## 2 Science-s. The Western, Causal Approach

The unconventional form of the title: "SCIENCE-S" has been chosen to make clear, that there is no such term as "science" with a definition of universal value. Each historical period, each culture had its proper "science" and the modern times split them up into so many specialities, so that science as an all-embracing term is no longer meaningful. Let's have a look at standard definitions [1]):

def: *Science: (greek **episteme,** lat. **scientia**) a cultural branch that neither was nor is blossoming throughout all times nor in all nations. So did the Greek discover s. in its independent cultural function, without developing it, and it has been overtaken and carried on as a special cultural ideal by the western European people.* (1) *S. is the essence of human knowledge; the whole of cognition ordered after principles (Kant); the factually arranged interrelation of true judgments, probable assumptions (hypothesis, theory) and possible questions about the whole of reality or specific areas and aspects of the same. Different from unarranged (empirical) knowledge s. tackles not only the **THAT**, but as well the **WHY**, the reasons, causes (Aristotle) of the things. it progresses analytically from the "whole" to the "parts"; synthetically from this to that; by induction from experience and observation to terms, judgements and conclusions, from the single, special to the general, but as well through deduction from the general to the special, always checking the one against the other (method). The scientific progress consists in the systematical advance (- system) ... Towards the special sciences philosophy has the specific task, to stake out the areas of really related objects. The staking out of the object area is no schematical-technical division, but is in the same time a creative draft, on which the whole concrete terminological work and questioning of s. relays. ... And what has to be stressed here as the most important, this area-creating draft of reality and the constitution of its being only lets the being - that it determines - get visible" (Heidegger) and that is, because the philosophy has first to work out the thinking instruments, before a new area of reality gets visible at all (technique e.g. only got possible, when the metaphysical preconditions of - ruling the nature in the present sense were given; (rationalisme).*
*The occidental s. grew out of the spirit of the Greek, moving from a mythological view of the world to its understanding in terms (...). the s. of the Greek culture was an integral science and the start of special-science-thinking, especially stimulated by Aristotle and his school, by the great physicians (Hippokrates, Galenos etc.) and by the atomists, didn't impair the containedness of the s. and the view of life. The Christian middle-ages as well tried successfully to pursue s. as a harmonical whole (...).*
*Only in the ending Middle Ages (detected only by a few thinkers)*

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[1]) Philos. Wörterbuch. (uba)

*the replacement of s. by Natural Science took place. Those "new s.s." started their triumphant advance since the days of the renaissance, when the mathematisation of experimentally found experiences was recognised and the natural laws were searched for and detected in exact ways. This new shape of science got such an importance, that Kant measured the value of a special science by considering its content of mathematics.* 2) *Through this experimental-mathematical s. the philosophy of life of the occidental man has been basically changed and his influence on other continents has risen, esp. through the establishment of an exact-scientific base of medical s.s and the technique, that so far had merely been based on handicraft skills. With the extension of the new s. an ever increasing stratification into special s. was needed, through what the view of the whole of reality and the basic purpose of ss. as a world-s. got lost. Rationalism turned into the only form as well for education. The resulting overdoing of the intellectualistic education had a reaction on s. and caused the scientist to be more and more a specialist and the scientific institutes more and more institutes for the education of specialists. - THEORY OF SCIENCE. The lack of orientation of the special sciences towards a common goal led to the "crisis of science" that was not only a crisis in trust concerning the matter, but a crisis of the scientists. "The fact that nowadays everywhere the quest goes for the roots, theoretical principles are tried in their manifold possibilities and played of against each other, delivers the semi-knowing to doubts; where there is no fixed point, the awareness is floating in the air. Cognition is only seen like this, by those who don't participate in it. The creative steps towards new principles let the buildings of cognition shake, but catch them immediately in a continuity of research, that, questioning the acquired, preserves it in a new sense for the whole of the special s. While: the crisis of the s.s is a crisis of the persons, that have taken it up, if those have not been true in their quest for knowledge" (Jaspers: Die Geistige Situation der Zeit, 1956): Isolated thinkers have tried to put the special sciences together to a system derived from a comprehensive fundamental idea: Francis Bacon, Leibnitz, d'Alembert, Comte, W.Wundth, B. Erdmann, Ostwald u.a. Only the return to a wholistic way of contemplation seems of any help in overcoming the "crisis of s.", and they might in our present reunite the special sciences and philosophy to a s. in the proper sense. Certain principles of cybernetics, valuable in different areas of s., proof nowadays to be a connecting link for that. (- cybernetics) Special s. are classified after their objects as well as after their method. We differentiate between descriptive, explanatory, type forming, generalising, event-, law-, structure- s.s, purely theoretical disciplines, technical teaching of art and so on. Further on there is the division into practical and theoretical, general and special s.s., ideal and real s.s. Exact s.s we do mostly call those, that execute their reasoning with measure and number as mathematics, physics and astronomy."*

Comments:

1) The Chinese, Indian and Arab contributions to science has been neglected here! The reason is understandable, as science-s that emphasise finalities, as Islamic and Con-

fucian approaches, do not fit into the presented definition. Even the fact, that the Arabs saved (from the inquisition), translated and developed the Greek knowledge, has been omitted here. Without the Islamic interest and its translations, most of the Greek philosophy and science would have been lost for Europe!

