Teaching medicine upside down

Some educational implications of the theory of cognitive structures

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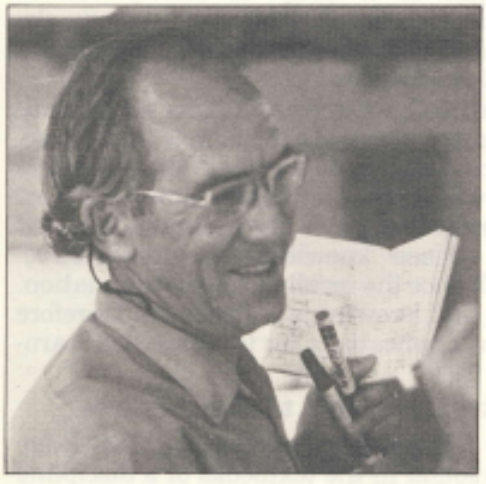

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Curriculum vitae

Jacques Kriel started his studies at the University of Stellenbosch where he obtained a BA Hons (Philosophy) in 1961. He then studied medicine at Wits and received the MBChB in 1968. He worked as a Registrar in the Dept of Internal Medicine, UOVS from 1971–1974, received the MMed (Intern) in 1974 and FCP (SA) in 1973 and became Senior Specialist in this Dept in 1975. He then moved to Bophuthatswana where he worked from 1976–1982: first as Director of Health Services (1978–1979) and then as Rector of the University of Bophuthatswana (1979–1982). Since 1982 Professor Kriel has occupied the Claude Harris Leon Chair of Medical Education and is Director of the Centre for the Study of Medical Education.

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"If they think that way, why don't they teach that way?" Final Year Medical Student 1985

Summary

This article explores the implications of the theory of cognitive structuring of information for medical education. It postulates a difference between the classical structuring of knowledge in clinical textbooks and the way that same information is structured in the memories of practising clinicians, the one being the reciprocal of the other. The relation of this postulate to the contextual learning model proposed by Coles as an alternative to the present 'theory first' model of medical education is discussed and it is postulated that if the process of restructuring is taught to medical students, it will improve learning.

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Why do medical students in their clinical years find it difficult to recall and apply at the bedside knowledge from the pre-clinical years and information learnt from medical text books and clinical lectures? Why do recently qualified doctors find it difficult to recall and apply information mastered previously for their final examinations? Why do General Practitioners find it difficult to see the relevance and application in their situation of the information presented to them by medical specialists in Continuing Medical Education courses?

The answer to these questions is complex but research into learning has suggested at least some possible answers. Some researchers have for example found that recall and application is facilitated if aspects of the recall situation is encoded in memory when that information is being learnt. Other

research has suggested that knowledge does not have a single structure, but that the same information base may be structured differently depending on the use to which that knowledge is to be put. The manner in which information is structured during learning may therefore also affect recall and application of knowledge.

This article attempts to explore the possible role of these two aspects of research into learning, focusing mainly on the role of knowledge structure.

The structuring of subject matter plays a central role in instructional design

The structure of knowledge

The view that *knowledge is structured,* that is, that the elements of information are inter-related in an ordered manner, is now well established[1]. An idea can be obtained of what is meant by the structure of knowledge by looking at the textbooks of a specific discipline. Although various textbooks may differ in detail, they usually show a broadly similar pattern or framework in which the information is arranged[2].

However, it is now postulated that the information *in memory* is also stored in a structured manner[3]. The term *cognitive structure* has, amongst others, been developed as a hypothetical construct which psychologists use to account for the way in which information seems to be stored in memory. A cognitive structure is a body of closely related information in memory in which the various elements are linked to one another to form a structure or framework or scheme[4].

Numerous studies have shown that the structuring of subject matter plays a central role in instructional design. This is so because the cognitive structures in which the information already present in memory are stored, guide the interpretation and assimilation of new knowledge. Cognitive structures also influence the recall of stored information. the postulate that knowledge is structured therefore has important implications for teaching and learning[5,6,7].

Classical structures and task structures

What is the relationship between the knowledge structures as found in the textbooks of a discipline and those in the memory of the practitioners of that discipline?

Teachers and practitioners of scientific disciplines often assume that these structures are identical. Based on this assumption, the task of the teacher is seen to be to teach the textbook structure, while the task of the learner is seen to be to memorise that structure because it is assumed to be the prerequisite for efficient practice. The expert in a field is thought simply to know more of the textbook structure than the novice.

Evidence is however now accumulating from various disciplines that the cognitive structures used by practitioners in the practice of their discipline, may differ significantly from the classical organisation of knowledge found in the textbooks of that same discipline. Experts in a field do not necessarily have better memories or know more than the novices in that field; they know *differently*, ie there is a qualitative difference between their cognitive structures and those of novices in the field[4].

