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Secondly, views on teaching and learning are elaborated, starting from a constructivistic educational approach. This section focusses on the crucial role of pre-knowledge in learning processes, and on consequences of this approach for decision making on an intended curriculum. It implies that the students' own ideas about regulation and homeostasis are important and are used as a starting point and bridgehead for further developing their insight and understanding

Furthermore, we report on exploring students' personal knowledge about the existing concepts, using their status and structure in scientific biology as a reference. Outcomes are important for making decisions about both the disciplinary content and the educational strategies to be used in classrooms.

A next step will be developing curriculum materials on the topic. These materials are intended to support implementation of a new programme for biology education at secondary level in The Netherlands. During the pioneering phase with these materials in biology classrooms, data will be collected on individual and collective knowledge acquisition, following the students over a period of about three months.

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Students' Personal Knowledge of Regulation and Homeostasis: Pioneering in Biology Classrooms

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INTRODUCTION

Regulation and homeostasis are vital functions in living systems. Understanding these concepts can be considered as an essential element in biological literacy (Demastes & Wandersee, 1992). However, up to now neither tradition nor theory seems to exist about how to arrange biology education on the concept of homeostasis.

This paper , firstly, reports the results of a survey carried out to describe and to analyze the status of the concept of homeostasis in scientific biology. If one of the aims of biology education is to show the specific nature of the discipline it is necessary to have at hand an updated 'state of the discipline', serving as a source of information on the subject matter.

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HOMEOSTASIS: ESSENTIAL BIOLOGICAL CONCEPT

Leading authorities in scientific biology, such as Ayala (1972), Von

Bertalanffy (1972), Smith (1961) and Prosser (1975) agree that *homeostasis is one of the main issues in biology*. The property of selfmaintenance, being one of the most specific features of living beings, depends mainly on regulatory mechanisms. The result of these regulations is often characterized as homeostasis. The principle of homeostasis is unique and specific for living beings. All literature concerning the origins of the concept of homeostasis points to the close relationship between the wording and elaboration of the concept of homeostasis by Cannon, about 1930, and the ideas of Bernard, seventy years earlier (Adolph, 1961; Goodfield, 1960; Hardy, 1983; Holmes, 1969; Langley, 1973; Leake, 1964).

Claude Bernard postulated about 1860, that 'La fixité du milieu intérieur est la condition de la vie libre'. His postulate stresses the crucial role to be fullfilled by the cell-surrounding environment: only within very narrow physico-chemical limits is the survival of (individual) cells in a multicellular organism secured. Bernard described the relation between the constant qualities of body-fluids (blood and tissue-fluid) and the capacity of animal organisms to live a 'free life'. The relative independence of higher animals from their surroundings is based on the properties of the cell-surrounding environment. The proposition of Bernard was very important for the progression of research into internal regulation mechanisms, at first in human beings, later on in other warm-blooded animals.

Walter Cannon (1929, 1932) introduced the term 'homeostasis'. In his work 'The Wisdom of the Body' he describes 'homeostasis' as follows: 'The constant conditions which are maintained in the body might be termed equilibria. That word, however, has come to have fairly exact meaning as applied to relatively simple physico-chemical states, in closed systems, where known forces are balanced. The coordinated physiological processes which maintain most of the steady states in the organism are so complex and so peculiar to living beings -involving, as they may, the brain and nerves, the heart, lungs, kidneys and spleen, all working cooperatively- that I have suggested a special designation for these states, *homeostasis*. The word does not imply something set and immobile, a stagnation. It means a condition -a condition which may vary, but which is relatively constant'.
Cannon discusses some examples of homeostasis in the human body, but also speaks about homeostasis-in-general, using the word as a collective noun, viz. an indication of the sum-total of these equilibria. Cannons' elaboration of the concept of homeostasis emphasizes coordination processes and stabilizing mechanisms, thus placing the ideas of Bernard in a wider perspective.

