1. Quantitative Sciences

1.1 Human Cognition

> *Omnis homines, qui sese student præstare ceteris animalibus, summa ope niti decet, vitam silentio ne transeant, veluti pecora, quæ natura prona atque ventri obedientia finxit.*
> (Gaius Sallustius Crispus: *De coniuratione Catilinæ*)

Homo sapiens, the human species, not only resembles the apes physiognomically, but also its behavior and social structures show striking similarities with those of primates[1]. However, there is one fundamental distinction of the human species, which shall concern us here: man's partial ability of consciously understanding his existence. The ape lives on fruits and animals from the forest but he has no idea of the necessary conditions that produced these provisions.

Man's ability of cognition is related to the ability of formally handling symbols, which are called *words*. *Homo sapiens* is a social and highly communicative species. It is language that enables consciously understanding the world. Apart from the natural languages, mankind has also developed an artificial highly formal language called *mathematics*. The study of mathematics itself may reveal basic conditions of human cognition[2], but, in its pure form, it contributes little to our understanding of the world. This is so because in pure mathematics the formal symbols are not associated with any real objects. A language becomes a powerful tool of cognition only when the words are related to real objects. Also mathematics becomes a very powerful tool of understanding the world once we associate the mathematical symbols with real objects.

When we are concerned with the meaning of words we have to recognize first of all that several different words are often assumed to be equivalent. These equivalent words correspond to a *notion*.

On a basic level the association of words or notions with objects is achieved with examples. Usually it all begins by associating the sucking of milk from mother's breast with the sounds "mom" or "mama". On the very highest levels of cognition, which is in the fields of Sciences, one prefers to associate a notion with concrete objects without the use of examples. One explains a notion using example-based primary notions and previously explained notions in a general form. This kind of explanation of a notion is called a *definition.* Later we shall see why one avoids the use of examples, though examples may be useful tools for teaching.

Exercise: Define the following notions: table, chair, vertical, horizontal, perpendicular.

The famous "*Cogito ergo sum*" (*I think, therefore I am*) of René Descartes[3] has been criticized by Martin Heidegger[4] in his main work "Sein und Zeit": Descartes' statement is somewhat empty as long as one does not specifies the "sum" (*I am*). The *being* has to

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[1] Desmond Morris *TheNaked Ape* (Jonathan Cape Ltd, 1967); Frans de Waal *Our Inner Ape*. New York: Riverhead Books, 2005. ISBN 1-57322-312-3.
[2] For instance one may recognize the difference of truth and demonstrability.
[3] (*31 March 1596 , †11 February 1650)
[4] (*September 26, 1889, † May 26, 1976)

be understood in terms of relations as a *temporal being*. We are immersed in time. Any human present contains a past constructed consistently from memories and documents and it contains a constructed future of plans, expectations, hopes and fears. Scientific understanding of the world essentially concerns this temporal immersion of existence.

Scientific observations detect regularities and extrapolations of these regularities are used to predict the future. In very special circumstances a perfect prediction is possible. This is the case when one deals with simple and well separated parts of our environment. We shall call these parts of the environment *systems*. In other cases the future may not be predictable. This happens especially with systems not well separated from the rest of the world. Especially systems that interact with us in general show a future behavior that depends on our actions. This opens the possibility of influencing the future according to our will so as to pursue a purpose. In this case human cognition may help to achieve the goals more efficiently.

The goals or purposes may be related to moral standards. It is often stated that science cannot say anything about the goals and moral standards. This statement may not be true. Goals and moral standards are created by human individuals and human societies. Human individuals and human societies are objects of biological investigation and also of mathematical description, through game theory. It may be that the coming into being of a moral standard can be understood the same way as we understand why certain multi-cellular aerobic animals that live in oxygen containing gas atmosphere have a nose. Desmond Morris in "*The Naked Ape*" gives examples of such explications.

Prediction of future and optimization of the achievements of goals is by no means restricted to the human conscious intelligence. For instance a ball player predicts the successive positions of a flying ball in a fraction of a second and catches the ball without the help of conscious reasoning and without solving any mathematical equations. Perhaps the conscious thought "There comes the ball!" appeared in his mind, but that was not enough to catch the ball. Animals are also capable of using that sort of intelligence. How the unconscious neuron-based intelligence works and how it interacts with the conscious one is still badly known. Further, there exists even a sort of intelligence in the living world on the cell level. Cells react on external conditions in an intelligent way[5]. This is not so much surprising. Later we shall briefly discuss the biological cell and we shall see that it functions very much like a computer.

The unconscious neuron-based intelligence is also involved in the example-based association of notions and objects. If you ask a 12-year-old boy, who has not been exposed to much formal education, what a circle is, most likely he will answer: "A circle is a round drawing". If you then demure to this definition and argue that the drawing of an egg is also round, he will answer: "well I know what a circle is, but I can't tell it". It would be unjust to say that he does not know what a circle is. If you show him a large number of different drawings, some containing circles, he will correctly pick out the circles. Here unconscious neuron based intelligence works to form a notion. A definition is the attempt to elevate a notion to the conscious level. Therefore the use of examples is banned in definitions, because the examples would detain the notion in the realm of intuition. Once a notion passed into the realm of consciousness it can be treated formally and one may draw conclusions from its defining properties.

[5] For instance, certain bacteria are able to switch between different metabolic pathways depending on external conditions.

Here we shall be interested in the conscious intelligence. Sciences have given a tremendous contribution to our conscious understanding of the world. Especially the sciences that deal predominantly with *values of quantities* have improved our understanding. We shall call these sciences *quantitative sciences.* They constitute the basis of all engineering and they have modified human lives considerably during the last tree hundred years. The tremendous success of engineering is based on the ability of predicting values of quantities and of using these predictions for *quantitative planning*. We shall dedicate a whole section to explain what a quantity is, but before doing so, let us see a simple example to illustrate the power of quantitative planning.

Imagine a gifted boy wants to construct an incubator to hatch out bird eggs. He knows that the incubator needs a heating element in order to maintain an appropriate temperature. After a week of intense work he recognizes that the heating element is only able to elevate the temperature from 20^{o}C to 22^{o}C. Instead of indiscriminately constructing dozens of alternative heating elements he now uses quantitative planning. He measures the heating power and estimates the required power value with the help of a simple rule of three. If the power P_0 that he used with his abortive attempt yielded a temperature change of 2 degrees and he wants a change of, say, 20 degrees, he will construct a heating element that is capable of supplying the power $10\,P_0$ and that will result in a functioning incubator right away. For more complicated constructions a simple rule of three may not work. For instance, if one wants to construct an oven to melt glass, the quantitative planning would have to use more complicated mathematical relations. But the basic idea is the same; instead of making innumerous random attempts one heads for a working artifact guided by quantitative predictions. Industry saves money using quantitative planning and complex artifacts such as big airplanes, large buildings, computers etc. would be impossible to construct without quantitative planning. Quantitative planning is also the backbone of administration.

The quantitative predictions involved in quantitative planning refer to *values of physical quantities.* In section 1.6 we shall explain what a quantity and a value of a quantity is. These explanations will make use of mathematical language. Therefore we have to dedicate a few sections to basic mathematics. The discussion of mathematics will also reveal interesting aspects of human cognition.