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Knowledge Structures Promoting Problem Solutions. Possibilities of Graphic Representation of Knowledge in Thesaurus-Like Fashion[1]

Bauer, G.: **Knowledge structures promoting problem solutions. Possibilities of graphic representation of knowledge in thesaurus-like fashion.**
Int.Classif. 16(1989)No.2, p.73-81, 6 refs.

Knowledge to be processed for problem solving purposes can best be adapted to the human brain where it is stored in the form of "concept configurations", by a representation in the manner of a structural diagram. The method discussed here for the graphic representation of knowledge in thesaurus-like fashion (TGW method) promotes the formation of the "internal problem representation" by transforming the textually available knowledge into a structural diagram-like form. In such a structural diagram, the concepts of the statements relevant to the problem are pre-ordered with the aid of "ordering lines" corresponding to the categories (facets) of the knowledge field concerned. In this way an open, discipline-independent orderingsystem for the knowledge available for the solution of the problem is established, into which even knowledge from quite different disciplines can be integrated. A sort of "dialogue" between the graphically represented structural diagram of the knowledge available for problem solution and the knowledge stored in the problem solver's memory leads, as more and more knowledge is acquired, to optimization of the structural diagram and thus also to favorable preconditions for the problem-related activation of knowledge in the problem solver's working memory. These structural diagrams of knowledge can also be used as aids toward more effective interaction between man and computer. A typical multidisciplinary problem is used as an example to illustrate the application possibilities of the TGW method.
Author

1.Introduction

Knowledge[2] is "structured" information, and problem solving is a structured process. If the human brain operates in symbolic images (NEDOBITY) (1), then a structured image form of textually formulated knowledge would have many advantages over other methods, especially over those operating with natural language. As is known, the structural (graphic) formula of a chemical compound may represent a very great deal of knowledge in concise form and, in contrast with the chemical name of the compound concerned, is marked by a high degree of condensed information and transparency. Of course, the presentation in structural form of any given store of knowledge presupposes a certain formalization of the existing knowledge in the natural language, a formalization analogous to the structural formulas in chemistry and carried to a degree adapted to the given application purpose, such as has been done, for example, in thesauri of information retrieval systems. From these points of view, knowledge presentation would then mean a thesaurus-like presentation of knowledge structures, and the processing of knowledge the reshaping of such knowledge structures.

In earlier publications (see 3-6) the author has proposed a graphic method to represent knowledge in a structural diagram form applying the thesaurus-principle. With the help of the TGW-method[3] exemplified here, the formation of the "internal" presentation of problem knowledge is promoted by transforming the "external", textually formulated knowledge into a structural diagram-like form. In such a structural diagram the concepts (as units of knowledge) of the statements relevant to the problem are ordered by means of "ordering lines" (Ordnungslinien) (see Fig.2b), which represent categories or facets of the knowledge field concerned. In this way concepts from very heterogeneous branches of science or fields of knowledge can be orderd with the help of a special ordering system based on the category principle. Free combination of the categories (facets) represented as "ordering lines" is possible. In this way aspects, or the changes of them as more knowledge is acquired, can be made better perceptible or visible. In the course of such acquisition of more knowledge, the store of knowledge presented in a structural diagram form (according to the TGW method) is brought into line step by step with the specific situation of the problem-solving process. It is especially the formulation of questions and working hypotheses during problem solving which is facilitated by this method (see Figs.4a, 4b, and 5).

These "structures of knowledge" can also be useful as vehicles for more effective interaction between man and computer.

2. Application possibilities of the TGW method. Some examples and illustrations

"Condensation" of textually formulated knowledge

When starting on the solution of a problem, the available store of knowledge is usually incomplete or even contradictory. Therefore the suitable representation of the knowledge selected for problem-solving purposes is of decisive importance for efficient and intelligent action. It is clear that a structural diagram-like representation is especially suited to this end. Fig.1 and Fig.2a show how different textual formulations of the same statement can be "condensed" into a very simple diagram-like representation without loss of information. Single and complex statements can be represented in directly readable form (e.g. statement 6, or in more abstract form, e.g. statements 1-5, Fig.2b).