In the 19th century looking at and reasoning about life and living beings were rooted in a *vitalistic view*. Vitalistic thinking 'refers to views that life is infused by a vital principle which is absent in non-living matter and which has been conceived of as a vital substance, fluid, or force' (Sattler, 1986). A *mechanistic view* on life was predominant in biology in the first

decades of the 20th century: biological facts and processes were interpreted and explained using physico-chemical points of view.
In the years after the description of the concept of homeostasis by Cannon, the biological sciences have been strongly influenced by Von Bertalanffys' *general systems theory* (1968). Von Bertalanffy states that 'machine-models' are inadequate to describe living organisms. The genesis of natural machines is inexplicable 'in a universe of undirected physico-chemical events', and properties of metabolism, biological regulation and self maintenance cannot be represented and explained by using this model. He concludes that 'a machine-like structure of the organism cannot be the ultimate reason of order of life processes, because the machine itself is maintained in an ordered flow of processes. The primary order must, therefore, lie in the process itself'..... 'We express this by saying that living systems are essentially open systems. An open system is defined by the fact that it exchanges matter with its environment, that it persists in import and export, building-up and breaking-down of its material components'.
According to Von Bertanlanffy (1972), the concept of homeostasis is to be considered as an application in biology of the concept of feedback 'which is basic in cybernetics and was biologically formulated in Cannon's concept of homeostasis' and 'The models of both open system and feedback apply to a wide range of phenomena in physiology, and represent essential expansions of physical theory. The two conceptions should be clearly distinguished; the feedback model (homeostasis) should not be considered a cover-all for physiological regulation in general or identified with "systems theory".'

Scientists such as Waterman (1962), Ayala (1972), Amen (1966) and Miller (1978) stress that the framework of the general systems theory leads to *interpreting and explaining homeostasis as a decisive function in maintaining stability in living systems*. Waterman (1962) considers the systems perspective as an overall organizational scheme, providing 'a framework, within which all the numerous parts may be ordered'. Amen (1966) introduces a biological systems concept combining the general systems concept with the concept of hierarchical organization of organisms ('levels of biological organization'). This modern view on biology, often qualified as holistic, is specified as *organicism* (Beckner, 1959). Von Bertalanffy, quoted by Sattler (1986), pointed out that organistic biology transcends both mechanism and vitalism.

Amen (1966) and Miller (1978) point to the universal character of the general systems theory. Consequently, they conclude that all biological levels of organization show 'homeostasis': biological processes are incorporated in a homeostatic (or cybernetic) system. This last opinion is not yet generally accepted in scientific biology. The question if regulation of populations and ecosytems is homeostatic is unsolved. Empirical data, illustrating the occurrence of feedback regulation based on set-point mechanisms, are absent in literature (Begon, 1990). The question is subject of a continuing debate among biologists. An interesting example of this debate is demonstrated in the discussion between Engelberg & Boyarsky (1979) and Patten & Odum (1981).

THE PRESENT STATUS OF HOMEOSTASIS

It is obvious that the general systems theory has strongly changed views on life and living beings. Looking at organisms as open systems with enclosed subsystems and maintaining a steady-state is an important step in the evolution of explaining homeostasis and its significance. It means that Cannons ideas, placed in this new perspective, can be detailed as follows.

Firstly, it appears to be necessary to distinguish between homeostasis, being an umbrella term for stable situations or conditions, and homeostatic regulation, being a regulatory mechanism in a homeostatic system.
This means that homeostasis is defined as sum-total and result of several homeostatic regulations. For explaining homeostatic regulations in function of the exchange of energy and/or matter and information it is essential to distinguish between the system and its environment, and to nominate the biological levels involved.
Secondly, the main elements acting in a homeostatic regulation can be represented in a model, adapted from the cybernetic theory on negative feed back regulation. It means that regulation depends on continuously processing of information on a certain property or quality of the system, and on comparing this information with a standard level to be maintained (the so-called set-point), and -if necessary- on making corrections to restore the desired level.Following this view, *homeostasis is considered as the result of a very specific type of regulation, the built-in set point being crucial.* Homeostatic regulations are essential in processes of self-maintenance and self-organization (autopoiesis) (Maturana & Varela, 1984).

