids on the chromocytes of the blood(Journal of Experimental Medicine)41(4) 439–443** 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)A contribution to the theory of permeability of thin films(Journal of Cellular and Comparative Physiology)5(4) 495-508** proposed the protein-lipid-protein sandwich model, and suggested proteins coat both sides of the lipid bilayer, forming a stable structure. **Singer;Nicolson (1972)The fluid mosaic model of the structure of cell membranes. Science, 175(4023), 720–731** described the membrane as a dynamic structure with proteins embedded in or attached to a bilayer of lipids.





***252 A*rrangements of polar phospholipids**[a] ***253* 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.253***), 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 p143).

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.239***p132), keeps the amino acids of DNA and RNA strings in the right sequence as a 'backbone' (***Fig.247***).

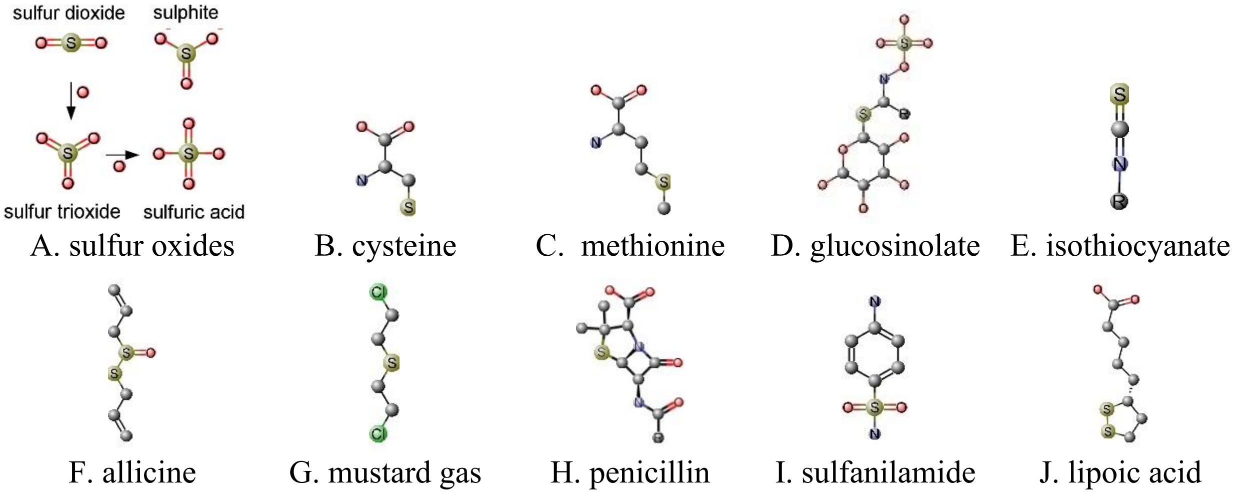
Phosphorus, not connected with carbon, is a major component of bones and teeths
Hydroxyapatite[c] is a crystalline complex of ions *outside* the cells of an organism, making up 50% of the volume of bones and teeth (***Fig.276***p146).[d] It is not connected to carbon, not organic, and in a sense not '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)Traité élémentaire de chimie(Paris)Cuchet 1, 2** refers to the presence of calcium phosphate in bones
Berzelius (1808–1818)Lehrbuch der Chemie 9 p540… confirmed the presence of calcium phosphate and carbonate in bones and teeth.
Liebig (1842)Animal Chemistry or Organic Chemistry in its Applications to Physiology and Pathology 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)X-ray diffraction analysis of the crystal structure of human bone(Nature)173 4394 1001–1002 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)Letter to the Royal Society (London)** described "animalcules" (microorganisms) from tartar scrapings**.**
Fauchard (1728)Le Chirurgien Dentiste made early references to tartar and its effects on teeth.
Fox(1803)The Natural History of the Human Teeth described tartar in more detail. **Berzelius cs(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)

199 Zwaveloxiden.mrv
199 Cysteine.mrv
199 Methionine.mrv
199 Glucosinolate.mrv
199 Isothiocyanate.mrv
199 Allicin.mrv
199 sulphur mustard.mrv
199 Penicillin.mrv
199 Sulfanilamide.mrv
199 Lipoic acid.mrv



***254* Some organic sulfur compounds**[a]

Sulfur dioxide (SO_2)[b] is a well-known industrial pollutant of the atmosphere.
***Fig.254*A** 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.254*A**)[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 extend 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.245***p134 as an element in the amino acids (with nitrogen N) Cys and Met (cysteine and methionine, ***Fig.254***B and C). There it appears with a hydrogen atom as -SH (a 'thiol') or as $-CSCH_3$ (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.254***D) 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.254***E**)** gives taste to mustard, radish, Brussels sprouts, watercress, East Indian cherry and capers. Allicine does so to garlic (***Fig.254***F**).**

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a Zie https://en.wikipedia.org/wiki/Organosulfur_compounds
b **Priestley(1777)Experiments and Observations on Different Kinds of Air(London)III** discovered sulfur dioxide in 1755. **Lavoisier(1789)Traité élémentaire de chimie(Paris)Cuchet 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)A New System of Chemical Philosophy** clarified molecular compositions like SO_2 and SO_3. **Gay-Lussac;Thenard(early 1800s)Annales de Chimie et de Physique** investigated SO3 and its formation via oxidation of SO2.
e *Carbon* trioxide should also be distinguished from a negative 'carbonate' ion $CO3^{--}$. With Ca^{++}, $CO3^{--}$ produces the very stable 'calcium carbonate' (CaCO3), the building block of eggshells, shells, limestone and marble.
f **Lewis(1916)The Atom and the Molecule(J. Am. Chem. Soc.)** introduced the concept of shared electron-pair, elaborated by **Langmuir(1919)The Arrangement of Electrons in Atoms and Molecules(J. Am. Chem. Soc.)** e.g. for sulphur.
g **Goodyear(1844)Improvement in India-rubber fabrics(U.S. Patent)3633** invented vulcanisation in 1839, but patented it later than **Hancock(1843)Vulcanisation of rubber using sulfur(British Patent)**

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.254***Gp138) has been a deadly chemical weapon of war.

Penicillin (***Fig.254***Hp138) 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.254***Ip138) 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.254***Jp138) 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^-) 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.

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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.

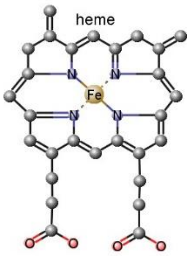
CARBON CONNECTS WITH METALS (CA, MG, K, NA, FE)

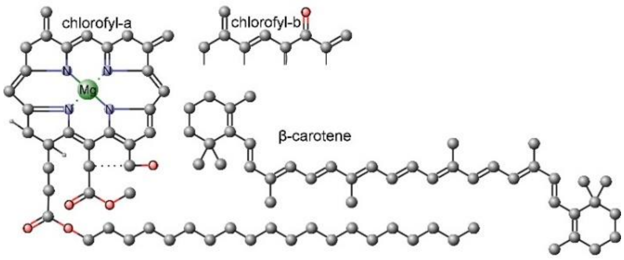
Metals enable nerves to function, mainain turgor and are required in enzymes
Ca and Mg are building materials of bones. K^+ and Na^+ ions change the potential of nerve axons, enabeling electron transfer. They also maintain the moisture tension in cells ('turgor').
Zn and Mg are required in different enzymes.

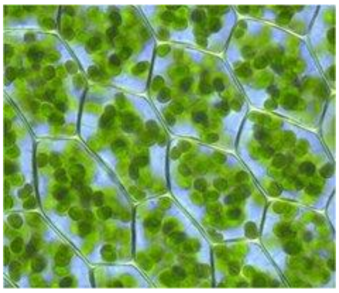
Metals are indispensable in blood and leaf green
Hemoglobin (in red blood cells) consists of four long protein molecules in a globe each with a 'heme' component (***Fig.255***). Chlorophyll (leaf green, ***Fig.256***) looks like heme, but it contains manganese (Mg) instead of iron (Fe).

200 heem.mrv

201 chlorofyl and carotene.mrv







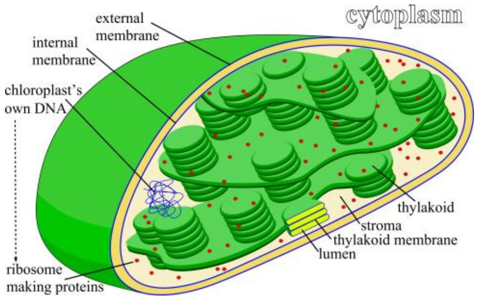
255 Heme ***256 Pigments in leaf green*** ***257 Leaf green components*** [a]

Hemoglobine can hold 4 molecules of oxygen (O_2) or carbon dioxide (CO_2) and transport them inwards and outwards through the bloodstream.[b]

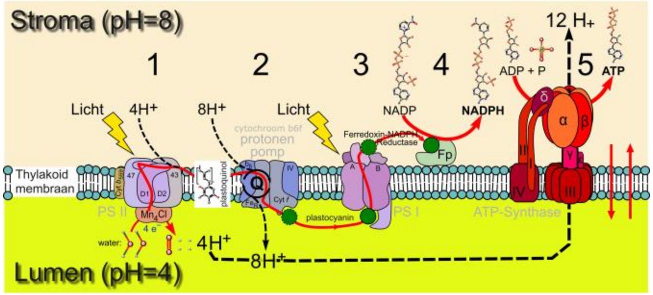
PHOTOSYNTHESIS CAPTURES ENERGY FROM LIGHT[c]

Chlorophyll and carotene (***Fig.256***) 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.257*** and ***Fig.258***p141). 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, posthumous)Ortus Medicinae** demonstrated that plant mass comes mainly from water, not soil (precursor to photosynthesis understanding). **Priestley(1777)Experiments and Observations on Different Kinds of Air(London)III** showed that plants release a substance (now known as oxygen) that supports animal life. **Ingenhousz(1779)Experiments upon Vegetables** demonstrated that plants produce oxygen only in sunlight and only by their green parts. Senebier**(1800)Physiologie végétale** Proved that carbon dioxide is taken in by plants and is necessary for photosynthesis. Saussure**(1804)Recherches chimiques sur la végétation quantified photosynthesis** showed water is also involved and confirmed mass balance. Sachs**(1868)Lehrbuch der Botanik** identified chlorophyll as the site of photosynthesis and starch as a product. Niel**(1931)The Comparative Biochemistry of Photosynthetic Mechanisms in Bacteria** generalized photosynthesis as $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ **Calvin c.s.(1950-1957)The Path of Carbon in Photosynthesis(Journal of the American Chemical Society)** elucidated the Calvin cycle, the dark reactions of photosynthesis, after multiple articles (1950–1957) in the Journal of the American Chemical Society



258 A chloroplast[a]



259 A thylakoid-membrane[b]

Chloroplasts are cells within a cell (***Fig.257***p140) with their own membranes and DNA. A chloroplast (***Fig.258***) on its turn contains hundreds of even smaller disc-shaped 'thylakoids', again with their own enclosing membrane (***Fig.259***). 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 thylakiod membrane contains 5 devices

In ***Fig.259*** 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.250***p136), and 5 ATP (***Fig.249***p136) 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 (mitochondrium, p136 ***Fig.299***p156), running on sugar instead of light.