2) E. Mach [2]) expressed this opinion of Kant even stronger: "It can be said of all sciences **and** of mathematics, *"that they are only sciences as far as they "operate with terms."* **Because our logical rule extends only as far as terms whose content we determined ourselves.**" (emph. in text).

We may retain as basic principles of "science":

1 - Cognition ordered after principles. Factual interrelation between true judgements, possible assumptions (hypothesis') and possible questions.
2 The principle of causality.
3 Systematic methodology (test, experimental verification - or 'falsification' (Popper).
4 Systematic advance of knowledge! Progress!

But even this clear set of factors does not allow to determine what is science and what is not. Anderegg: "*Who gets involved closer with it* (medical sciences. the author) *first encounters problems of a general kind, especially the fact, that so far no binding definition of the term 'science' does exist*" [3]) is to be taken a bit relative. Chalmers makes clear what (philosophy of) science is able to do and what not, and restricts the judgment of Anderegg to the scientific method, the major concern of Feyerabend as well: *"Philosophers don't have the tools that allows them to put forward criteria to be fulfilled, that a cognitive sector can be recognised as "scientific". ... We can try to criticise each sector of cognition, criticising its aim, the adaptivity of the method used to reach the aim or presenting an alternative and superior method to reach the same aim and so on." "Looked at it from this standpoint, we do not need a general category "science" in regard to it, that some scientific sectors can be declared as "science" or calumniated as non - science."* And: *"... there is no timeless and universal concept of science or scientific method, ..."* [4])
Neither scientists (at least those engaged in Kuhn's "normal science"), nor the financing government agencies will be happy about that. Let's go back one step to the process at the base of science:

Def.: ***Cognition*** **[5])***: The appropriation of the content of sense of experienced facts, states, processes, with the aim of finding the truth. In the philosophical sense, to cognise something* (the English language is here quite precise!) *is*

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[2]) Mach, E: *Erkenntnis und Irrtum.* Leipzig 1906. p. 385:

[3]) in Anderegg - Hensel, H: *Zur Problematik des Wissenschaftsbegriffs in der Medizin*. p. 29:

[4]) both in Chalmers: *Wege der Wissenschaft*. p. 167:

[5]) *Philosophisches Wörterbuch*

*to re-cognise. ... Cognition contains a judgement, based on experience.*

*Cognition independent from inner and outer experience can only be gained by creative phantasy (arts!). ... In cognition subject and object, as cognising and (re-)cognised are in opposition. The subject grasps and the object is grasped. The grasping happens, as the subject moves into the sphere of the object and transfers it into its own sphere, more precisely, that the determining pieces of the object are repeated in the picture, building up inside the subject. This picture is objective, while not being identical with the object. The object is independent of the subject. It is more than just a thing of cognition, this more is the trans-objective. Besides being an object there is the being as such. Is the object thought independent of the cognitive relation, it turns into a thing. The subject can be a subject for itself, that means it can be aware of its capacity of cognition. Besides the quality of being capable of cognition, it has a so-being. The so-being of the object implies, that besides the seized part of the object, there stays an unknown rest. The fact, that we can never seize the object of cognition completely and without rest, never in its complete determination, is as well reflected in the non-conformity between the object and its picture. If the subject knows of this difference, there is the phaenomenon of the problem, that loads the cognitive process with tension and pushes for further cognitive efforts. The compensation of such a tension goes into the direction of the cognitive process, by which the frontier between that, what has been recognised and that, what should be re-cognised, is transferred to the transobjective. The quest for cognition, whose effect is the cognitive progress, is a progressing getting-ready for the determinations of the object. For the urge of cognition that what should be re-cognised is inexhaustible, infinite.*

*The cognitive process finds its limits at the rarely movable borders of cognisablity. Behind there is the un-recognisable, the trans-intelligible (erroneously often called the irrational). ... the existence of the transintelligible is the reason, why cognition never gets a rest. The sphere of the transintelligible, to what the being as such (as well reality) and being for itself is belonging to, is the medium that allows the effect-connection between object and subject. In what way the transfer of the determining pieces from the object to the subject takes place, is essentially unknown. If we presuppose that all being, as belonging to the common sphere of the un-recognisable, conditions and determines itself mutually in a way, if we consider, that the subject is the most responsive and sensitive among all being, it results, that the whole system of the being has to appear, from the transobjective through the object and the picture before the subject. It is, seen in that way, a grasping of the nearest links of the relation between object and subject.*