Thirdly the range of homeostatic regulations can be defined more precisely. This refers to the consensus in scientific biology that homeostatic regulations are found in animal organisms. The occurrence of homeostasis and/or homeostatic regulations in populations and ecosystems is still widely debated.
In recent textbooks of human or animal physiology the concept of homeostasis is elaborated according to these views (e.g. Withers, 1992).

HOMEOSTASIS IN BIOLOGY EDUCATION

Next to scientific biologists, also biology educators will agree in that regulation and homeostasis are main issues. Understanding of these concepts can be considered as an essential element in biological literacy, and for that reason as a must in biology education.

One of the first attempts to introduce these concepts in biology education in a more systematic way was made in the BSCS-program, by introducing the unifying theme 'Regulation and homeostasis'. But a survey of the BSCS-materials reveals that the attention paid to the concept of homeostasis is restricted to a simple example: the (non-biological) room-thermostat. This is a clear example of reducing a biological phenomenon to a mechanistic analogy. A conclusion could be that within the unifying theme Regulation and homeostasis the concept of homeostasis and its importance remain underexposed.

In other textbooks or curriculum materials a brief description of the concept of homeostasis is found incidentically. In all these cases homeostasis is described as a situation of stability, based on a mechanistic view on life. It is remarkable that attempts to include new points of view from scientific biology in biology education are so scarce.

Only some authors report on experiences and problems with teaching and learning the concept.

Kuhn (1967; summarized in Novak, 1977) reports on an experiment with advanced organizers as learning variables. The topic of homeostasis was used as an eight-hundred-word advance organizer with one group of students, and as an eight-hundred-word historical statement (nonorganizer or blank) with another group. The differences in mean scores between the classes with advance organizers and those with the historical passages were significant both after instruction and three weeks later. The difference between the advance organizer and the nonorganizer text is that the advance organizer text provides the students with information about structures and processes involved in feed-back regulations. Analogies and figures are used to illustrate and support written information. The second text comprises of a historical overview of the ideas of Bernard and Cannon. The reference to regulation mechanisms is very limited: 'This concept embraces the idea that there are, within living organisms, mechanisms (natural powers) which tend to right things when they have gone astray, to return the state of health normal, even to oppose the change toward abnormality as soon as the change begins.' The results of this study confirm that providing students with detailed facts and figures on regulatory mechanisms yields better learning outcomes.

Barass (1985) states that problems with learning and understanding the concept are closely connected with the dual meaning of the concept. He proposes to distinguish between the processes and mechanisms of homeostatic regulation calling these 'homeostatic mechanisms' on the one hand, and the sum-total of these regulations, calling this 'homeostasis'. The term homeostasis then serves as an 'umbrella-concept'. These findings agree with our description of the present status of the concept, given before.

Demastes & Wandersee (1992) report on a teaching strategy to promote understanding the principles of thermoregulation, being an example of homeostatic regulation. The group of students involved 'explored a series of provocative questions, mainly focussed on temperature regulation of the own body'. The authors describe some weaknesses and consequences of their approach. From their experiment can be learned that this approach is useful to introduce the concept of thermoregulation, but that it is necessary to add other concepts and terms. They stress that starting with more popular terms and explanations requires more time, but also yields greater understanding.

Simpson & Marek (1988) compared biological understandings of students from big high schools with those of students from small schools, by testing their understanding on four biological concepts, including homeostasis. Written responses were judged on five levels of understanding. The authors conclude that students attending smaller schools show 'greater misconceptions in the areas of diffusion and homeostasis'. No difference was found in the other two areas of biology. This study only reports final outcomes of testing, but doesn't describe learning environments and strategies used to promote understanding the concepts.
Westbrook & Marek (1992) describe in a cross-age study the understanding of the concept of homeostasis held by students across several levels. Information about learning environment and instructional strategies is not included in this study. The authors didn't observe a decrease of misconceptions across the grade levels. Examples of certain persistant misconceptions are given. They conclude that their study provides a description of student views, but that it has limited application in terms of conceptual development and change.