(1) The first machine in ***Fig.259*** 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 ($2H_2O$) in oxygen (O_2) 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 O_2 is discharged to the outside air, where animals live by re-oxidizing C to CO_2.

(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 luma 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 (p142).

(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.

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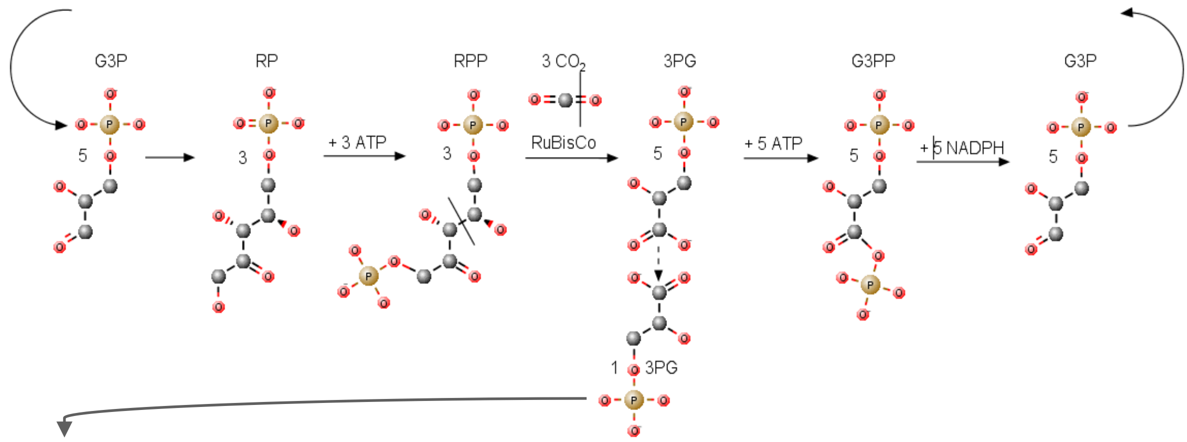
a https://es.wikipedia.org/wiki/Plantae

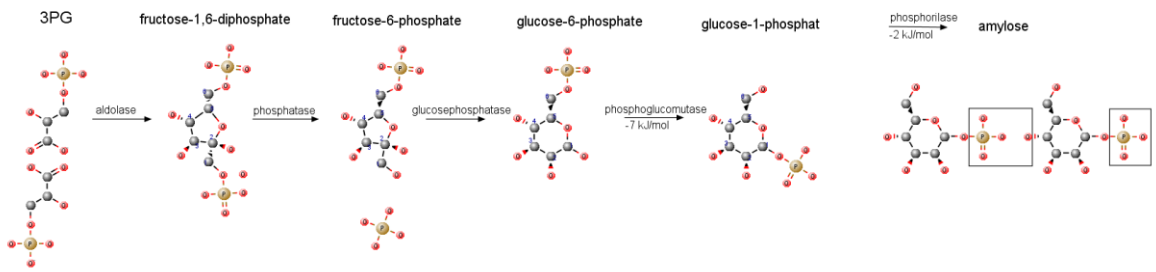
b Adaptation of a figure from https://nl.wikipedia.org/wiki/Lichtreacties

c **Anderson;Boardman(1964)Fractionation of the photochemical systems of photosynthesis. I. Chlorophyll contents and photochemical activities of particles isolated from spinach chloroplasts(Nature)** separated PSII, PSI, and reconstructed their function. History Anderson Vener c.s.(1997)**Plastoquinol at the quinol oxidation site of reduced cytochrome b₆f mediates signal transduction(PNAS)** reconstructed the function of the cytochrome b₆f complex. https://pubmed.ncbi.nlm.nih.gov/11038603/ **Jagendorf;Uribe(1966)TP formation caused by acid–base transition of spinach chloroplasts(PNAS)**confirmed that a proton gradient powers ATP synthase in thylakoids. Energized by sugar, the charging factory ('mitochondrium' ***Fig.299***p155) does so in other cells.

The Calvin cycle incorporates CO_2 in organic bonds making sugars and starch

260 The Calvin cycle makes '3PG'…[a]





261 … of which finally starch is made[b]

In the stroma inside a chloroplast (the green granule in leafs), the charged compounds ATP and NADPH from the thylakiodes offer the energy for the great achievement of green plants: processing the CO_2 we produce as animals and with our machines, causing a climate change.

The 'Calvin cycle' (***Fig.260***) incorporates carbon dioxide CO_2 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.261***).

Pairs of 3PG's (***Fig.261***) are transformed into phosphates of fructose and glucose, and finally into 'amylose', polymerizing into a long molecule. Together with 'amylopectin' (***Fig.240***p132), this 'starch' is the energy supply in each plant and the largest share in our food.

In ***Fig.261***, the enzyme 'glucophosphatase' changes the pentagonal fructose ring into the hexagonal glucose ring with the same chemical formula ($C_6H_{13}O_9P$), but it is a different molecule ('isomer'). Enzymes making a different isomer are called 'isomerases'.

The next enzyme of ***Fig.261*** ('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.

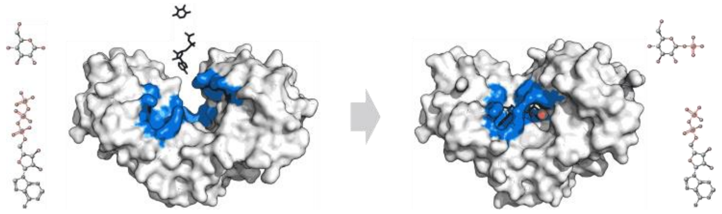
---

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.

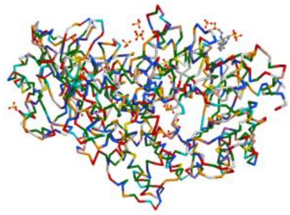
b The required enzymes are written above the arrows, for RuBisCo see e.g. https://en.wikipedia.org/wiki/RuBisCO. The produced energies below the arrow -2kJ/mol and -7kJ/mol indicate that the reaction is a self-sustaining chain reaction (p130).

ENZYMES ARE PROTEINS, ENABLING OR ACCELERATING CHEMICAL PROCESSES [a]

207 Hexokinase_induced.x



262 An enzyme attaches a phosphate group to sugar [b]



263 Its structure [c]

Names of enzymes usually end on '-ase', where a sugar ends with '-ose', an alcohol on '-ol, an aldehyde on -al and so on (***237***p132 and subsequent figures).
For each reaction you need a specific enzyme. The internet contains impressive catalogs[d] of those tens of thousands enzymes that keep life going.

hexokinase(amino acids).xlsx

In ***Fig.262*** 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.

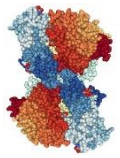
This happens very fast and the enzyme itself remains unchanged. You need only a little of the enzyme to 'phosphatize' a whole glass of sugar water with ATP in the blink of an eye.

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.

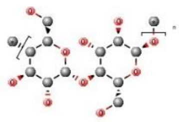
210 lactose.mrv

212 cellulose.mrv

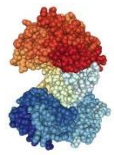
264 Lactose



265 Lactase [e]



266 Cellulose



267 Cellulase [f]

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.239***p132).

Cellulose (***Fig.266***) 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 Payen;Persoz(1833)Mémoire sur la diastase, les principaux produits de ses réactions et leurs applications aux arts industriels(Annales de chimie et de physique)53 73–92 reported the first experimental evidence of enzyme activity of amylase, the first enzyme ever discovered. Pasteur(1857)Mémoire sur la fermentation alcoolique(Comptes Rendus de l'Académie des Sciences)45 1032–1036 demonstrated that fermentation was due to the action of living microorganisms. Buchner(1897)Alkoholische Gärung ohne Hefezellen(Berichte der Deutschen Chemischen Gesellschaft)30 117–124 showed that cell-free extracts of yeast (Zymase) could ferment sugar outside living cells, refuting Pasteur’s microorganisms. Sumner(1926)The crystallization of the enzyme urease(Journal of Biological Chemistry)69 435–441 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

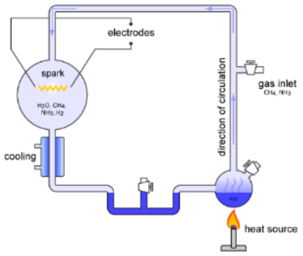
e http://www.rcsb.org/pdb/ngl/ngl.do?pdbid=3WEZ&bionumber=1 https://www.rcsb.org/3d-view/jsmol/3WEZ/2

f http://www.rcsb.org/pdb/ngl/ngl.do?pdbid=5E09 https://www.rcsb.org/3d-view/jsmol/5E0C

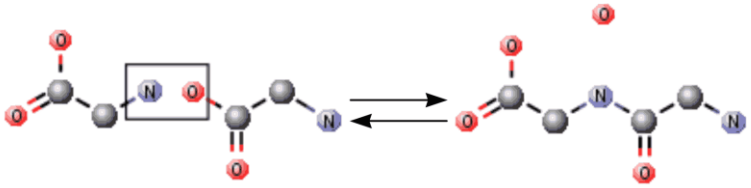
g Our DNA has no sequnce of amino acids for cellulase, but (in case you want to eat grass) here is the amino acid sequence of the cellulase:
MDEGAKQTDIQSYVADMQPGWNLGNTFDAVGDDETAWGNPRVTRELIKTIADEGYKSIRIPVTWENQMGNAPDYTINEDFFSRVEQVIDWALEEDLYVMLNLHHDSWLWIYNMEHNYDEVMAKYTALWEQLSERF
QGHSHKLMFESVNEPRFTRDWGEIQENHHAFLEELNTAFYHIVRESGGSNTERPLVLPTLETATSQDLLNRLHQTMKDLNDPNLIATVHYYGFWPFSVNVAGYTRFEEETQQDIIDTFNRVHNTFTANGIPVVLGEFGLL
GFDTSTDVIQQGEKLKFFEFLIHHLNERDVTHMLWDNGQHLNRETYSWYDQEFHNMLKASWEGRSATAESNLIHVRDGEPIRDQDIQLHLHGNELTGLQVDGDSLALGEDYELAGDVLTMKADALTALMTPGELGTN
AVITAQFNSGADWHFQLQNVDEPTLENTEGSTSNFAIPAHFNGDSVATMEAVYANGEFAGPQNWTSFKEFGYTFSPVYDKGEIVITDAFFNEVRDDDIHLTFHFWSGEMVEYTLSKNGNHVQGRR
see https://www.rcsb.org/3d-view/5E0C. If it does not work, then there are many other types of cellulase.