*The principles of cognition, that's to say the ways and means, in which cognition takes place, have so to be the* *same for all subjects. On the other hand results e.g. out of the calculability (possible inside the known limits of error) of physical processes, that the laws of mathematical logic (and so the validity of apriory insight) transgress the logical-mathematical sphere and are valuable beyond it. The use of a mathematical sentence for a natural event means a transgression of the logical sphere into the real one. There are logical coherences and relations, that coincide with those of the real world. The logical sphere does so mediate between the world of the pictures and the world of the real. The principles of cognition are so not only the same for all subjects, but they appear as well in the world of objects, indeed as the categories. Cognition is possible, because the categories of cognition and the categories of being are identical. But neither are all categories of cognition in the same time categories of being, neither are all categories of being in the same time categories of cognition. If the first would be the case, then all cognition would have as a content the pure truth, it the latter would be the case, so all being could be recognised without rest. The spheres of the categories of being and of the categories of cognition overlap only partly, and so only it can be understood, that the natural events seem to follow mathematical laws: that e.g. the orbits of the planets are elliptical in fact. Since the beginning of the 19th century, cognition is mainly identified as empirical cognition of the natural sciences. While the humanities are forced to look beyond the rational cognition."*

def: *Theory of Cognition: 1 critique of cognition, starting from a defined type of cognition, measuring it against the existing knowledge (Kant: Kritik der reinen Vernunft) & Metaphysics of cognition: searches the essence of cognition, starting from the potential of cognition contained in the being of the re-cognising and of the re-cognised. In the 19th and 20th century a lot of branches of t.o.c. were created: empiricism, empiriocriticism, idealism, illusionism, conventionalism, criticism, phaenomenalism, positivism, pragmatism, sensualism, scepticism. Nowadays studied as 'Theory of Science' in a formal logical way.*

def: ***Epistemology*** *(Greek: "theory of science"), theory of cognition; epistemological: do; the term is used less in the German and especially the English philosophy. Following the conception of cognition it is defined differently from Heraklit to Plato and Aristotle to the neoplatonic and Christian philosophy.*

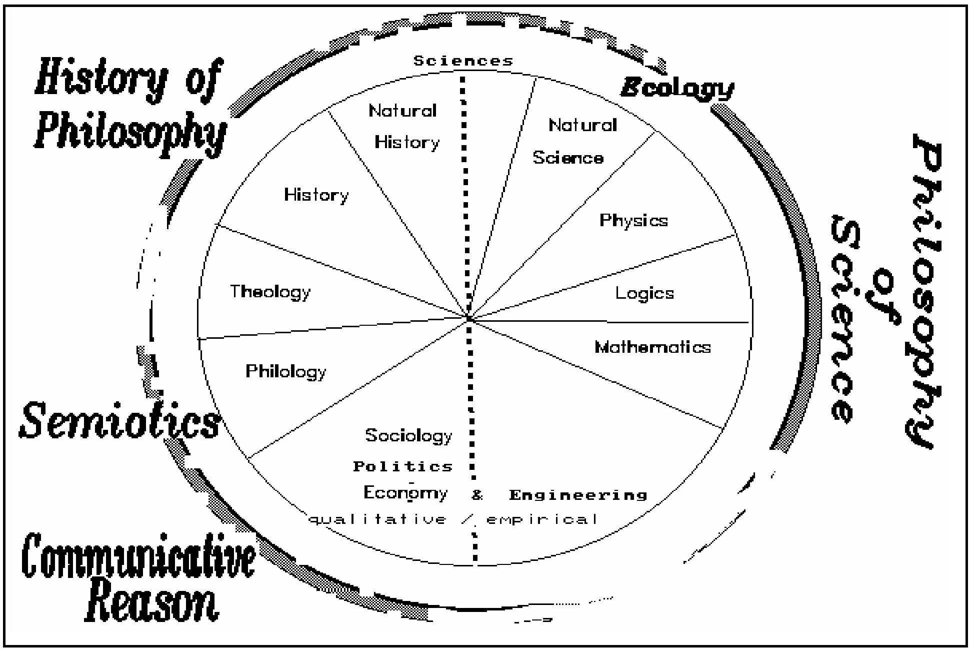
That means the theory of science depends on the philosopher? That this lacking precision is not a problem of terms and methods shows the favourite field of modern philosophy:

def: ***Theory of Science****: a modern section in the philosophical faculties, increasingly represented since the 2nd World War. With its formal character it has little relation to*