This last remark can be generalized to all studies mentioned above; it means that studies on effective teaching and learning the concept of homeostasis are nearly completely missing. So a conclusion can be that neither tradition nor theory is available about how to arrange biology education on the concept of homeostasis. This is one of the reasons for making a new attempt to elaborate the topic for use in biology classrooms.
Another motive for undertaking this attempt comes from the fact that biology education in secondary school in The Netherlands will change in the mid-nineties. From that time onwards the national final examination will be based on a revised and partly renewed program for biology. One of the themes to be emphasized will cover biological regulation, including the topic of homeostasis.
For those reasons we started a project, feeded and supported by research activities, to explore new ideas and opportunities for teaching and learning about regulation and homeostasis in regular classroom practice. Outcomes will be 'translated' into classroom materials intended for use by biology teachers and students (aged 16-18 years) at pre-university level. For this reason close cooperation with some experienced biology teachers was necessary.

In this new attempt we will apply two innovations. Firstly, the *organicistic view on life*, explained in the foregoing paragraph, is chosen as an explicite underlying philosophy of biology. It means that main elements of living systems theory will serve as a framework. Regulation and homeostasis wil be integrated in this framework. Relevance and importance of this choice for biology education is emphasized by Schaefer (1989): 'Systems thinking is a necessary tool for scientific progress. It implies both analytical and synthetical procedures and thus is sometimes called a 'holistic approach' to nature'.

Secondly, a *constructivistic approach to learning* will be taken as basic philosophy for elaboration of strategies of teaching and learning. Main arguments for choosing this approach come from studies reporting about experiments with teaching and learning complex concepts, and from considerations of pedagogical nature. This constructivistic approach will be elaborated in the next paragraph.

Looking for new roads of teaching and learning about homeostasis will concentrate on *assembling new views in biology with constructivistic views on teaching and learning*.

STUDENTS' PERSONAL KNOWLEDGE SEEN AND UTILIZED AS A LEARNING AGENT

What people know and think about themselves and about their surrounding world is an important factor in the process of learning. In constructivistic approaches to teaching and learning, the prior knowledge of the learner is exploited as a starting point and a bridgehead for acquiring new knowledge. In this view learning is a continuous process of reconstruction and enlarging prior knowledge (Osborne & Fryberg, 1985; Driver & Bell, 1986; Scott, 1987; Jonassen, 1991).

The knowledge of objects and events is part of the learners personal, viz. mental equipment. Whatever the nature of this 'personal knowledge' may be, the owner makes use of it from his personal mental tool box.

Communicating with other individuals in a meaningful way means that the 'personal knowledge' of the individual fits to the knowledge of other individuals. In this view meaningful depends on 'shared knowledge'.

Essentially, enlarging meaningful knowledge depends on reaching a certain level of shared knowledge: in the scientific world conferences and meetings serve as playgrounds to negotiate ideas about the interpretation and understanding of the world. New elements are added to the shared (body of) knowledge of a specific discipline when there is a consensus in views and conclusions.

Sharing knowledge depends on the use and acceptance of a system of common words and symbols: most disciplines develop own (written and spoken) language. So one could say that biologists use 'biologish' as their language, marked by a specific grammar, vocabulary and idiom. Translating these views to school- and classroom learning means that classrooms can be seen as communities of (young) people that are developing 'speaking terms' on specific objects and events, in this case from the living world.

It is clear that in a constructivistic approach of knowledge acquisition *the students personal knowledge is crucial:* it is starting point for developing further knowledge. Applying a constructivistic view on the latter it is one of the roles of teachers to promote that learners make explicit their personal knowledge, and exchange their ideas with other students of the group. This procedure is similar to the way in which scientists reach a consensus about certain objects or events: it may be expected that negotiating meaning leads to shared knowledge more and more.

This brings up the question to what extent these 'personal knowledges' can or have to be elevated to an accepted level of knowledge, shared by e.g. biology scientists.

Essentially, this question refers to the aims of biology education, and to the relation between biology education in secondary schools and scientific biology. Referring to scientific biology as a standard for judging the level of biology education and learners' understanding means referring to an external 'body of disciplinary knowledge', shared by an external group.

From a constructivistic point of view some other considerations are also relevant to science education. In a social constructivistic approach it are not only the products of scientific activities ('the bodies of shared knowledge') to be brought up in biology education, but also the ways and procedures that have yielded this knowledge. Procedures and tools used by scientists could be translated and applied to biology eduaction.