§ 34 LIFE SUPPOSES METABOLISM AND REPRODUCTION

THE ORIGINAL ABIOTIC ENVIRONMENT MAKES LIFE POSSIBLE, BUT NOT PROBABLE



268 Miller-Urey- experiment [a]



269Two amino acids join to peptide and vice versa

Hot water under a lightning atmosphere raises organic components

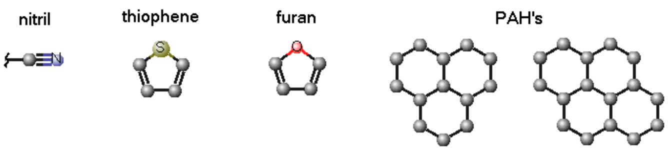
Assume first: life emerged in hot *liquid water* (H_2O) under a stormy, lightning atmosphere, mainly consisting of methane (CH_4), ammonia (NH_3) and hydrogen (H_2), no oxygen (O_2), and therefore no ozone layer (O_3) stopping ultraviolet radiation. So, rocks and minerals were hardly oxidized. Such an 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.268***). Due to built-in electric discharges, a large number of different organic substances, such as amino acids, arose in that circuit. First assumption: with targeted supply of energy, these amino acids could join together as building blocks in chains to all proteins necessary for life.

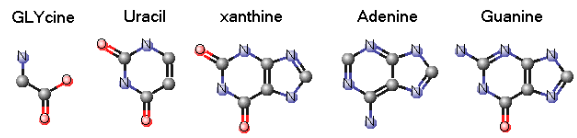
There are, however, about 500 different amino acids. Of these, 20 appear to be suitable for life. Roughly calculated, the probability of 20 specific amino acids out of 500 is 1 to $3.7*10^{36}$.(§ 21p71). The chance of an arbitrary protein string of say 100 amino acids in a particular sequence is 1 to 20^{100}. Both combined, the probability of a proteine starting life is 1 to $3*10^{166}$.
Very improbable.

Moreover, it is unlikely that a long protein chain may form without immediately falling apart by oxidation. The backward arrow in ***Fig.269*** 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



270 Components found in volcanic emissions



271 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: ***Fig.****Fout! Bladwijzer niet gedefinieerd.*), carboxylic acids, esters (***Fig.241***p133), nitriles, pentagonal thiophenes, furans and variants of PAHs (***Fig.270***) with other components: chloro-, methyl- and sulfur.".[c]

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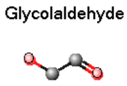
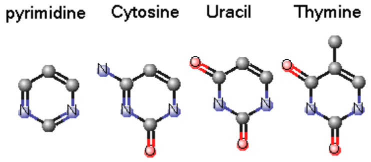
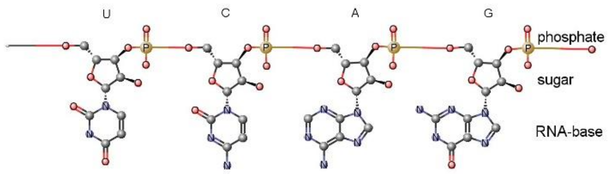
a https://en.wikipedia.org/wiki/Miller–Urey_experiment
b Miller(1953)A Production of Amino Acids under Possible Primitive Earth Conditions STOR(Science)0515 117 3046 p528
c Schwandner(2013)Halocarbons and other trace heteroatomic organic compounds in volcanic gases from Vulcano(Geochimica et Cosmochimica Acra) 101 191-221.

Meteorites may have delivered a protein, some RNA bases and phosphor







218 Glycolaldehyde.mrv

219 pyrmidine, cytosine, uracil, thymi

220 UCAG.mrv

272 Found in the Milky Way

273 Predicted in gas clouds around the sun

274 The four RNA bases UCAG (Uracil, Cytosine, Adenine and Guanine)

Third assumption: meteors caused high temperatures locally, adding (***Fig.271***p144), receiving and producing complex compounds. In meteorites (***Fig.271***), among others, the protein glycine (GLY on p134 and the two preceding figures) and the RNA bases ('nucleobases') Uracil, Guanine[a] and Adenine were found (U, G and A on p135).

Carbon is the most common element in the universe after hydrogen, helium and oxygen.
It appears for 20% as PAHs (***Fig.270***p144). 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.

Glycoaldehyde (***Fig.272***) 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.273***, C and T on p135) 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.262***p143).
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.275***p146), 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 assumption: 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.

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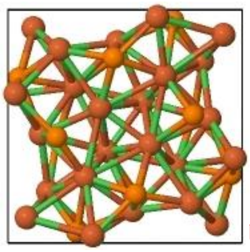
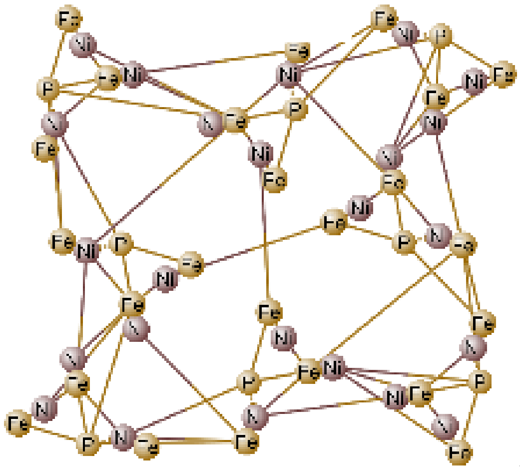
a https://en.wikipedia.org/wiki/Murchison_meteorite
b Meteors could have a diameter of 500km. Such an enormous impact may have caused the separation of the Moon.
It gave so much heat that the oceans evaporated, and clouds to great heights enveloped the whole earth in darkness.
Only after 3000 years rains would have filled the ocean again.
c Thymine behaves in the DNA as Uracil in the RNA.
d **Pasek(2017)Schreibersite on the early Earth Scenarios for prebiotic phosphorylation(Geoscience Frontiers) 8 329-335**
e Perhaps not only meteors: https://www.sciencenews.org/article/phosphorus-earth-earliest-life-forged-lightning-chemistry


a


b


+H_2O

275 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.

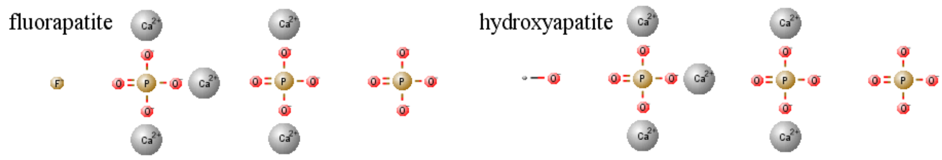
The amount of organic phosphor on Earth, however, is limited to what we ever received from meteors or lightning. After death, the organic phosphor of organisms may remain as sediment.

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 ($Ca_5(PO_4)_3F$ and $Ca_5(PO_4)_3OH$) from the finite stock that is still stored in a few mines worldwide. Morocco holds 75% of the reserves.

221 calcium fluorophosphate.mrv

221 hydroxyapatite.mol

221 hydroxyapatite.mrv

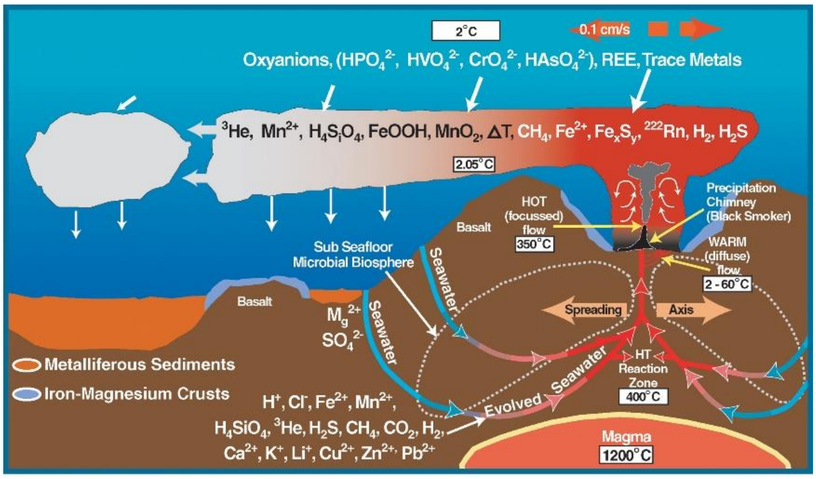


276 A precious resource of phosphate

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)Water interaction with fe2NiP schreibersite (110) surface(JPhysChem)C 126 2243−2252**,
d https://en.wikipedia.org/wiki/Peak_phosphorus .
e **Schroder(2010)Sustainable Use of Phosphorus(Wageningen)Univ DLO Foundation Oct**,

GRADIENTS MAY HOUSE A METABOLISM



277 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 vulcanos 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.277***).

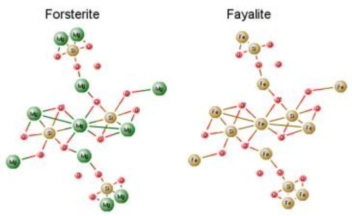
A *horizontal* gradient of descending temperature and chemical composition emerges around the volcano. These vertical and horizontal gradients provide an endless number of reaction conditions that may produce organic compounds ('metabolism').

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].

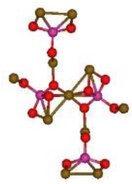
The first mineral that crystallizes (already at 1200°C) in the cooling magma is **olivine** (***Fig.278***). Such mineral weathers on exposure to CO_2 and water ('serpentinization'[d]).
It therefore is found less on the earth's surface than in magma and in the earth's crust.