If the structurally presented store of knowledge becomes too large or is badly arranged it is advisable to sepa-

rate the "active" part of the knowledge from the "passive" one (see Fig.3). The "active" part is that selection from the information which is the essential knowledge for rational problem solving. The "passive" part, far from falling into oblivion, is associatively connected with the "active" one by "recollection bridges" (see Fig.3). The "active" part of knowledge is then used as starting point to formulate the first working hypothesis (see Fig.4a).

Textual form of hypothesis 1: *"It is not changes of the cholesterol speculum that form the decisive aspect, but rather the conversions of cholesterol in the course of metabolism as probably influenced by genetic factors."*

The "structure" of hypothesis 1 now supplies the pattern for the question to ask (question 1, Fig.4a). Question 1 is formulated in a structural form analogous to that of hypothesis 1. Question 1 is read in the following textual form:
"Do you know of any substance that is converted in the course of metabolism, is influenced by genetic factors and can cause any disease?" Answer 1 is the result of information retrieval. In Fig.4a we see an analogous structure to that of question 1. Answer 1 is read in the following textual form: *"The conversion of aromatic hydrocarbons in the course of metabolism is controlled by an enzyme which may or may not be present due to genetic factors. Only if this enzyme is present will a cancer-producing action form causing pulmonary cancer, be synthesized"*. Hypothesis 2 is constructed analogously to the structure of answer 1 (see Fig.4a) and is read in the following text form:
"The conversion of LDL bound to cholesterol in the course of metabolism is controlled by an unknown substance x, which may or may not be present due to genetic factors. Only if this substance x is present will an unknown substance y causing cardiac infarction be synthesized". A schematic representation of changes of structures and concepts during the described phase of the problem solving process is shown in Fig.4b. Hypothesis 2 is based on a selection of only 10 informative statements from the literature until 1977 (see 4). If we compare the structure of hypothesis 2 with that of the essential results of BROWN and GOLDSTEIN (Nobel prize winners in physiology or medicine 1985) we can draw the conclusion that the TGW method also promotes among other things, the recognition of analogies and is a rational aid toward recognizing relevant parts of a problem with a relatively small store of knowledge. With the help of the TGW method it is furthermore possible to represent in a structural diagram form the historical course of changing aspects during the construction of a store of knowledge. As the structure of knowledge is progressively built up, new aspects can be made "visible" (new ordering lines appear, see Fig.6). These changes constitute important (meta)information which is helpful for the problem-solving strategy. The changed aspects can be expressed by a notation (see Fig.6). The aspect notation is only defined by the concepts, which are situated on the ordering lines. A formulation in text form is not necessary.

3. Concluding remarks

Systems based on knowledge processing (expert systems) are to carry out "intelligent" functions. But for this to be possible several conditions and requirements in the fields of human knowledge processing and suitable conceptordering must be met. The graphic method briefly described here can be an aid in the field before starting to apply a computer for knowledge processing. If problem solving is first of all a processing of "concepts" rather than of words or terms), then a thesaurus-like representation in diagram form seems to be a useful variant in comparison with natural language processing. Here it is not possible to describe the TGW method in detail or to discuss its theoretical and psychological aspects. Further information and special literature can be supplied by the author upon request.

Notes

1 Paper presented at the 13th Annual Conference of the German Society for Classification, Augsburg, April 10-12, 1989.
2 'Knowledge' is defined here as 'potential information'. For the semiotic relations between 'data', 'knowledge' and 'information', see KUHLEN (2).
3 TGW = Thesaurusartige Grafische Wissensdarstellung (thesaurus-like graphic representation of knowledge).

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Fig. 1: "Condensation" of textually formulated knowledge by a "structure-like" representation (Application of the TGW method)

Formalization of Paraphrases. Paraphrases of the sentence:

"Helium is used as a cooling agent in "nuclear reactors".

"He is used for cooling in nuclear reactors"
"He finds application as coolant in nuclear reactors"
"He is used as a coolant in nuclear reactors"
"He is applied as a coolant in nuclear reactors"
"He is utilized as a coolant in nuclear reactors"
"He plays a part as a coolant in nuclear reactors"