*the classical doctrine of science. "It rose out of the endeavour to treat philosophical questions with the same precision, terminological clarity, short: scientific responsibility as the special sciences do in relation to their fields." (Stegmüller). The classical philosophy, that, after its methods and objects, can't be put on a par with the special sciences, is an open, problem-(oriented)-thinking with partly not rationally sizeable backgrounds of thinking and being. Though thought as true source of culture and education in the fundamental thinking, historically and systematically taught at universities, it is dismissed by representatives of t.s. as "opaque mixture of terminological and pictoral-mythological thinking, unfounded speculative word-splitting and language-dreaming". T.s. is considered as grown out of the aristotelic logic that had stagnated over 2000 years and who's modern form arouse out of terminological embedding of statements, predicates, locical operations, sentences and others by mathematical symbols, as well as of the integration of "higher areas" of logics. From its partial fields the formal classical and intentional logic have to be mentioned, further on as special fields - constructive, intuitionist, epistemic, multiple value logics, modality logics, emirical logics, term- and theory construction, axiomatisation and others more.*
From part of adherents of modern interpretation of the classical philosophy and its constantly new questionable concepts, t.s is strongly attacked at the faculties, what doesn't change the fact, that critics of science, considering the scientifistic symptoms, think their time has come. We do believe indeed that it is easy to see, which positivistic-dogmatic congealment t.s. brings along. But as can be deducted from the sentence quoted above, science imposes authoritatively to philosophy to be exact, clear in its terms, intersubjectively understandable, controllable, scientifically responsible. After all what philosophy was and still is, as it presents itself out of often newly emerging aspects of critical problem-thinking, is not asked. It should, it must be such, as the narrow rationalism of t.s. prescribes.
There are moderate representatives of t.s. as well, that mainly deal with methodical questions, their history, with critique about rendering them absolute a.o. and do only accept the logical formalism of s. on the methodological side. - The rejection of the rigorous t.s. that pretends to replace philosophy may be legitimate. This controversy should yet not lead to a contempt of the new formal processes, that continuously gain importance in large fields of logic calculus. If the request, t.s. has to take its place inside the mathematical institutes, to go its proper ways in the framework of the total (quantitative and structural) formalism, can be fulfilled, is so far contested. In the future the formal t.s. might gain the status of a special discipline of the narrow rational field in the range of its classical-philosophical representatives.

Summarising Science and Philosophy: The function of philosophy is described as "**drafting areas of cognition, develop concepts and instruments of thought**". So science still starts with philosophy.

Later on, in chapter "3 - Development" and "4 - Orientation" we will see, that science ends with philosophy as well - if taken serious. Philosophy has to search truth wherever it finds it and by whatever means it can get hold of it. Philosophy has to deal with values and finalities, with matters science can't deal with. To restrict it to causality and causal methodology, to make it a formal science, is straight away absurd!




The start of science was philosophy, but science was so successful in its endeavour to explain and modify nature, that philosophy stayed behind and either tries to understand itself (History of Philosophy) or to jump on the bandwagon of the natural sciences (Philosophy of Science). Its integrative power has been lost in the 19th century. The natural sciences, especially their arrowheads mathematics and physics, being happily busy with themselves and proud of their success, don't give much for the quest for meaning and aims, while on the opposed side theology takes truth for given and does not much care for amelioration of the real world we live in. In the field of natural sciences only ecology starts to stretch out its hands towards ethics and ethnology, especially as the finiteness of our world gets clearer and more pressing. Through eco-economy even doomsday gets

now predictable, as a world population of 20 to 30 billion humans is going to use up the whole productivity of earth. It does not even need 20 million. If we take into consideration the *ecological footprint,* that is between five and six for Central Europe, a much lower population will have the same effect.
The humanities that had not only to start with complex inter-related sets of factors, but have to integrate contingency and human freedom as a major factor, could neither take the certists' road nor the falsificationists', but had to content themselves with working for a better understanding of the human being, and possibly giving him some hints how to direct his life. As outdated as the 'History of Philosophy' may look, most of the questions and problems put forward by the Greek have not been answered satisfactorily so far, especially what concerns ethics. Even the aims of Diogenes (the funny guy in the barrel) might get a new drive, considering the fact that our generation is using up the world's reserves.
The sciences of language is important, because all our thoughts, all our science and all our understanding is expressed through language. Ethnoscience tries to find the basic rules of cognition in the structures of language. Foucault even tries to reduce all science to literature!

In the following chapters cognitive problems are going to be analysed with increasing complexity. First an example of natural science: The historical development of botanical sciences, its - relation to the real world and a description of complexity in tree physiology. Then we shall see how sociology deals with complex problems and how non-material, rather fluid matters, as **MEANING**, can be dealt with. Sociology created the bulk of the methodology used in this research, as it has to deal with motives and action. Political sciences do mainly profit from those methods. but they restrict themselves to the description of political systems and do not (should not) make recommendations on how those should look like.
Economics is more dangerous. It describes models and recommends some of them as "natural", that means as good, as appropriate to guide human action. Management going to the limits, as it is setting and using motives and values to direct action. Science assists here in the creation of ideologies that often assume almost religious qualities. But - Dealing with values and aims (finalities) is a matter of ethics and philosophy. So here we have to close the circle. Science starts with philosophy when it starts to develop instruments of thought - science ends with philosophy when it recommends action.