In the field of Medicine, it was Taylor[8], who in 1976 distinguished between what he called a "knowledge structure" (the knowledge structure as found in textbooks) and "task structure" which refers to the manner in which that same body of information is organised in the memory of the practising clinician. According to Taylor, this reorganisation of information from a knowledge to a task structure, is necessary in order to get the information into "a framework suitable for decision-making" in the clinical situation. Taylor then suggests that this transformation takes place in the process of actually *managing clinical problems*, and considers it to be fundamental to the whole process of medical education.

The structures used by practitioners in practice may differ significantly from the knowledge found in the textbooks

The term *knowledge structure* as proposed by Taylor could be confusing when used specifically to indicate the knowledge structure as found in textbooks. We suggest that the structure as found in textbooks be referred to as the *"textbook structure"* or the *"classical structure"* (because it represents the paradigmatic or classical organisation as accepted by all the practitioners of that discipline). Although information as organised or structured in

memory is referred to as a schema or a cognitive structure, we suggest that the term *task structure* or *decision structure* be used when it is intended to indicate a specific organisation of information in memory which is required for more efficient clinical application, and which differs from the classical textbook structure.

The difference between textbook and task structures

So what is the difference between the structure of information in the textbook and that in the memory of the clinician?

Taylor[8] suggests that the knowledge required for clinical practice is structured in a form which is the *reciprocal* of the form that is found in clinical textbooks. The textbook organisation is based on bodily systems, disease processes or pathological concepts, while the physician's point of departure is an aspect of the clinical presentation. The information in the textbooks takes the form of "disease A is characterised by pathological features P, Q and R, and can present clinically with signs X, Y and Z". The clinician's point of departure, however, is an aspect of the clinical presentation and takes the form of "a clinical picture characterised by X, Y and Z can be 'caused' by diseases A or B or C, which each have certain distinctive pathological features and aetiologies".

*Experts need not know **more** than the novices, they know **differently***

What is this aspect of the clinical setting which acts as the point of departure for the clinician's thought processes? Black[9] suggested that in renal disease "the first step in the diagnostic process is the allocation of the patient (or strictly speaking, his illness) to a syndrome. Even when we think that we recognise a specific disease such as "acute nephritis", we are really recognising a syndrome, and brief reflection reminds us of other disorders which can duplicate the clinical picture". According to this view therefore the diagnostic process starts with what could be called *syndrome recognition*. Black then delineates eight syndromes which point directly to renal disease (such as acute renal failure, chronic renal failure, acute nephritic syndrome, nephrotic syndrome, urinary infection, etc) and eight syndromes of which renal disease is not the only cause (such as hypertension, sodium depletion, polyuria etc).

To say that clinical diagnosis is a process of syndrome recognition may be confusing, because it is using the term syndrome in a wider context than that in which it is usually understood. But what Black is saying, is that clinical thinking starts with the recognition of a clinical pattern of some sort or another. The diagnostic process could therefore possibly be characterised as *pattern recognition*[10], rather than as a process of problem solving (although problem solving obviously comes into it). Bordage and Sacks[11] prefer the term "prototype matching" while Gale-Grant and Marsden[12] emphasise the importance of what they call "forceful features" in the retrieval setting which triggers off the necessary recall of information.

... get the information into a framework suitable for decision-making in a clinical situation

They all, therefore, emphasise that the diagnostic process starts with the recognition of some feature of the clinical setting and not with the recognition of "a disease". Since most textbooks use diseases as their major organising principle, this would reconfirm the postulate that *the task structure of the clinician could be characterised as the reciprocal of the textbook structure* in that it is organised around clinical information in one form or another.

The contextual learning model

Research findings within the general field of information processing thus indicate that diagnosis does not consist of the application of a previously learnt body of textbook knowledge, nor does it consist of the cognitive process of problem solving. In their daily tasks, doctors do not solve problems, they recognise patterns or prototypes or forceful clinical features through which the relevant clinical information in memory is accessed.

These processes require a very specific type of knowledge base which has been described as deep and rich[11] and elaborated[16]. By an elaborated knowledge base is meant that information is stored in memory structures in a highly interconnected

The physician's point of departure is an aspect of clinical presentation

manner which facilitates recall. On the basis of research findings at Southampton Medical School where elaborated learning appears within the context of a specific curricular arrangement Coles[17] has proposed a generalisable educational model which he calls the contextual learning model.