"Structural diagram-like" representation according to the TGW method

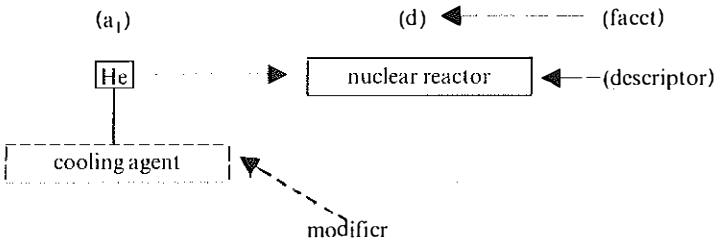
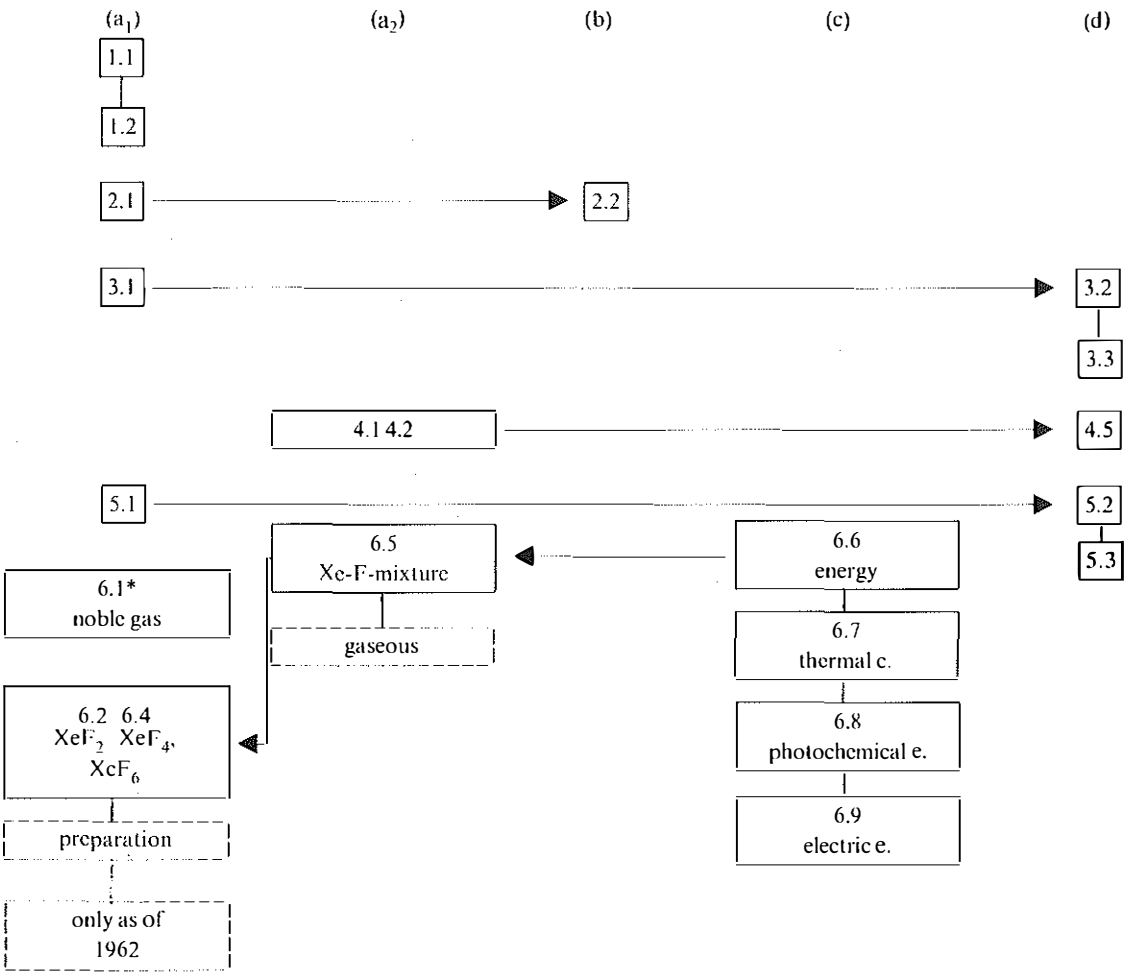


Fig. 2a: Construction by stages of the knowledge base "Helium" in thesaurus-like structured form