## 2.0.1 Example: A Historical Transsect through Botanical Sciences.

In this chapter we are going to have a look at the forth and back between "*Gestalt*"- and reductionist- approaches from Albert the Great who liberated science from religion to tissue culture, where "*Gestalt*" is an inherent property at the molecular level, and ecological modelling, focussed on botanies and tree physiology.

The earliest approaches in plant cultivation have been undertaken in Mesopotamia some 10,000 years ago. Egypt as well has a long tradition in using, growing and breeding fruit trees, medical plants and incense. In China the pharmacopeia of Tzu-I has been established in 500 BC!

As any science, botany has to look back to the Greek, not because they would have been very advanced in botany as such, but because they shaped the whole universe of thinking. Most of the philosophical and scientific (epistemological) terminology goes back to the Greek. Their approach was quite open, not limited to rationalism, but using other forms of cognition as well, if considered appropriate. (The main concern of Greek philosophy being anyhow ontology). Pythagoras developed mathematics, geometry and harmony. Socrates tried to determine man's place in the world through dialogue (*Ethics! The State!*). Platon already analysed the relation between term and object - the idea. The highest idea being the 'beautiful goodness' (*Kalokagathie*) and the four main virtues: wisdom, valor, considerateness and justice. Aristotle developed the empirical-analytical (causal) explanation of nature, setting nature as the creative force. Diogenes tried to reestablish the human freedom in relation to wants and artificial luxuries. He and his disciples, the *Cynics*, criticised the artificial lifestyle and demanded to leave natural what is natural and to give nature its right! Pyrrho established scepticism, Asclepios the medical oath (4th c.b.C). Zenon and the Stoa developed ethics further on and, last not least, Neoplatonism (Philon) brought God back to a rationalised world through Gnosticism. A remarkable way from the formal approach of Pythagoras towards the spiritually oriented one of Philon!

The base for this development was the Greek town, the ***polis***. (The same place that gave 'politics' its name.)

Narrow-mindedness in sciences is neither limited to religious orthodoxy nor to the Middle Ages. Scholasticism is mentioned for the first time by Plini [6]): *"Experience, the most efficient teacher of all things especially in medicine, gradually degenerated into mere words and verbiage. For it was pleasanter to sit diligently listening in lecture-rooms than to go out into the fields and look for different plants at the different seasons of the year."*

In botany Theophrastus had an integral approach, but after him only the herbal component was studied. The tradition in the next 300 years was continued by Cato the elder, Varro, Virgil and Columella. Then the tribes out of the wilderness overrun the

[6]) Natural History XXVI,11 (ca. AD 70) p. 58:

whole Graeco-Roman culture when it had turned decadent. Germans, Ostro-Goths, pushed by Alans, Huns, Awars, Bulgars, Petscheneggs, again pushed by Kumans and Mongols flattened the Western Roman empire and its culture. During the buildup of a larger empire, the Karolingian one, the Arab expansion was already under way in the south and east, while the spread of Christianity in Europe had just started. At the court of Carolus Magnus scientific activities restarted - but incomparably inferior to what was done at the Arab courts of Spain, Egypt or Mesopotamia. The study of plants was clearly directed towards its medical use.

The quarrels between the scientists and the clergy happened almost in the same time in the Islamic and the Christian realms, the twelfth and thirteenth century (A.D). Albert, as a king and religious man, was able to do scientific studies independently from religion. Ibn Rushd, much less lucky, run into heavy problems with Ghazali and the clergy, who considered philosophical science as secondary in relation to the religious sciences (s. chapter 3.6). If it was the effect of Ghazali or the onslaught of the Mongols that put an end to the Islamic science, is still a matter of learned disputes.

The further development in Europe was not easy either. For **Roger Bacon** science was of practical use. He considered mathematics as the most important instrument of science and tried to convince his students, that one should study the object as such, the reality, rather than books about it (Aristotle). In those years many fights with church and government have taken place, especially what concerns the study of the human body (dissection!).

This awareness leads in the 16th century (**Renaissance**) to the establishment of many botanical gardens. Economics was involved as well, not only because the study was focused on medical plants. The plants  introduced from the newly discovered continent proofed to be economically very interesting: Potatoes, sweet potatoes, maize, tomatoes ("love apples", first used as aphrodisiac), runner beans, frenchbeans, pineapples, sunflowers, jerusalem artichoke, capsicum. For gardens: yucca, sumach, passion-flower, trumpet vine, morning glory, rubarb (Central Asia), aubergines (tropical Asia) and tulips (Persia)!