Van Oers (1988) pleas for developing and working with models in classrooms. This can promote social interaction: model-based discussions in classrooms give students opportunities to use and compare personal and scientific represention of reality. In this view the model functions as a tool, emerging from and evolving during the discourse. This function is similar to the status of models in science: they comprise a hypothesis, suited to making statements on reality, i.e. to describe, explain and predict it. This approach is based on Vygotskis' cultural-historical approach of learning. Van Oers describes how students can be taught to (re-)construct and use models for solving theoretical or practical problems in science.

Driver & Bell (1986) argue that active exploration of models by students fits the constructivistic idea 'that learning involves an active process in which each learner is engaged in constructing meanings whether from text, dialogue or experiences'.

For classroom use this could mean that procedures and strategies are practiced that enable students to reflect on and to communicate their (personal) interpretations of reality with others. This procedure promotes developing a common language and view on essential features of biological objects and events, using suitable and intelligible elements from the discipline, its language and its tools.

What consequences have these views ? It is evident that if we want to use the students' personal knowledge as a bridgehead for teaching and learning in classroom settings, this knowledge should be known. This means exploring procedures to trace this knowledge. Data about the nature of this knowledge will provide data comprising information for decisions on educational contents and procedures.

Deadman & Kelly (1978) support this sequencing of decision making by saying that '...pupils' understanding of a topic is investigated first and then, through a gradual building-up process in which development, research and teaching are combined, ways are explored directly with the pupils by which their understanding can be increased'.

The next paragraph comprises results of exploring students' personal knowledge. Three studies are reported. Students ideas and preconceptions on an example of own 'human body biology', viz. temperature regulation are described, followed by an experiment to test students' ability to incorporate their knowledge in handling a living systems model.

PIONEERING WITH STUDENTS' IDEAS ON HOMEOSTASIS AND LIVING SYSTEMS.

Could young people be supposed to know and to have ideas about homeostasis ? In our first explorations of students' personal knowledge of homeostasis we concentrated on facts and phenomena connected with thermoregulation, being an example of homeostatic regulation. The choice of this example can be accounted for by the fact that thermoregulation is one of the few regulation processes which is accompanied by signals that can be experienced and observed at the outside of organisms. It is reasonable to suppose that students have knowledge of temperature regulation, at least of their own body. It was our aim to find out *what students know and think about the regulation of body temperature, and about the constancy of body temperature*.

We used texts and tasks to trace and describe students' understanding of the concept of homeostasis, following an idea suggested by Simpson & Marek (1988). The text describes what happens when a person is subjected to strong physical exercise. After they have studied this text, students are invited to explain individually why respiration- and heartbeat-frequency show changes, and why body temperature doesn't change.

Text and task have been submitted to 160 students (aged 16 - 18 years old), coming from different secondary schools. All the students had followed biology courses over two years at least, and were now participating in biology programs at secondary level.

Based on results of these explorations, we classified students' ideas in *two types*.

The *first type* comprises ideas in which the *constancy of body temperature is taken for granted by 'the body'*.

Typical examples of this type are:

-The body cares for a constant body temperature
-The body tries to keep its temperature on 37°C
-The body tries to avoid changes in body temperature

-You are trying to keep your body temperature as constant as possible

-Man is warm-blooded: the body temperature has to be kept on 37°C
-The temperature inside the body has to be constant.

If holders of these ideas refer in their explanations to a *disruption* of the constancy, they point to illness: a change in body temperature is considered as pathologic or associated with fever.

Examples of these explanations are:

-Body temperature only changes if you are ill
-A non-constant body temperature is unhealthy
-After strong physical exercise you don't get a fever.

In the *second type* of explanations, students report of a direct relation between the constancy of body temperature and sweating: they think that *sweating regulates body temperature.*
Two subtypes can be distinguished:

-Body temperature doensn't change *as a result of sweating*, or
-Body temperature changes, this *causes* sweating, followed by a fall of body temperature.

None of all students referred to *internal* parts or processes of the body that are involved in temperature regulation.