Parts of knowledge in textform (1-5 = number of statements)	Structure-like representation according to the TGW method
1 Helium is a noble gas	(a1) noble gas — He
2 Helium was discovered in 1894 by Ramsay	He → Ramsay; discovered; 1894
3 Helium is a cooling agent in nuclear reactors, used especially in high-temperature reactors	He → nuclear reactor; cooling agent; high-temperature reactor
4 Further cooling agents besides helium: H_2●, D_2●, C●$_2$, liquid Na	H_2●, D_2●, C●$_2$ liquid Na → nuclear reactor; cooling agent
5 Helium is used as filling gas in dirigibles and balloons	He → airships; filling gas; balloons

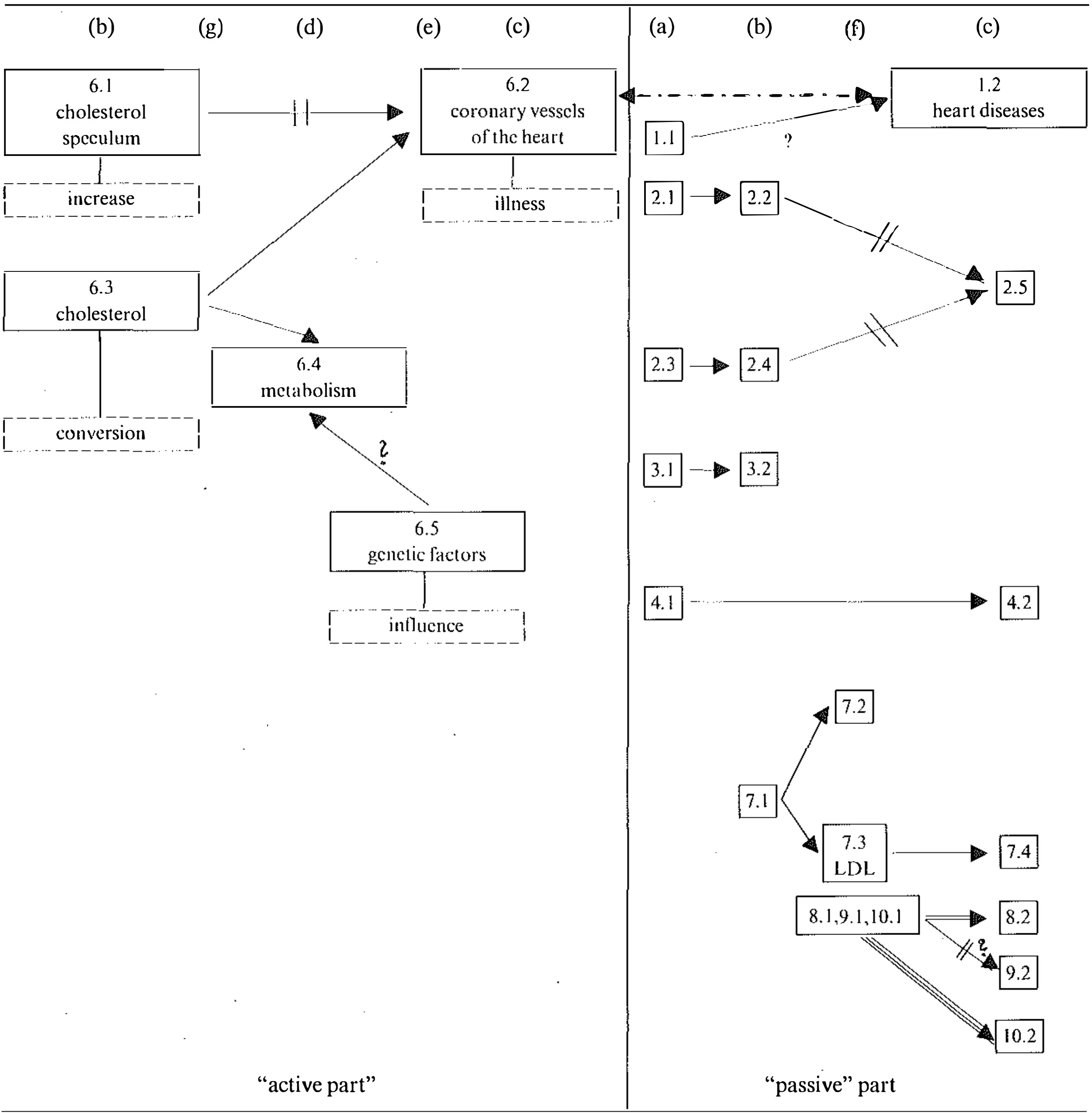
Fig.2b: Further complementing the structure-like representation by the following text:
"Only in 1962 did it become possible to prepare compounds of noble gases, e.G. XeF_2, XeF_4, XeF_6, from XeF-mixtures under the influence of thermal, photochemical or electric energy".