In the seventeenth century mathematics got definitely dominant in the sciences through the works of **Descartes**. **Jungius** established the importance of the experimental verification, what had been done in the Arab world by **Al Jazari** in the 12th century already. That is described as well as: The advent of the mechanical philosophy, of the experimental, modern science, or just of ***"the use of scientific method".*** Ray in his *Historia Plantarum* described the relation between plants and habitat - an early approach to ecology. **Locke** claims that God and moral values can be deducted by reason. From this time onwards God seems to be definitely out of science, until the 20th century will be forced to re-establish  ethics - in the form of environmental ethics.

The eighteenth century introduced on the analytical side of science, plant physiology and chemical-physical studies.

In the description of plants some enormous synthetic work has been done by Linné and others, establishing systems of related plants. The knowledge was enlarged for the historical dimension by the study of fossil plants, for the spatial dimension by plant geography and for the "*Gestalt*-Dimension" by anatomical-morphological studies. With its "*Jardin du Roi" (*later *"Museum d'Histoire Naturelle*"), managed by Buffon, France was that time the theoretical and practical leader in biological science. Duhamel du Monceau, a student of Bernhard de Jussieu, started the study of breeding, plantations and of the exploitation of trees ('environmental engineering').

In the first half of the nineteenth century the Germans, esp. Schleiden, studied the development of plants, their life cycles, the integration of different levels of structure and activity within the plant body and the relation between plants and the environment. This favoured comprehensive theorizing over pedantic empiricism and with it a certain wholistic approach in science. In general the nineteenth century brings an enormous increase of special sciences, splitting up botanies manifold into chemical physiology, metamorphosis (predecessor of genetics), cytology and microbiology. Jessen disdained on one side the scholastic development in classical botanies that blowing up terminology to a nonsensical size. On the other side he saw that the specialisation of botanies into microlevel studies, especially cytology, presented a step in reductionism, that would be difficult to integrate into the whole of the plant. With the totally new concept of Darwin, changing variability over time and the connected selective adaptation, he was not at home at all either. He refuted it as "non-scientific."

Under Liebig's influence state-aided agricultural research and extension took off on quite a large scale, with the aim to increase crop production. This helped Germany to stay at the top of plant physiological research for the rest of the century.

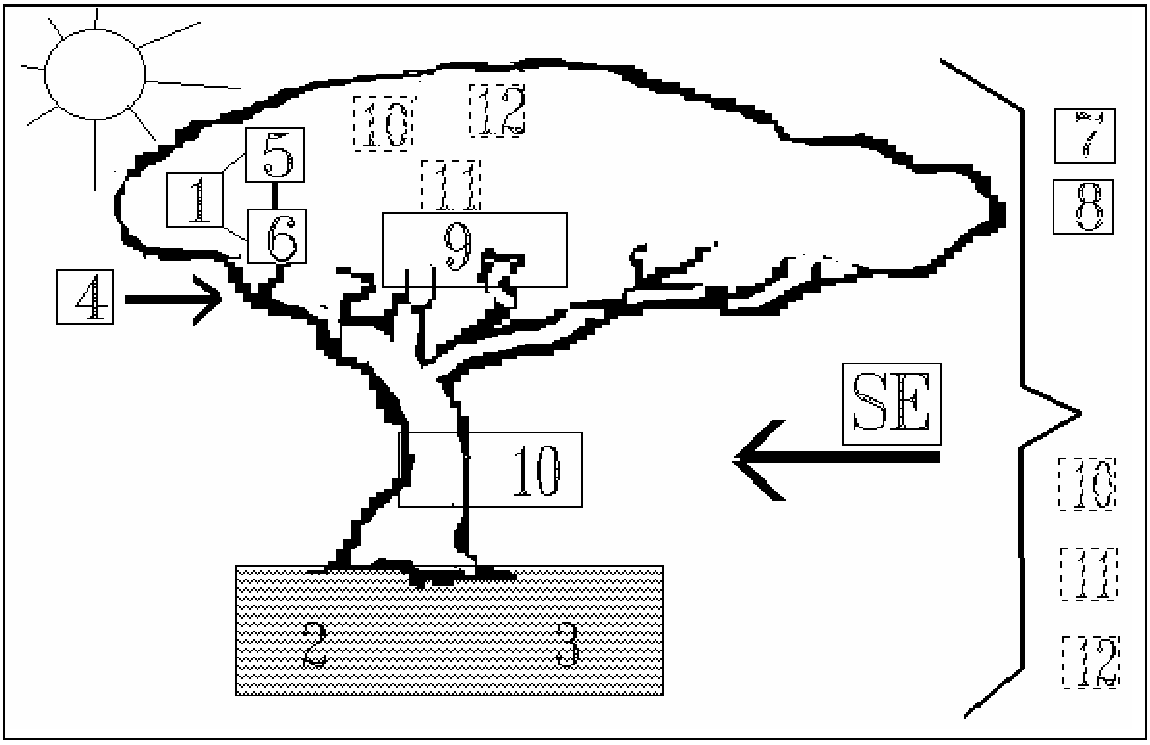
In the 20th century specialisation got definitely much worse. Still, some integrative concepts have been developed as well in plant sociology and especially ecology. But even these are split into many specialities:

- Aut-Ecology: The relation of the organism with its environment.
- Syn-Ecology: Self-regulation of ecosystem
- Human-Ecology. Cultural Ecology. Ethno-Ecology - Ethno-Botany ...
- Ecological Economy
- Ecological Ethics ...