A first conclusion from these data could be that certain students make use of explanations showing elements of *vitalistic* thinking. What's going on in the inside of the body, the internal processes, remains unnamed, and the constancy of body temperature is attributed to the body-as-a-whole: a kind of black-box.
It is striking that the students from the other group don't give any specification of internal processes as well. Their ideas on temperature regulation comprise only external phenomena too.

From these data we conclude that the students consider the constancy of body temperature as a matter of course. As a consequence it couldn't be expected that students see temperature regulation as coping with *warm-and-cold-problems*.

An other study was carried out to investigate students' ideas about warm-and-cold-problems more in detail. The aim was to find out what students know about heating and cooling of animals.

We arranged an experimental setting, with two small groups of students and used a text comparing the way of living and the environmental conditions of three subspecies of foxes: the arctic fox, the red fox, and the fennec (a desert fox). These animals share the property of being warm-blooded (endothermic), but are subjected to very different environmental and climatic conditions. Students worked in small groups, reading and discussing the text. Finally they were invited to work out a diagram showing there ideas about maintainig constant body temperature. This study revealed that students were not aware from the phenomenon of continuous production of heat in animals, caused by cell metabolism. The absence of this notion will imply that they don't see temperature regulation as a necessary, continuous process of body temperature control. Therefore, we think that understanding temperature regulation as a function of the animal will only develop, if the principle of metabolic activity, more specific of that of basal metabolism, is known. Awareness of this fact provides a necessary tool for constructing functional explanations of temperature regulation processes.

A final remark regards the terms 'warm-blooded' and 'cold-blooded', known by students and settled in their minds already for many years. In biology education all over the world these terms are established. It is likely that these terms induce of misunderstandings. These misunderstandings seem to hinder students in making steps to thinking, reasoning and comparing types of thermoregulation as strategies of survival. Westbrook and Marek (1992) also point to this.

It is interesting to point out the German vocabulary. Here the terms 'gleichwarm'(=equal warm) and 'wechselwarm' (=alternate warm) are used. These words stress that there is always 'warm' (=heat) available).

In another study we explored *possibilities to work with a living systems model*. Therefore we developed a model to be used in secondary biology classrooms. A second aim of this study was to show that students can make sense of this model, and are able to use it effectively in a problem solving task. Basic ideas for the model were from Miller (1978), and given concrete form in a diagram, called '*biostruct*'. Care is taken that the biostruct represents the central notions of Millers' conceptualization of a living system, viz. the distinction between system and system environment, the processing of matter and/or energy and information, and subsystems being the functional structures of every system. The interplay of processing of information on the one hand, and of matter and/or energy on the other hand, forms the basis for regulation and homeostasis in living systems.

A problem solving task was chosen to investigate the usefullness of this model. This task invites students to use the biostruct in expressing their views on regulation in a living system. The students were asked to explain how a living system succeeds in satisfying its internal needs for different substances. They had to give their solutions by indicating aspects in the model diagram, which they considered important, and to explain these solutions. All students had received instruction in biology before, but the notion of living systems had never been part of their curriculum.

The study was carried out in a standard high school, preparing students for studies at a university. The group participating in this project, consisted of 92 students, aged 16-18 years. The procedure in the classroom was as follows: the students received an explanatory text about living systems, and a large sheet with the biostruct, i.e. the visualized living systems model. After they had studied these materials for 15 minutes, the students received the following written assignment: 'Each biostruct functions in such a way that it is continually able to satisfy its internal need for specific substances'. In the assignment the students were asked to imagine which processes and relationships would be most essential in this general property of a biostruct. They were suggested to search for those arrows in the diagram which might mark these processes and/or relationships. Next they had to choose and mark arrows they judge as most important, and to give in their own words a short explanation of the meaning they attributed to each of these arrows.During the project students proved to be interested and cooperative. From their reactions we could learn that they were challenged by the model and its representation.