224-225 olivijn.mrv

278 Olivine[e]



279 Components of olivine 2D



280 Fayalite 3D

The components of olivine are forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4).
The magnesium-containing component of olivine ('forsterite', ***Fig.279***) bonds CO_2 and decays into harmless and stable limestone or dolomite.
This CO_2-bonding capacity of olivine is seen as an opportunity to combat climate change.[f]

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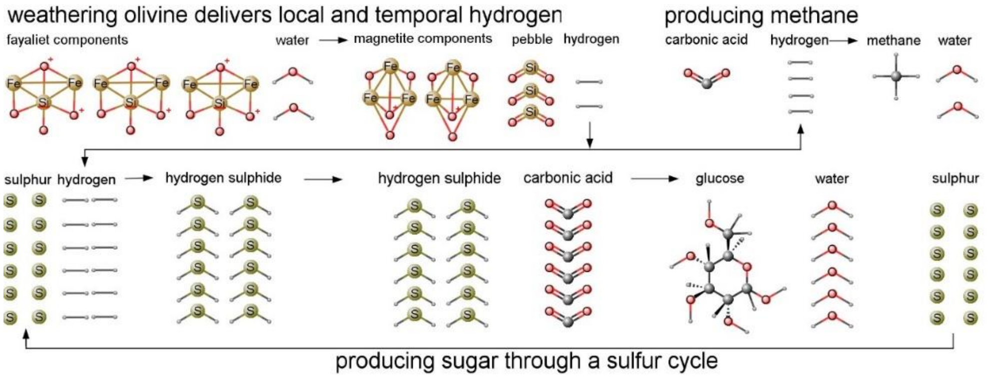
a https://en.wikipedia.org/wiki/Hydrothermal_vent
b https://nl.wikipedia.org/wiki/Magma_(gesteente)
c https://en.wikipedia.org/wiki/Thermosynthesis
d https://en.wikipedia.org/wiki/Serpentinite
e https://nl.wikipedia.org/wiki/Olivijn
f A liter of olivine ('green sand') as soil cover or natural fertilizer compensates for the CO_2 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



281 Hydrogen from olivine (fayalite), used to make methane and sugar in a sulfur cycle

The iron-containing component of olivine ('fayalite', ***Fig.280***p147) falls apart with water in iron oxide ('magnetite'), gravel and loose hydrogen molecules (***Fig.281***).
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 ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$).

There are still primitive single-celled organisms ('archaea' ***Fig.297***p156) using methane as the only source of energy and carbon ('methanotrophs'), without oxygen ('anaerobic').[b]
Free hydrogen can bond sulfur (S) with energy gains ($S + H_2 \rightarrow H_2S$).
This results in the required hydrogen sulphide (H_2S, smelling of rotten eggs).

To this day, 'purple sulfur bacteria' convert CO_2 into glucose $C_6H_{12}O_6$ with hydrogen sulphide by 'chemosynthesis': $12H_2S + 6CO_2 \rightarrow C_6H_{12}O_6 + 6H_2O + 12S$, leaving pure sulfur (S) in small granules available for another cycle (***Fig.281***). In this cycle, hydrogen (H_2) 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]

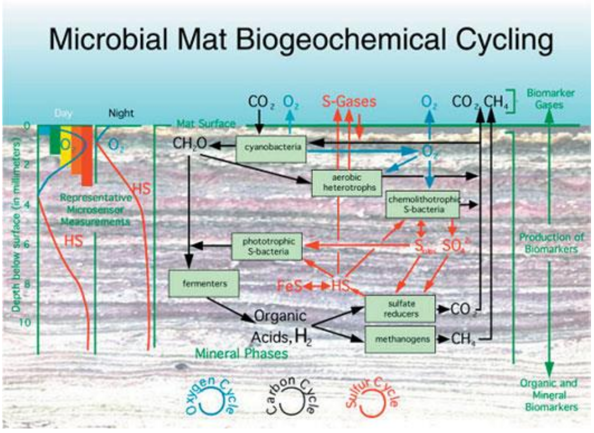
Microbial mat gradients may enable an early kind of metabolism

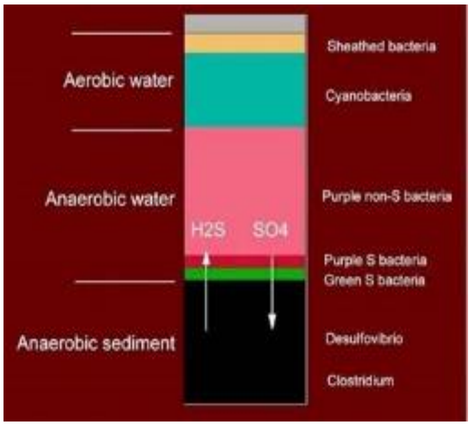
The oldest survivors known are 'microbial mats' ***(Fig.282***p149), layered structures of a few millimeters thick. Their vertical gradient (gradual transition) of stacked (from bottom to top increasingly complex) life forms, sometimes with silicic bacteria[d] at the top, protecting the mat against the 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 120ºC (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)Abiogenic Hydrocarbon Production at Lost City Hydrothermal Field(Science)0201 319 p604**
b **Wang(2014)Methanotrophic archaea(The ISME Journal)8 1069–1078**
c https://en.wikipedia.org/wiki/Sulfur_cycle
d https://academic.oup.com/bbb/article/85/6/1324/6240178





282 Microbial mat [a]

Compare the ecosystem of vertically successive environments with those in our intestinal flora. Our intestinal trackt 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 micro-organisms 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 (p131).
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.281***p148). Such a cycle keeps going by itself (exotherm) or by an external source that repeatedly delivers energy (endotherm).

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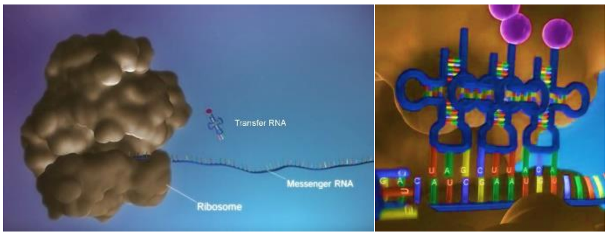
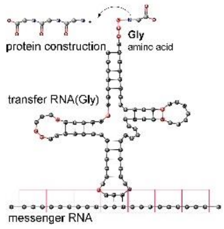
a Fenchel(1995)Ecology and Evolution in Anoxic Worlds (Oxford)Series in Ecology and Evolution Fig.4.12 p188. Downloadable from: https://epdf.tips/ecology-and-evolution-in-anoxic-worlds-oxford-series-in-ecology-and-evolution.html

229 Klaverblad.mrv
230 Codon-Anticodon.mrv

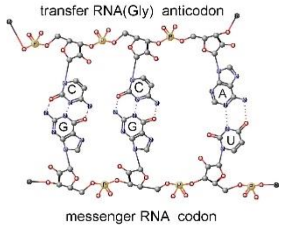
Reproduction of large molecules requires a memory



283 Protein production in a ribosome [a]



284 mRNA and tRNA [b]



285 Codon and anticodon

The repeated formation of large, complex molecules such as proteins, amino acids in a strict order (p134), 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' p157).[d] LUCA should have lived in hot water, in an anaerobic, chemically active environment with H_2, CO_2 and iron.[e]

Fig.283- ***Fig.285*** show in more detail than on p135 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 (p135).

That specific tRNA searches in the cell 'its' amino acid and takes it to a protein factory ('ribosome' p135). 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]

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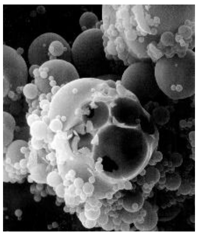
a https://www.youtube.com/watch?v=gG7uCskUOrA gives an impression of this reproduction. More details are shown in https://www.youtube.com/watch?v=kmrUzDYAmEI en https://www.youtube.com/watch?v=8Hsz_Vmcy-Y
b The cross-shaped structure of the tRNA molecule is the same for all tRNAs, but the amino acids that make up the chain are different. Only the red marked parts are the same in all tRNAs. The red-rimmed anticode portion is shown enlarged in ***Fig.285.***
c **Schrodinger(1948)What is life(Cambridge)University Press**
d **Wade(2016)Meet Luca, the Ancestor of All Living Things(The New York Times)0725**. **Weiss(2016)The physiology and habitat of the last universal common ancestor(Nature Microbiology)1 16116. PMID 27562259**
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

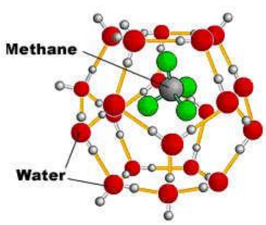
At more than 140ºC, amino acids may also link up to peptides without intervening RNA.
When their solution dries out, then they become longer polymers, proteins.
At 70°C, with phosphoric acid as a catalyst, protein-like structures ('proteinoids') are formed, in which 18 of the known 22 amino acids have been found.[a]

In water, some of them are unilaterally water-averse (hydrophobic). They then make (in the same way as the phospholipids on p137) spherical 'proteinoid microspheres', also found in volcanoes. They, however, do not yet have the correct sequence to form a functioning protein.

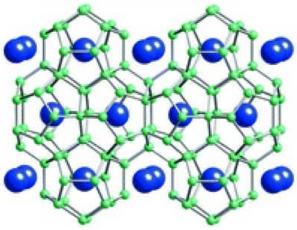
ENCLOSURE PROTECTS AGAINST EXTERNAL ENTROPY



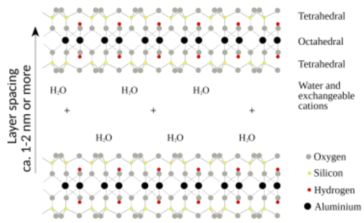
286 Microsphere [b]



287 Methane clathrate in water [c]



288 Hydrogen clathrate in silicate [d]



289 Montmorillonite [e]

Enclosure with a membrane, or a shell of chinin 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.286***), then a concentration gradient[i] 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.287***).
When heated, the methane is released ('burning ice').[j] Also CO_2 and H_2 can be trapped in water or in other polymers such as silicate this way, without escaping as gas (***Fig.288***).

The common type of clay montmorillonite (***Fig.289***) 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.