The sciences dealing with plants and nature have always oscillated between reductionist (micro-level) and integral (macro-level) studies. They have a high responsibility nowadays to raise the awareness of policy makers and business leaders in what concerns the natural limits to growth. What is still needed is a "development and management philosophy" (- not science!) able to guide and regulate human development in its social, political and economic expression, towards sustainability.

## 2.0.2 An Example on Complexity in Natural Sciences (Tree Physiology) - Research on Drought Resistance

Factors and Levels in Plant (Tree) - Physiological Research:




The main elements of influence (ME), interrelations (I) and areas of study (S). (s. s reference literature in appendix).

1 Water Status: (ME) water content, osmotic potential, water potential, turgor.
(I)Interrelated with: Calcium-Potash content of plant, dependent on Ca / K availability and relation in soil. Water availability in soil.
(S) (main studies on this factor!) multifactorial, in relation with osmose, sugar, starch, K - Ca. The problem, so far unanswered, is the drought limit: is it the loss of turgor - the cessation of photosynthesis or is it death?

2 Soil: (ME) water content, water potential, water availability: dependent on structure, texture (esp. clay-sand-matrix content. Depth. Oxygen. Minerals: esp. Ca, K, N, P, K.)
(I / S)(A: 2-4) - Soil science is a special scientific discipline. Nowadays using complex modelling!
The impact of competition and allelopathy on the soil level is largely neglected, as soil is anyhow still largely a "black box".

3 Symbiosis (Mycorrhyza): (ME) specific for each plant.

(I) Depends on sugar supply by plant as well as on soil: pH, water content, organic and mineral content.
(S) (B [matrix]: 1-3): Mycorrhyza (9, 1923), again a matter for specialists.

4 Climate: (ME) Temperature, rainfall (amount and distribution), air humidity, windspeed, insulation (quantity of light), wavelength, (quality of light).

(I / S)multifactorial (s. chapter 4.1.1) The influence of wind on evapotranspiration (6, 1907). Natural conditions. Nowadays air pollutants have their special influence.

4.1 Evaporation: Soil. Mulch. Vegetation.

5 Transpiration / Stomata: Dependent on (I / S) climate: temperature, humidity, wind, light, water status in plant, sugar in plant, K/C in plant, age of leaves, (C: 5-8): 31, 1970; 32, 1971). Requires complex modelling! Transpiration is largely dependent on the age of the tissue (3 years old needles of silver fir evaporate more than double the amount of water than fresh needles e.g.! [7]) and as well correlated with form!

6 Photosynthesis (Growth-Storage-Dissimilation): Mainly dependent on (I) water status, temperature and light, opening of stomata ($CO_2$ supply!), but as well on mineral supply. The temperature has the main influence on the utilisation of the products: the more the temperature exceeds the optimum, the more of the products is lost by dissimilation.
(S) Photosynthesis as producer of sugar and starch, was soon understood in its importance (1896), the double peaked curve (8, 1921). The study is difficult due to its (I) multivariate dependence. Even modern devices, controlling wind speed, temperature, humidity and determining $CO_2$ change between inflow and outflow, can't really determine what is going on at the plant level, as the measuring device is influencing the quality and quantity of light.

7 Time: (ME) Daily and seasonal cycles. The ripening process of leaves is decisive for resistance, as young leaves are very sensitive, e.g. they have a very low resistance against water loss and frost.
Cyclic, non-linear, progressive, but in a non-continuous way (summer - winter, rainy season - dry season).

8 Age: (ME) whole plant, organs (e.g. Leaves: loss of adaptive capacity of stomata with age; wilting - death under stress. Stem: Formation of core zone with age, limiting transport capacity while increasing storage capacity. Organelles. (matrix E: 8-10): partial, function of time and stress, (I / S) e.g. the aging of organs. Double impact or related impact or frost and drought has been studied as early as

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[7]) s. Herzog, M. & Rotach, P.:

1930 (no 11). Later studies with mosses, where death might be a valuable criteria (no 23, 1954 and no 25, 1956).

9 'Gestalt': (ME) size & form: e.g.root depth and horizontal extension, xeromorphic attributes of crown and leaves ... (matrix D: 8-9) (I): multivariate dependence on soil, water, climate, competition, age e.g. Form changes with age. As tissue of different age has different evaporation quality, the quotas of needles per age (year) that are still present on the tree do influence the overall transpiration process (s. 1).