To analyze students' understanding and interpretation of the principle of regulation we considered some specific relationships and subsystems, depicted in the diagram, as most essential. Students' understanding of the regulation principle was judged by using this criterion. If a student explicitly referred to these components we considered this as an understanding of crucial factors in regulation processes. The model proved to be rather succesful: about 27 % of the students met the criterion. Apparently at least this part of the students could handle the model, and link it productively to their existing biological knowledge. It should be kept in mind that the participants hadn't received any specific preparation. This holds for both the biological content of the model, c.q. diagram, as well as the ways of proceeding and reasoning with such a model.

On the basis of this study we propose elaborating the systems concept for use in secondary education. The outcomes suggest that students without any specific knowledge of the living systems concept can handle this model. As far as we know there are no examples of incorporating the living systems concept as a central theme in biology education and/or curricula. We believe that working with the living systems concept can function as an organizing tool for teachers and students too; it can help them to look at and to understand biology subject matter in a more integrated way. In this respect the model serves as a framework too, and concurs with the ideas of Merill, Kelety and Wilson (1981). These authors plea for a general-to-detailed sequencing of the subject matter to be taught.Other theoretical considerations support the use of a visualized model. In general such models offer opportunities to gain experience in scientific thinking and reasoning: moreover these models are accepted tools in communicating on complicated and dynamic phenomena (Genter & Stevens, 1983; Norman, 1982).

TOWARDS A CURRICULUM ON HOMEOSTASIS AND REGULATION

Designing a curriculum means decision making about intended contents and strategies of learning: it implies choosing and assembling 'what'-components, viz. the biological subject matter with 'how'-components, viz. strategies and procedures that promote learning.

Organiscism viz. living systems theory will serve as basic biophilosophy and point of departure for selecting and sequencing the *biology component* of the curriculum. It means that the systems perspective and the principle of hierarchical organization are directional. The living systems concept and the distinction between levels of biological organization provides a framework for understanding regulation and exchange of matter, energy and information.
Translating this into curriculum, elements the principle of interaction between a biological system and its environment will be illustrated at cell, organism and population level. Structures and processes involved will be visualized in a unifying living systems model, applicable to all levels of biological organization.

In this approach, types of regulation will be compared at cell, organism and population level. It means that both principles and specific types of regulation will be dealt with, supported by a basic model of feed-back regulation. This yields a design comprising the following selection and sequence of biological content matter.
The curriculum opens at *cell level*, bringing up the way in which Paramecium is coping with environmentalchallenges. To illustrate regulation at the *level of the organism* the example of temperature regulation in man is chosen. From the exploration of students' personal knowledge we learned that this is a rich and fruitful source of ideas. The case of the person, that is subjected to strong exercise, is very suitable for inclusion in the curriculum too. An important point we concluded from the previous explorations was that it is necessary to provide information on the (basal) metabolic activities, previous to information on temperature regulation.

The topic will be completed with the example of fever, being another stress situation for the organism, with symptoms well-known to every human being. At *population level* the example of two interacting populations is elaborated. A final exercise in thinking and reasoning on living systems is applied to the concept of superorganism.

The choice of *strategies and procedures promoting learning* is based on a *constructivistic approach of learning*. In this approach the challenge is to do justice to both the individual and social aspects of learning. Crucial is how to proceed with personal knowledge, and how to promote active working with and communicating with others about this knowledge. For designing the curriculum it means that opportunities should be incorporated for individual and collective activities, to clarify and discuss personal knowledge, opinions and explanations. A permissive classroom climate will be obligate to promote exchanging and negotiating the various personal ideas.

he results and experiences from the previous investigations of students' knowledge will be used in the curriculum materials. The challenge of pioneering with personal knowledge in classrooms is translated into problem-oriented tasks, inviting students to explicitate previous knowledge and ideas, followed by a phase of exchanging and communicating ideas and solutions with other students. In the design, models, diagrams and symbols will be as vehicles for communication.

The precise ways in which teachers want to organize interaction and communication in the classroom can be different: students can do their work individually, followed bij task-group activities, to reach agreements, or the teacher can work directly with students' ideas in a classroom discussion on the tasks and questions. So it is possible to introduce experiments in the curriculum too. The curriculum-materials are intended to be applicable in different classroom settings, and by teachers with different educational styles and philosophies: it is up to the teacher to make ultimate decisions about the intended classroom procedure

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