Facets: a_1 = noble gases and their compounds
a_2 = substances associated with the concept "noble gases"
b = names of persons
c = kinds of energy influencing chemical reactions
d = objects in which noble gases are used, etc.

*6. 1 ← number of descriptors within statement 6
↑
└ number of statement 6

Fig.3: "Active" and "passive" parts of knowledge
Field of knowledge: *"Influence of nutrition on heart diseases"*.



*LDL = Low Density Lipoproteins
"Recollection bridge"

Fig.4a: Formulation of questions and working hypotheses during problem solving

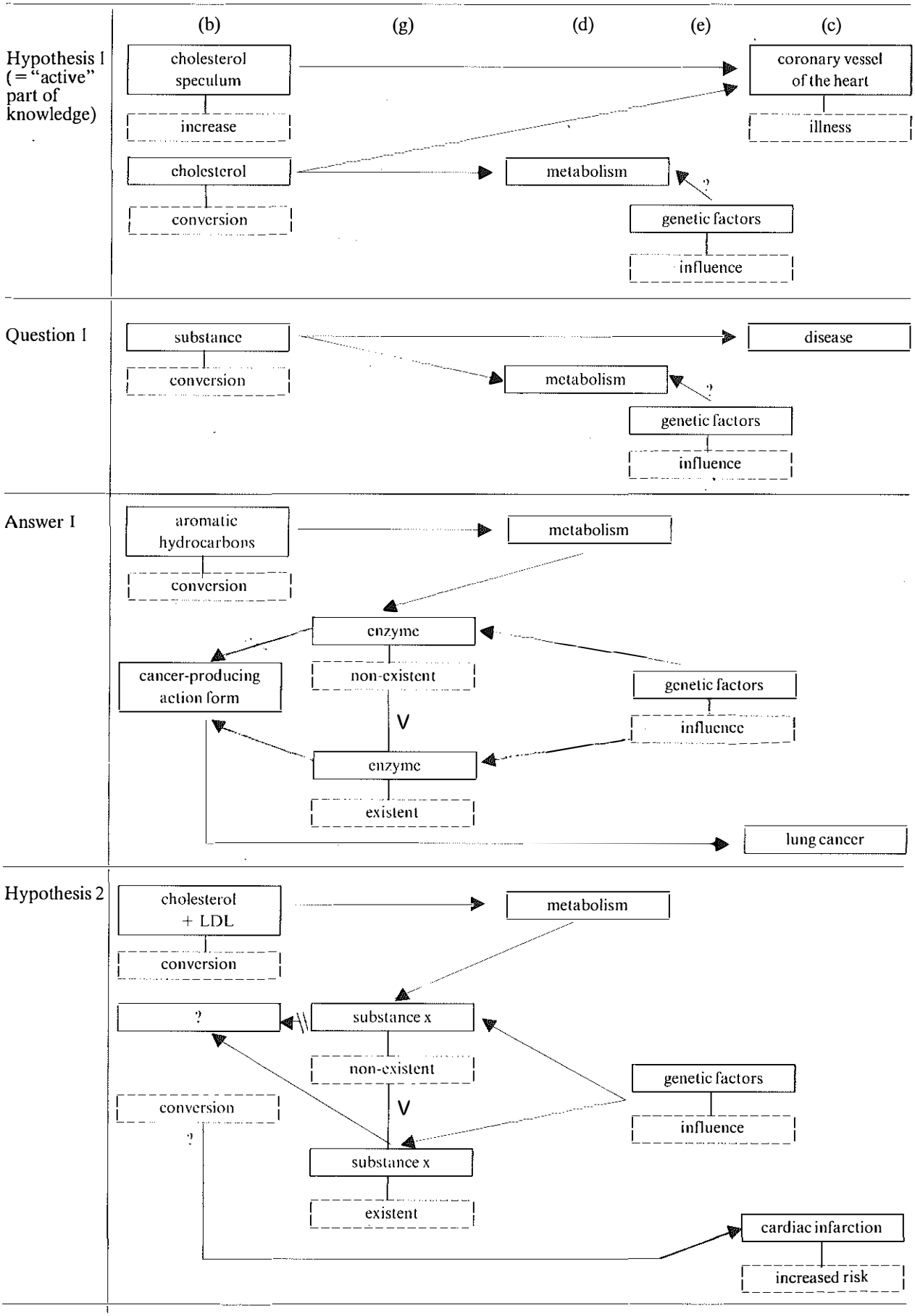


Fig.4b: Changes of structure and concepts during the process of formulating working hypotheses 1 and 2 (schematic representation of Fig.4a)