10 Organs: (ME) roots: water uptake, symbiosis. Stem - branches: water and photosynthetic products storage, use and evaporation, leaves (photosynthesis, transpiration). (I)
(I) Reductionism: e.g. detached leaves (28, 1956 and fn 3) can not be taken as representative for the transpiring behaviour of a whole living tree, as:
a) they are more or less dead (s. 1, 8).
b) the water-thread connecting it with the tree has been cut, the tension released, transpiration will so increase.
c) the sugar supply stops, dissimilation sets in, osmotic pressure declines.
d) the criteria for a critical drought is set as the cellular death.
(S: Morphology, Cytology, Microbiology).

(S) The study of 11 and 12 is even further away from THE INTEGRAL TREE. It is not to be denied that very important results have been found in those fields, some of them leading even to a re-integration of the whole, as osmosis in the 19th century and hormones in the 20th.

11 Organelles: (ME) chloroplasts, stomata, tracheids ...
(I) (S)
(S) Organelles: Here reductionism shows its worst forms, when the study of drought impact on plants is reduced to the direct impact of drought on protoplasts (16, 1931 to 17, 1970; 21, 1943)

12 Biochemistry (hormonal regulation, enzymes ...) :

The study of hormones and other biochemical agents in the plant looks quite promising (12 Biochemistry: 30, 1967) - unluckily studies, if done properly, meet here the same problems with complexity on different levels as old-fashioned research models.

SE: Syn-Ecology / Community ads to the complexity of the research:
The competition for light and space, impact of herbivores and pests anyhow is a different field. While there is clearly a higher sensitivity under stress, those (admittedly highly complex) factor combinations have not been studied. The most complex approaches including climate, pollution (pH, $SO_x$, $NO_x$, F, CH, $O_3$), soil (with mycorrhyza), water status of plant and

photosynthesis have been done under the threat of forest backdying (e.g. Switzerland: NFP 14+: Lägern). But this kind of approach with its complexity results in highly complex research structures, enormous amounts of data and costs - and results that are very difficult to inerprete.

If we want to do scientific experiments on those factors as a quantitative analysis, we have to deal with quite some complexity. The formula for combinations without repetitions of n elements in k classes is:

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click here to view equation.

Already for 10 factors we get the following number of combinations:

| | | |
|---|---|---|
| 1 factor | : | 10 |
| 2 " | : | 45 |
| 3 " | : | 120 |
| 4 " | : | 210 |
| 5 " | : | 252 |
| 6 " | : | 210 |
| 7 " | : | 120 |
| 8 " | : | 45 |
| 9 " | : | 10 |
| 10 " | : | 1 |
| Total | : | 1023 |

What is most often studied are combinations of two to three factors. The rest is - no, most often not kept constant - but - just neglected!  An analysis of the literature used by Winkler in his "*Plant Ecology*" (1973) showed the following results (If you think that Winkler is just outdated check e.g. Krebs, C.J: *Ecological Methodology*. That's by no means better!)

| | |
|---|---|
| 1 factor/level: | 12 |
| 2 " | 28 |
| 3 " | 7 |
| >3 " | 0 |

Of main interest were climate and transpiration (4/5), water, organs & photosynthesis, time.
The <u>independent factors</u> water, storage, soil and symbiosis ad up to 15 possible combinations (4 single factors, 6 combinations of 2 factors, 4 combinations of 3 factors, 1 combination of 4 factors). In addition there are  hierarchically nested subfactors, e.g. water: supply, transport, storage, loss (evaporation)!
The dependent factors transpiration & photosynthesis only represent 3 combinations (2 single & 1 combination of 2 factors).
What complicates tree physiological research additionally are the <u>permanently present factors</u>:
- climate (4): can be kept stable for experiment!
- form (9): can't be controlled, but can be quantified, while needing at least 3 dimensions: height, width and depth!
- time (7) and age (8) can neither be controlled nor properly

measured, as they are non-linear, but cyclic (time) and noncontinuous, stepwise for age (winter / dry season).

The largest package of multivariate statistics is the SSS: General Linear Models. This kind of programs can handle large amounts of factors, interdependencies and data, probably much more than science can deliver, if we take as a minimum lets say 10 repetitions per factor. In the case above, *the integral tree*, this is asking for thousands of trees as samples! Even if we are able to eliminate large of the interactions. The main problem is: very few of the processes and interactions are linear. So large parts of the model will be based on guesses, assumptions and neglections.

The main aim of this chapter was, to make clear, that instead of defining critical points, e.g. setting criteria for the impact of drought (lethal, inhibition of assimilation, ....), we should detect them - and if statistics can't be used for that purpose - then don't use it!

So in the end we come in our dear natural sciences to the same conclusions as the humanities: before we want to explain effects by causes, we have to understand what is going on in an integral way - to be able to describe the processes and, if possible, to quantify them. Chapters 4.1 to 4.7 will be dedicated to that.