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a https://en.wikipedia.org/wiki/Proteinoid ; **Fox(1992)Thermal Proteins in the First Life and in the Mind-Body Problem(Berlin)Springer In Haefner p203-228**
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)Thermal Copolymerization of Amino Acids to a Product Resembling Protein(Science) 128 1214–1214**
i https://nl.wikipedia.org/wiki/Concentratiegradi%C3%ABnt#Ori.C3.ABntatie_in_een_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

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 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.

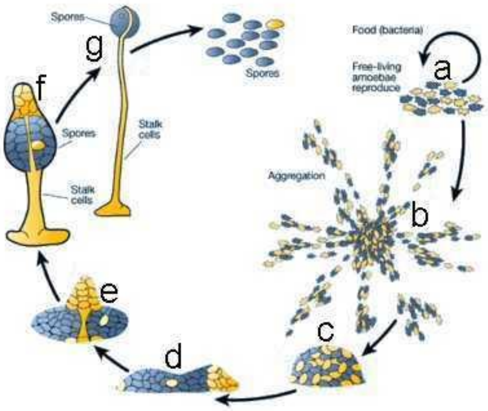
Enclosed cells multiply
If the conditions of environment, metabolism, reproduction and enclosure are met at the chemical level, then life has cells that can differentiate and compete, the two conditions for natural selection and evolution.

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.

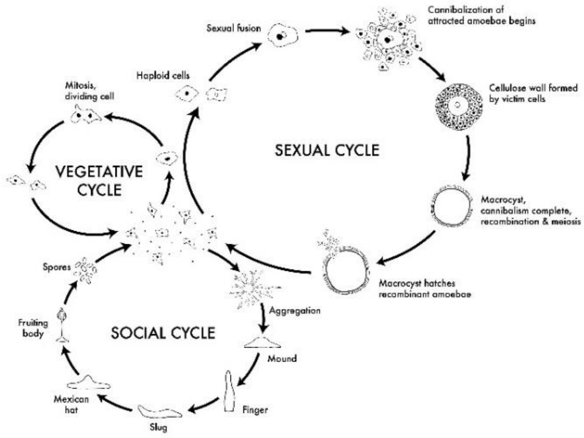
a **Subramaniam(2011)Semi-permeable vesicles composed of natural clay(Soft Matter)7 2600**

§ 35 ORGANISMS ORGANIZE

CELLS GROUP, DIFFERENTIATE, ENCLOSE, REPRODUCE, UNGROUP AND COMPETE



290 Life-cycle Dictyostelium discoideum [a]



291 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.290***), get different tasks ('cell differentiation') and reproduce socially, sexually or vegetatively (***Fig.291***).

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.290a***).

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.290b***).
There they attach themselves to each other as a 'pseudoplasmodium' (***Fig.290c***).
This organism takes the form of a 2 to 4 mm long snail (***Fig.290d***).

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.290e***) making a stem.

They strengthen the stem with cellulose on the outside.
The other cells move upwards (***Fig.290f***). 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.290g***).

In case of food scarcity, the individual amoebae can also breed sexually (***Fig.291***).
As soon as a male and a female cell are united ('zygote'), then one large closed cell ('macrocyst') 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.

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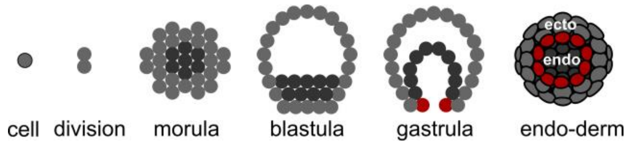
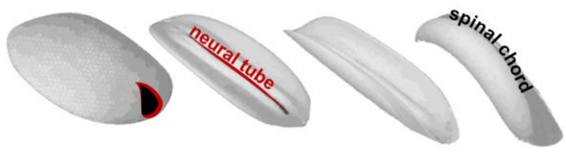
a Shaulsky http://dictybase.org/Multimedia/index.html
b Brown http://dictybase.org/Multimedia/DdLifeCycles/index.html
c https://en.wikipedia.org/wiki/Dictyostelium_discoideum
d ATP and ADP have three and two phosphate groups (***Fig.249*** p125). AMP has the same basis with one phosphate group. cAMP is a variant of this.

ORGANS SPECIALIZE



292 Cells develop 2 interiors and Polarity



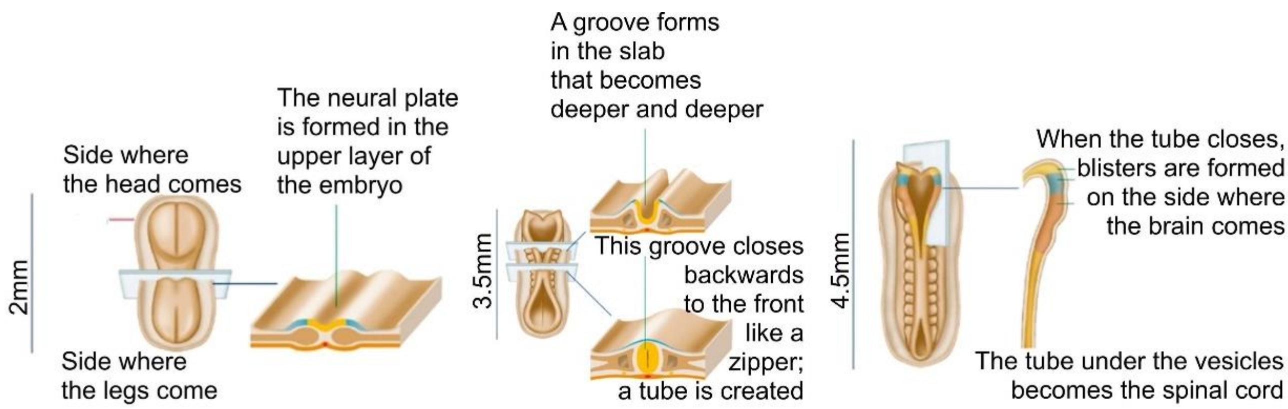
293 Folding develops a third interior [a]

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.292***), 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.292***),).[d] The blastula *polarizes*.[e] Cells concentrate on one side.

On that side they develop an indentation ('gastrula' ***Fig.292***),) 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.

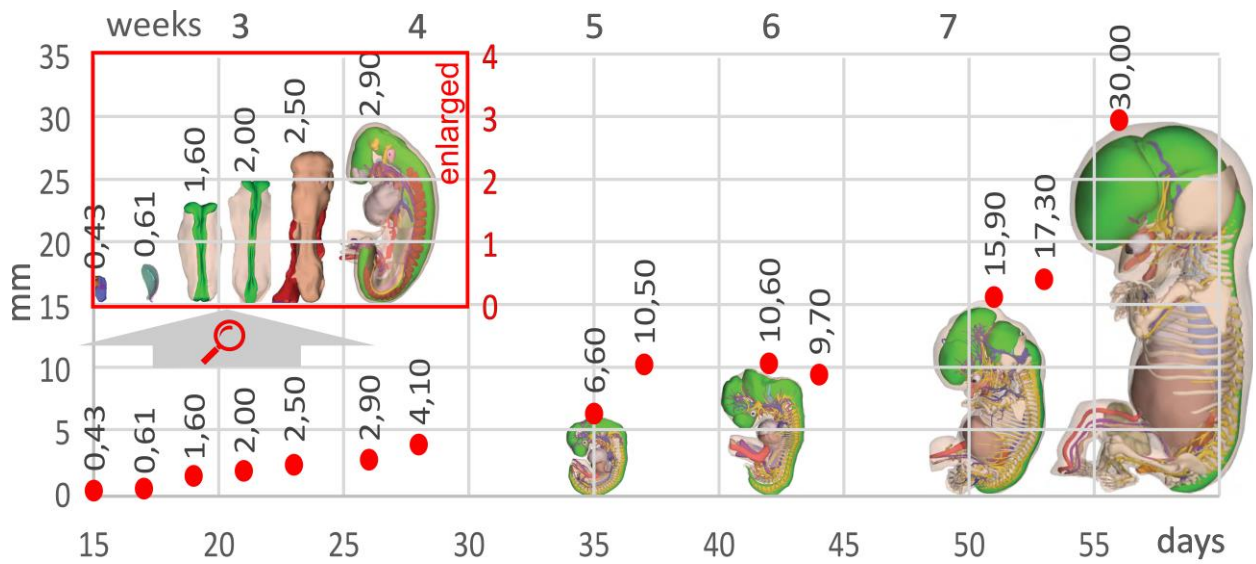
The bag flattens and folds around a neural gutter (***Fig.293***) into a neural tube (***Fig.294***).
If it does not close properly, then the future child may be born with an 'open back'.
Muscles, skeleton and skin will develop on the inner 'dorsal side' (back side).
On the ‘ventral’ side (belly side) organs for metabolism and blood circulation will develop.



294 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)The problem of organic form(New Haven)Yale University Press**
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

Embryo.xar

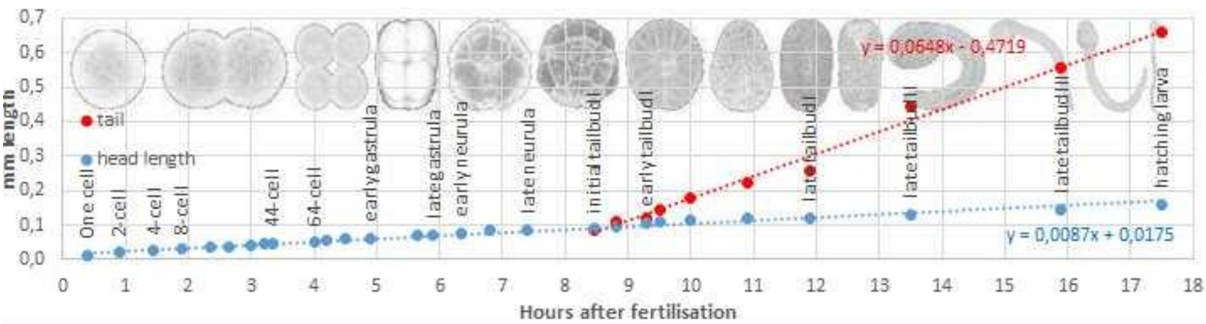


295 Human differentiation and growth in 60 days [a]

On day 17 (0.61mm), a brood bag has been developed at the endoderm on the belly side (not shown in ***Fig.295***). 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.296***)

242 Ciona Intestinalis .xlsx



296 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’.