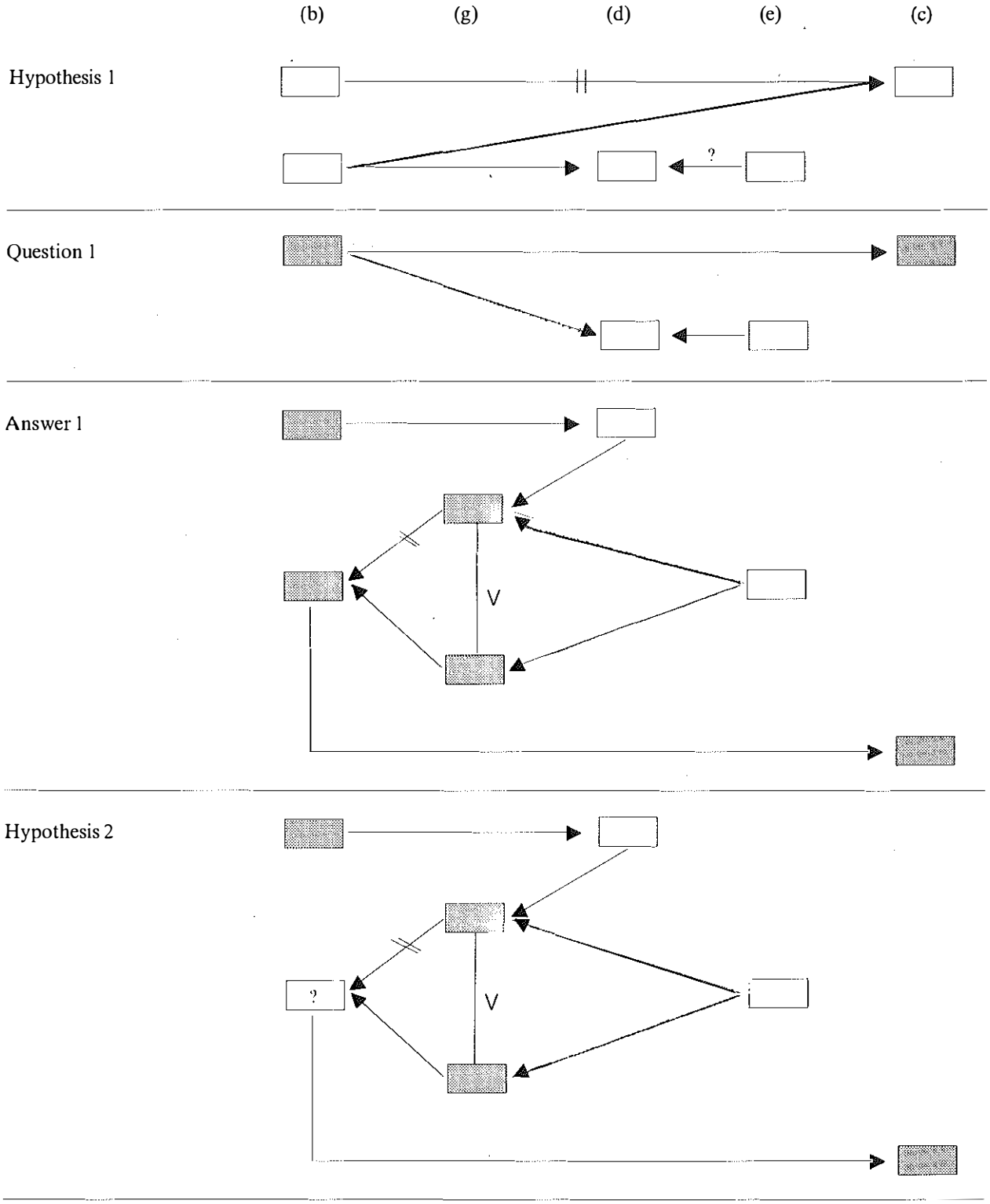


Fig.5: Structure of hypothesis2 compared with the structure of the essential results of Brown and Goldstein (Nobel-prize winners in physiology or medicine 1985)

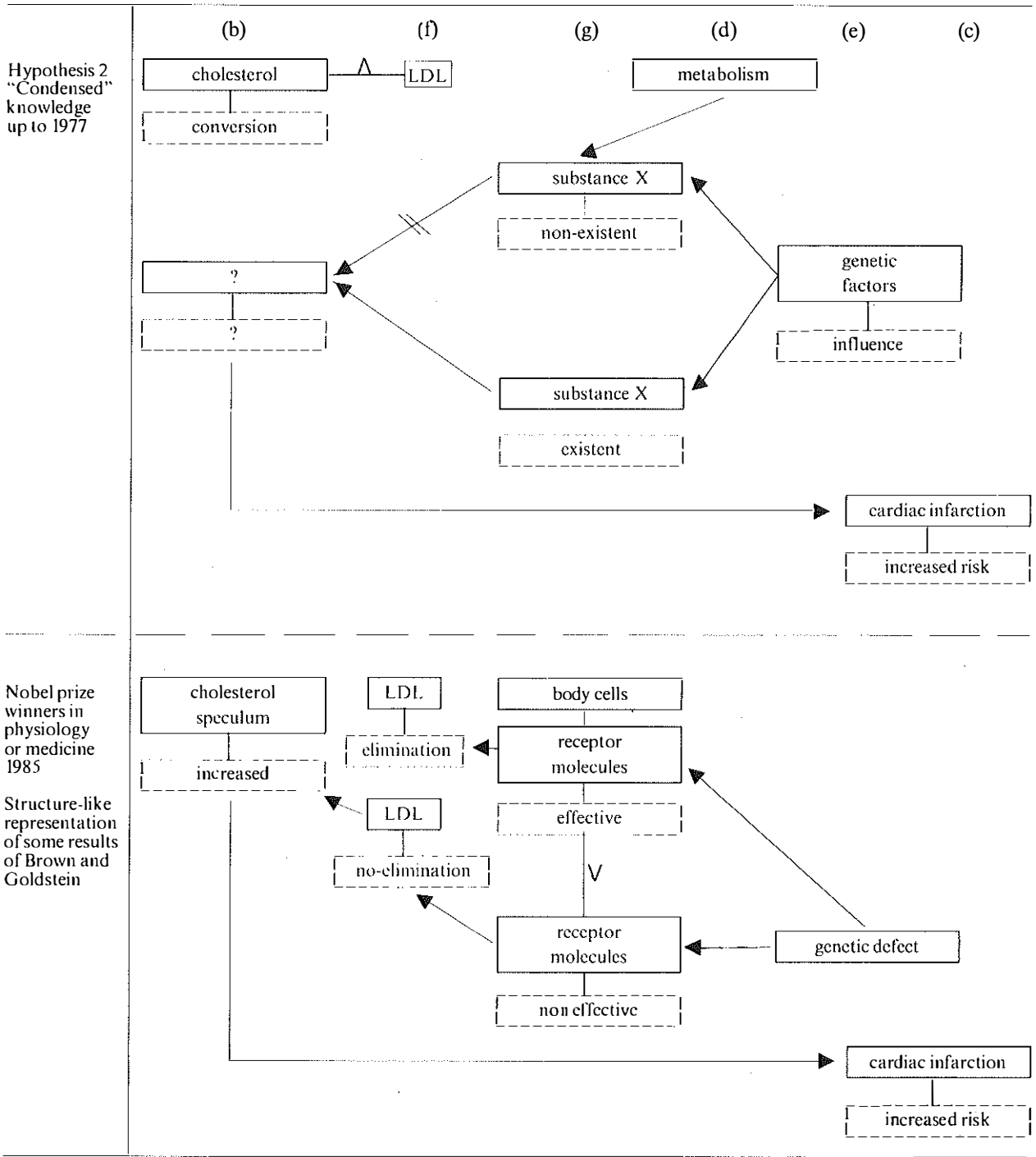


Fig.6: Historical course of changing aspects from 1972-1986
Field of knowledge: "Influence of diet on diseases of the heart"