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a http://3datlas.3dembryo.nl/
b https://anatomypubs.onlinelibrary.wiley.com/doi/10.1002/dvdy.21188

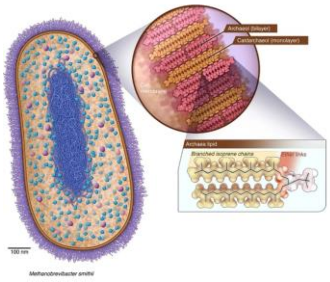
The division of tasks between cells and organs is controlled by signal molecules.[a] Cells receive and disperse enzymes and 'hormones' in order to initiate locally and temporarily the right processes. They spread from sending cells in the fluid between cells and organs ('plasma') in decreasing concentration ('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.

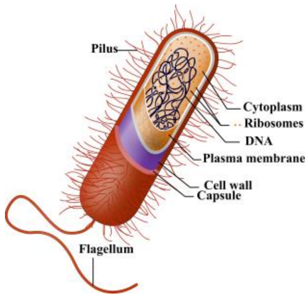
Signal substances are also produced by special glands spread throughout the body ('cytokines'), by different cell types to their neighbors or between senses, nerve cells ('neurotransmitters'), muscles and other cells, or stimulate other organismes ('ectohormones' such as 'pheromones').[b]

ORGANISMS DEFEND THEMSELVES AND REPRODUCE

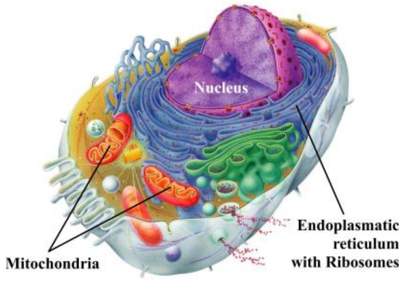
Methanobrevibacter.xar
214 Bacterial cell.xar
Cell-structure eukariota.xar



297 Archaea [c]



298 Bacteria [d]



299 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.298***), or a two-fold membrane ('bacteria' ***Fig.297***).

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]).

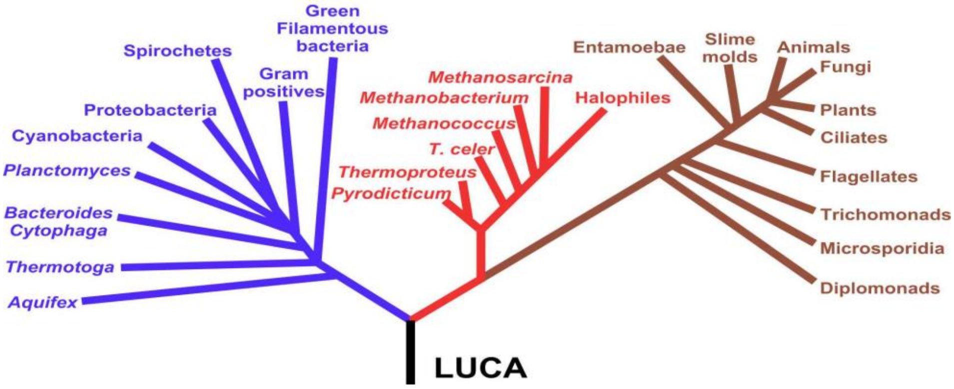
Prokaryotes rapidly divide (mitosis within 10 minutes) and also can rapidly change due to that plasmid exchange. In bacteria, the DNA is spread throughout the cell, but archaeae concentrate it in a nucleic nucleotide without membrane or supporting protein ('chromatin' as in 'eukariota'). Both have loose 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.299***), 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/Signaalmolecuul
c Image by Gottlieb, Wacher, 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



300 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 (p150), reconstructed from the common denominator of all known DNAs has had numerous extinct predecessors.
The ribosome (the protein factory p135) 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 p150 in a bacterium), replicating alongside the DNA during cell division ('extra-chromosal 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.299***p156) 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 (p141) are regarded as entangled plastids that share their own authority.

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a https://nl.wikipedia.org/wiki/Fylogenie
b Jinks(1964)Extrachromosomal inheritance(Englewood Cliffs)Prentice-Hall Inc

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.

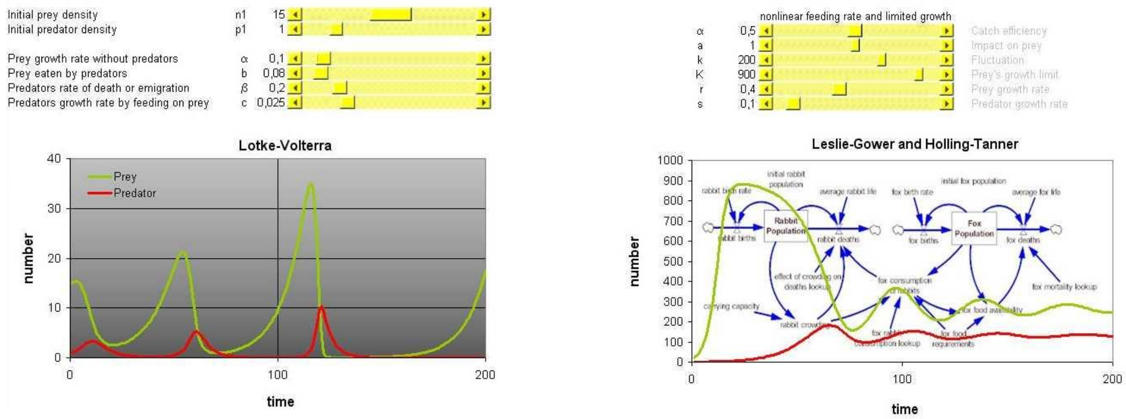
The microbial mat is a prototype of cooperation

A microbial mat (***Fig.282***p149) 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 H_2, CH_4 or hydrogen sulphide H_2S were probably the first 'layer' or 'phase'.

Competition stabilizes a population

Ecology also includes competition and 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.301***) that can be simulated mathematically (see also p69 and p70).



301 Predator prey simulations [c]

Such a negative feedback prevents exponential growth of herbivores that would lead to 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 p78). 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.

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a https://nl.wikipedia.org/wiki/Concentratiegradi%C3%ABnt#Ori.C3.ABntatie_in_een_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)Infektie en immuniteit(Utrecht)Spectrum Aula**
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.

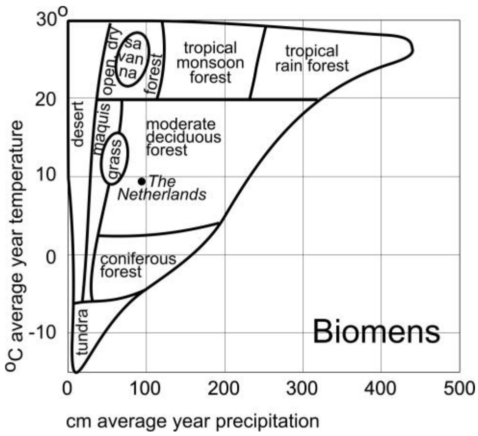
Vegetation is the basis of all food chains. Since plants usually cannot move, their sexual reproduction is dependent on massively distributed male gametes, which happen to hit a female gamete of the same species. Specialized insects reduce that hazard, but in flowering plants the pistil receptors should 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 (p143). 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
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	0.30	virus	



302 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.302*** expresses a frame by its 'nominal radius' R, its grain by r ≈ 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.
'Synecology' studies 'biotopes' R=1km with components called 'communities' r=300m.[b]
'Autecology' studies the environment R=1m of individuals r=0.3m, for example their strategy for survival as 'ruderal', 'competitor' or 'stress-tolerator' [c].

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 For The Netherlands see **Weeda(2000)Atlas van plantengemeenschappen in Nederland(Utrecht)KNNV**
c **Grime(1989)The abridged comparative plant ecology(London)Unwin Hyman**
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 diciplines, 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.

suitable molecules.xlsx

Suppose that ‘laboratory setups’ of 0.3µm (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 $3*10^{36}$ per year.[b]

If only one billionth of them yields a suitable organic molecule, then there are still $3*10^{27}$ organic molecules that could be composed. The probability that 1000 molecules of that $3*10^{27}$ 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.

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a **Baer;Miyamoto;Denver(2007)Mutation rate variation in multicellular eukaryotes: causes and consequences(Nature Rev. Genet.)8 619–631.**
b **Shapiro(1986)Origins(New York)Summit**, 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.[a] 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.300***p157).

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.

§ 36 MINIMAL SUPPOSITIONS OF BIOTIC POSSIBILITY

Abiotic	:	difference ⥣	change ⥣	object ⥣	separation ⥣	combination ⥣
Biotic	:	metabolism ⥣	regulation ⥣	organization ⥣	specialization ⥣	reproduction

The row of **B**iotic conditions supposes the **A**biotic conditions, with similar counterparts.

B1 **Metabolism**: a flow separated from its context, a selective input and a *different* output.
It *supposes* the **A**-conditions of difference (with its place, direction, sequence etc.), of primary change (movement, flow), coherent object, an improbable separation and combination.
It *enables* to imagine a secondary change, changing the primary flow (regulation).

B2 **Regulation** supposes all preceding **A**-conditions *and* Metabolism. If regulation fails, then you have to check all of these conditions to find the cause(s) of failure. If there is no difference between input and output, no flow, no coherent object, no separation, no combination or no metabolism, then you may conclude no life. It enables to imagine an organization of objects.

B3 **Organization** of different regulated objects supposes all preceding **A**- and **B**-conditions.
If it fails, check particularly 'coherence' of objects as substance⥣form⥣structure⥣function⥣ intention: the quality of the objects, their dispersion in space and time, their connections and separations, functions and intentions. Organization enables to imagine specialization of objects.

B4 **Specialization** requires similar remarks. It shows, however, most clearly the scale-sensitivity not yet mentioned in the preceding conditions, but equally valid there.
The organization may be specialized in a larger context or internally at different levels of scale.
It enables an image of reproduction as a specialized function.

B5 **Reproduction** copies or combines objects at different levels of scale: genes, organelles, cells, organs, organisms or organizations.
It enables reduced copies or combinations of the environment within an object (imagination).

[a] With or without a suppositions of self-organization. **Kaufmann(1993)The origins of order(Oxford) University Press** took the possibility of self- organisation into account

7. CULTURE SELECTS SUPPOSITIONS AND CONDITIONS

What is the designerly content of culture? Which discoveries are acually inventions, designs of a model? Do they cover a broader field of possibility beyond probability?

This chapter takes culture as 'a set of shared conceptual suppositions and material conditions'.
I conclude:

A culture selects local techniques of adaptation and accomodation in order to survive.
These are based on shared suppositions, such as current sciences and the humanities.
Cultures differ by scale. A national culture differs from a continental one.
They differ by (physical and mental) climate. Cultures on the coast differ from inland ones.

Culture is designed, invented by man. That supposes imagination. It covers a broader field of possibility than actual reality. It enables *and* it limits imagination by traditional concepts.

§ 37 CULTURE SUPPOSES SHARED SUPPOSITIONS OR CONDITIONS

Culture in a broader sense ⇓ abiotic and biotic conditions
I define 'culture' as 'a set of shared conceptual suppositions and material conditions'. That includes the 'norms and values' in cultural anthropology[a] and sociology[b], but in the broader sense, it also includes selected abiotic and biotic conditions, techniques and economics[c], primarily 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 (p155) by which they choose the recipe from their genetic library for appropriate adapation, 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 and sound. What you might call their 'culture' is the adoption of the behavior of direct relatives.

People and some animals, however, do have the ability to supplement their 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 discovery of utensils is then for archaeologists a proof of human presence in the past.

Culture ⇓ technical conditions ⇓ an economy
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 abilities, techniques first (manipulating, walking, speaking, listening, reading, writing, applying), before norms and values can be taught.

The Latin origin of the word 'culture' means 'care', 'building' and in particular 'agriculture'. Agriculture is a neolithic *invention* with major consequences.

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a **Levi-Strauss(1955)Tristes tropiques(Paris)Librarie Plon** , **Mead(1959)People and Places(New York)The World Publishing Company** , or **Grottanelli ed(1965)Ethnologica - l'uomo e la civilta(Milan)SpA Edizioni Labor**, give mostly separate descriptions of different cultures ('ideographic'), albeit sometimes per theme. **Levi-Strauss(1962)La pensée sauvage(Paris)Librairie Plon** then interprets 'culture' as a collection of unconsciously applied social rules such as the common incest prohibition ('structuralism', 'structuralist anthropology'). **Kloos(1972)Culturele antropologie(Assen)Van Gorcum** already has a more materialistic basis. **Diamond(1997)Guns, Germs and Steel(New York)Norton** 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)Moderne sociologie(Utrecht)Spectrum Aula** 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)Erfenissen van de verlichting Basisboek Cultuurfilosofie(Amsterdam)Boom** p209 and the limitation to an upperclass of **Elias(1939)Uber den Prozess der Zivilisation. Soziogenetische und psychogenetische Untersuchungen(Basel)Haus zum Falken**.

c **Daryll Forde(1934)Habitat, Economy and Society(London 1968)Methuen**, 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)Traité de Sociologie(Paris)Presses Universitaires de France** has more attention to material, technical and economic conditions than usual sociology. History is rewritten in this sense by **Frankopan(2023)The Earth Transformed: An Untold History(London)Bloomsbury**.

COLLECTORS MAP THEIR SPACE, FARMERS THEIR TIME

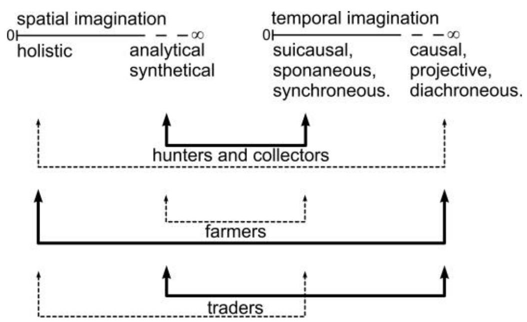
No culture may survive without an economic basis. That basis has been hunting and gathering for millions of years. Some 10 000 years ago, however, the invention of agriculture gradually drastically changed the recourses, technology, economy and culture.

The locally bound ('sedentary') way of life of agriculture demanded more defense and planning for sowing and harvest, reproduce and raise than roaming, hunting and gathering.
The land was brought 'in culture' and regarded as occupied 'possession' ('territory').
It was more closed off from a otherwise little known 'barbarian' outside world.

The distinction between *spaces* and their division into different survival possibilities is more important for roaming hunter-gatherers than for sedentary farmers. Call the distinction and division of spaces ‘analytical’.

Farmers focus more on a division of *time* for sowing and harvesting.[a] Call that ‘causal’.

Call their zero-points ‘holistic’and ‘sui-causal’ (***Fig. 303***).



303 Analytical and causal imagination

So, the ‘causal’ farmers have little interest in different spaces. Their imagination of territory is ‘holistic’. For them, however, the opposite analytical-suicausal connection of hunter-gatherers, keeps an important, but subordinate role (dotted line in ***Fig. 303***).
In free time, an 'artistically-religious' counterculture remains active, left to 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 divised 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.[b]

These three ideal typical cultures are reminiscent of Michelsons[c] 'lifestyles' in the urban environment: 'consumers', 'familists', 'careerists', similar to the three survival strategies of plants at Grime (note c p159): '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.

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a This thought emerged from my own observation of the great differences between Indian and Creole villages and their inhabitants in Surinam around 1970. I assumed a recent past as hunters and gatherers among the Indians and a centuries-old agricultural background at the Creoles. There was no observable greeting or farewell with the Indians, but no reservations at meeting, at the Creoles though. These invited me for the meal in order to go preparing it. The Indians gave me a beautifully decorated boat without reserve and turned around without seeing how I would deal with them, as if they were not interested in whether they would ever get it back. Did the time to make a new boat play no role for them? Did 'possession' have so little meaning for them? They were also less concerned with death than the fears that the Creoles shared with me. Making appointments was also more difficult than with the Creoles.

b 'Counterculture' is a term borrowed from **Roszak(1968)The making of a counter culture(New York)Doubleday&Company Inc.** He describes how (in the 1960s) such ‘counterculture’ could rebel.

c **Michelson(1970)Man and his urban environment(Reading)Addison Wesley**

Fishery cultures may take an ambivalent position, but you may expect the commercial-industrial culture in coastal areas with overseas trade and both prior cultures in the inland.

Harvest festivals then have provided an annual confrontation.
I associate the elated, wine-drenched ancient Greek Bacchus cult with this crucial confrontation with a holistic-suicausal counterculture. 'Bacchus (Dionysos) turned Apollo's head'.

The Bacchus cult caused resignation, ecstasy (ek-stasis, stepping out).
The bacchant stepped out its daily work in the inland or at the coast. Masks hided profession. This primal form of theater put daily life into perspective.[a] This annual exercerise to move into another role became useful in the lessons of the Greek sophists.

They first taught you to play the role of the opposing party before you make your own plea. This objectivation also became the basis for Plato's dialogues and the scientific debate: an arbitrary division of roles between defender and opponent, regardless of whether you agree with the statement that needs to be defended or not.[b]

Cults of collectors, farmers, and traders differ

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 (the counterculture) 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 spontaneous generation. Gods have no cause, they are their own cause ('sui causa').
That this beetle also lays eggs went unnoticed.

For the ideal-typical farmer, plants, animals and people are in a causal time series of parents and ancestors (the biblical genealogies), but these must have begun with something suicausal.
The deceased then move to that timeless space without cause and effect ('eternity').
Prayers are directed to them, until they are unified in one God.

Religion is mourning

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 is then 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'.

From both primary cultures I mentioned, I recognize remains 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 *sacrifice* that repays them or Him, the *Communion* as a physical absorption 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, long after the first revelation, themselves were given a sacred status with interpreting and regulating authority (Catholics, Shiites).

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a I do not share the interpretation of **Nietzsche(1878)Die Geburt der Tragödie(Leibzig)Fritzsch**.
b **Jong(2001)De functie van stellingen bij het proefschrift(Delft)TUD** In academic promotions and court cases, people are still dressed to play a role that is separated from the person.

If that authority and its rules are challenged, a conflict arises with those who appeal to the original sources (Protestants, Sunnites).

A commercial-industrial culture divides time *and* space
Sedentary agriculture enables the exchange of surpluses, products, and thus trade with an increasing role for reliable, precise *calculation* and recording, *writing*.

The following 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 *there later on* with a profit'.

Identity is difference with the rest and duration 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. 303***), a different acquired capacity for *overview* or *foresight*.[c]

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.

Private ownership takes on the meaning of a mobile territory (prestige, authority)[d].
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.

Migrants with an agricultural background are miserable, 'elend'[e], '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.

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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.

c This thought emerged from my own observation of the great differences between Indian and Creole villages and their inhabitants in Surinam around 1970. I assumed a recent past as hunters and gatherers among the Indians and a centuries-old agricultural background at the Creoles. There was no observable greeting or farewell with the Indians, but no reservations at meeting, at the Creoles though. These invited me for the meal in order to go preparing it. The Indians gave me a beautifully decorated boat without reserve and turned around without seeing how I would deal with them, as if they were not interested in whether they would ever get it back. Did the time to make a new boat play no role for them? Did 'possession' have so little meaning for them? They were also less concerned with death than the fears that the Creoles shared with me. Making appointments was also more difficult than with the Creoles.

d Jong(1978)Autoriteit en territorium(De As) zesde jaargang, nummer 31,

e The etymology of the German (and Dutch) word 'Elend' (miserable) is 'out of land'.

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.[a]

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.[b]

Surviving ideas

A predecesor of that belief is, that human spirits being freed from a body by death, can stay alife as good or evil spirits. An agricultural ('neolithic') variant is, that unconciously 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 Identity, for example, also plays an important role in **Elias(1965)The established the outsiders(London)Frank Cass & Co**

b **Kraak(2006)Homo loquens en scribens Over natuur en cultuur bij de taal(Amsterdam)University Press**, 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.

§ 38 CULTURE SELECTS AT DIFFERENT LEVELS OF SCALE AND TIME

'Culture' has different meanings at different levels of scale

You cannot compare immediately family cultures with a national culture. 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 rural cultures around.

Culture fluctuates 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.

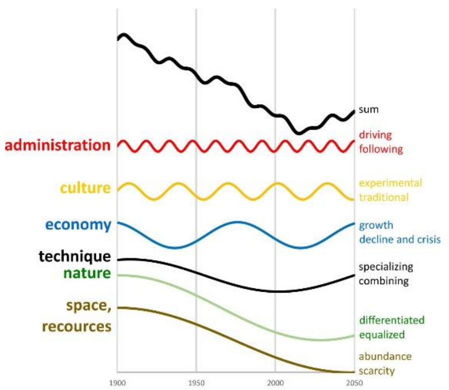
This may result in a synchronous cultural wave with a period of about 15 years (especially with a baby boom or a large-scale migration).[b] If the next puberty neutralizes the previous, the norms of the generation before those of the educators (grandparents or ancestors) may return.

The roughest extremes that can be distinguished in such a cultural phase change is a transition from 'traditional' to 'experimental' and vice versa (***Fig.304***).

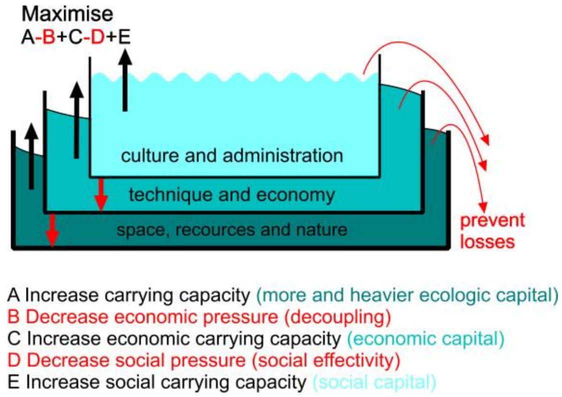
The administrative context layer that accompanies it, varies with changes of government between 'following' and 'driving'. Culture itself goes up and down with economic waves of growth and crisis. Economic decline brings war, migrations, birth waves and innovations, but also a rise of conservatism.

250 Fluctuating context layers.xar

251 Context pressure and carrying capacity.



304 Fluctuating context layers[c]



305 Context: pressure and carrying capacity

The driving technique and the science that follows and produces it, has long periods of specialist innovations in the order of magnitude of a century (for example until 1960), followed by a period of diligent *combination* in commercial applications ('implementation') such as the iPhone. 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.304***). ***Fig.305*** symbolizes their finite carrying capacity under the pressure of shaky containers with increasingly lighter liquids.

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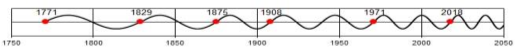
a **Becker(1992)Generaties(Amsterdam)Meulenhoff** distinguishes for example generations born between 1910-1920, 1930-1940, 1940-1955, 1955-1970.

b **Roszak(1968)The making of a counter culture(New York)Doubleday&Company Inc** describes the protest generation after WWII of the 1960s.

c with variations such as the Schumpeter-Freeman-Perez paradigm for the economy:

A free interpretation of the Schumpeter-Fr



Culture is mobile and vulnerable
The movement of ***Fig.304***p168 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 conditions bearing it (***Fig.305***p168).
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. 'The technology has solved everything so far and it will also solve new problems.'

The horizon of risks you oversee becomes smaller.
Insurers are selling fear and you should not think of your car stopping on the highway without quick help, or that 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 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 (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.

On another level of scale it is the call for walls around the own fort: 'own people first'.
The newspaper selects what its readers want to read and readers in turn deny what they do not want to read. This way every period in history also selects its own history.

Art and science change the conditions of imagination (suppositions)
Visual arts, poetry or music shift the boundaries of your imagination with images, words or sounds.[a] They not only bring about the enthusiasm[b] 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 form 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.308***p171).
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).

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a A 'verbal definition' of 'art' does not show what it *is*, but what it *does*.
b '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'.

These are parts of the artistic-religious *counterculture*, a counterweight to monotony or chaos in everyday routine of production and consumption. Between boredom and overload fluctuate recognition and surprise.
Too much repetition demands surprise, too much differences demand recognition.

Such a fluctuation is also visible in the architectural heritage. The turbulent, early Middle Ages full of uncertainty demanded strict, Romanesque architecture. The later Middle Ages brought more peace, wealth and boredom. The reaction was a more flamboyant Gothic architecture. The discovery of America opened a world full of uncertainties.

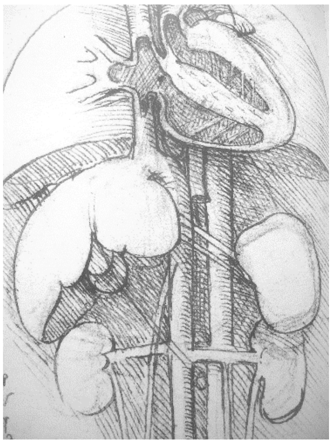
It meant a return to 'the ancients' with renaissance architecture. Science then also wanted to 'know for sure'. When the pendulum moved again to carefree abundance, Baroque architecture counteracted its boredom. In the storm surge of the industrial revolution, it switched to familiar neoclassicism.

When the revolution had gone and the sciences self-confident, the art nouveau took its task to surprise. The world wars called for modernism, the peace for post-modernism.

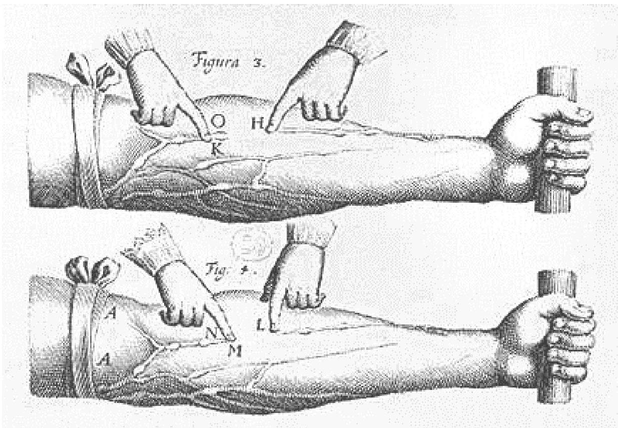
On a much smaller scale one finds more differences, ornaments and colors in the interior of those who are doomed to annoying work than in the businesslike, 'nice tight', quiet interior of those who have a busy job.

There are also differences between old, young and very young. The cross, the Buddha statue and the pop idols recall the religious component in the artistic-religious counterculture.

The precise anatomical drawings of Leonardo da Vinci (***Fig.306***) show the way in which artistic imagination can shift boundaries in a scientific representation.



306 Leonardo da Vinci's drawing of the heart in 1509[a]



307 Proof of blood circulation through Harvey in 1628[b]

Leonardo and Vesalius first had to observe carefully and to draw the anatomy before Harvey (***Fig.307***) could imagine a circulatory system and then prove how it works.

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 (For example cooking according to a recipe).

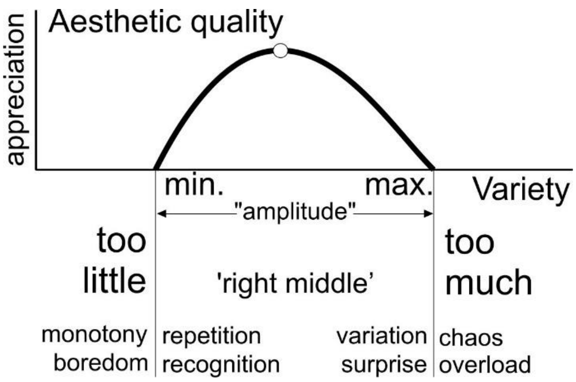
ELEMENTS OF CULTURE ARE ONCE DESIGNED
Designs *make* the difference of cultures. Language, agriculture and means of transport are *invented*, and changed the culture. Elements of science and humanities are *invented*, enabling

a **Zöllner(2016)Leonardo da Vinci(Keulen)Taschen** p446-448
b **Harvey(1628)Exercitatio anatomica de motu cordis et sanguinis in animalibus(Springfield 1928)Thomas** p28a

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 suppositions to make its realisation *possible*.
I use the list of 'minimal suppositions of possibility' that I proposed in order to classify some elements of culture as *realisable* designs. The first attempt concerns language.

You cannot perceive, choose or think without a difference.
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):



308 Aesthetic quality

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. 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 took its 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 (your aesthetic amplitude).

§ 39 MINIMAL SUPPOSITIONS OF CULTURAL POSSIBILITY

Abiotic	:	difference	⥣	change	⥣	object	⥣	separation	⥣	combination	⥣
Biotic	:	metabolism	⥣	regulation	⥣	organization	⥣	specialization	⥣	reproduction	⥣
Conceptual	:	imagination	⥣	safety	⥣	attachment	⥣	identity	⥣	influence	*(individual)*
Cultural	:	empathy		security		loyalty		publicity		power.	*(social)*

The row of **C**ultural conditions supposes the **A**- and **B**-conditions, with similar counterparts.
'Culture' is scale-sensitive. The words for individual culture extend to social equivalents (grey).

C1 **Imagination** may cover *the* distinctive human factor, supposing all previous A-B-conditions.
Animals may have some imagination in order to make decisions, but humans have more.
It should be little more, otherwise it could not have been added in a short period of evolution.
Animals may be simultaneously aware of little more than two images (e.g. 'flight or fight').

I suppose humans combine at least three. A third enables to conceive a *set* of two as a *category*, the *number* two itself, a logical *conjunction*, and a (causal) *sequence* or a *verb* between them. For example, you may create a category 'parents' combining 'mother *and* father', but also concepts as 'mother *or* father', '*if* mother *then* father' or 'mother *calls* father'.

Remembering such sets enables imagining sets of two sets, repeated on ever higher levels of 'abstraction'. That enables to combine images of actions in a time sequence (plans). If you have in mind a result to be realised by actions, then an imagined effect *precedes* the cause (a physical action). Human imagination enables to realise a wished effect supposing a sequence of actions.

In a social context, imagination plays the crucial role of **empathy**, the ability to put yourself in someone else's shoes, whether friend (sympathy) or foe (antipathy).
Empathy includes imagining otherone's ideas and suppositions.

C2 I cannot imagine **safety** without any *imagination* of more or less danger. The reverse I can.
So, imagination enables (⥣) a concept of safety, and in a social context empathy⥣**security**, regulated safety (e.g. insurance, government, defense, certainty, science).
C3 I cannot imagine **attachment** [a] (e.g. affection, focus, interest) without safety;
the reverse I can. So, safety⥣attachment and sequrity⥣**loyalty**.
Attachment is the basis of any social group.
C4 I cannot imagine **identity** [b] without attachment; the reverse I can.
So, attachment ⥣ identity and loyalty⥣public identity (**publicity**).
C5 I cannot imagine **influence** without identity (of an influencer); the reverse I can.
So, identity⥣influence and publicity⥣**power**.

a https://en.wikipedia.org/wiki/Attachment_theory
b I define identity as 'difference from the rest and stability in itself'.

INDEX

This index includes a list of figures with their source under ‘Fig.’.
If **bold**, then see the footnote on the page number. It includes all **literature references**.

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