Coles proposes that elaborated learning will occur

Table 1: *The Contextual Learning Model. (From: Coles C R. A Study of the Relationships between* **1:** *curriculum and learning in undergraduate medical education.)*

Phase	Event	Type of experience	Time scale
One	Establishment of an appropriate assimilative context	General, inclusive, personal, vivid and concrete	Prior to phases two and three
Two	Presentation of specific information related to the assimilative context	Any form of presentation determined by the constraints of time and resource	Closely following phase one
Three	Oscillation between specific information and its general context	Students relate infomation and experience, Teachers act as facilitators/mediators	During, or immediately following phase two

if the theoretical information to be learnt is presented in relation to a concrete, inclusive example of the theoretical information. This example must link up with the existing knowledge of the student and also encode meaningful aspects of the future situation in which the information is to be applied.

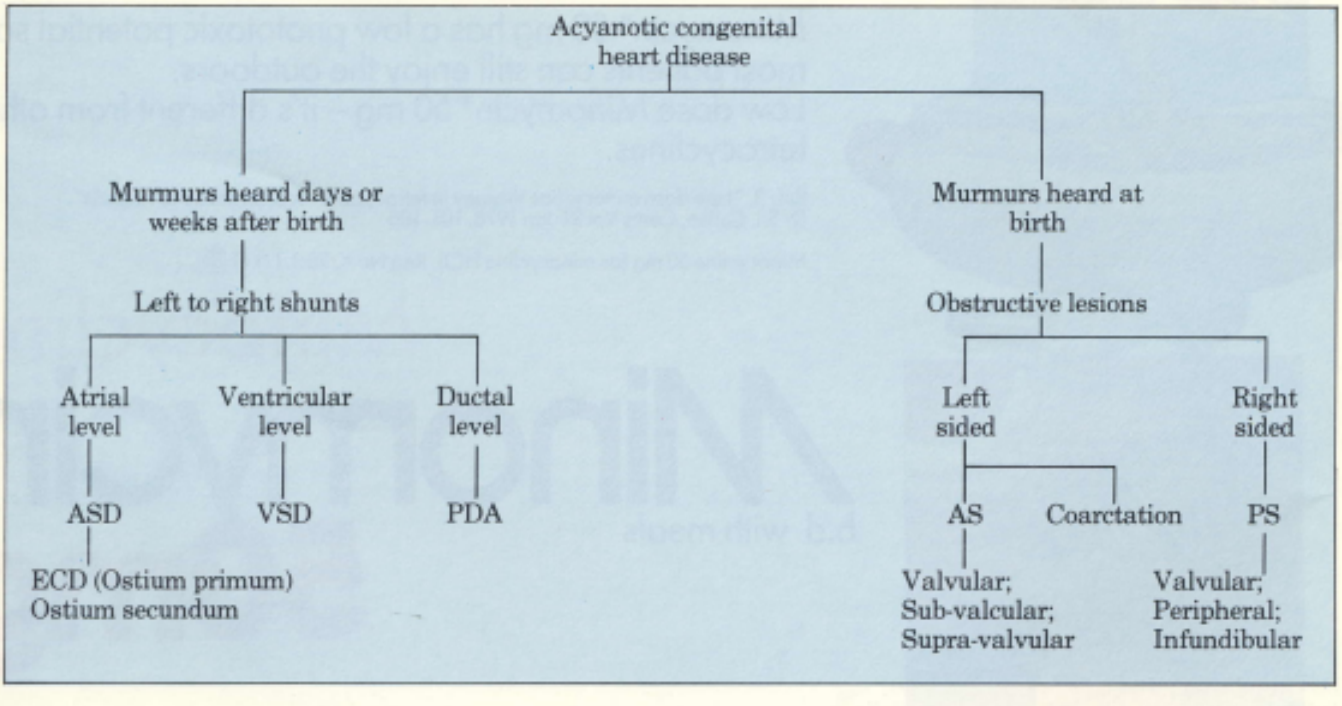
The model has three phases (see table 1). The exemplar establishes the learning context (phase 1) in relation to which information can be presented or sought (phase 2) after which the learner needs actively to relate the abstract information to the example or context (phase 3). This model has implications for curriculum and course design as well as for textbook writing.

There is a clear correspondence between Coles' general educational model and the suggestion that the clinician's knowledge organisation (task structure) is the reciprocal of the textbook structure. On the one hand this is additional support for Coles' general model. On the other it has a direct bearing on phase 2 of the model as it suggests that the information presented or sought in this phase needs to be appropriately structured. For this purpose the usual classical textbook structure may be inappropriate and an organisation based on forceful or prototypical clinical features may be more appropriate.[2]

Textbook and task structures in paediatric cardiology

The textbook by Burton W, Fink[13] called *Congenital Heart Disease - a Deductive Approach to its Diagnosis,* is written *as a practical guide* for

Figure 1: *Schematic representation of organising concepts (task structure) used by a Paediatric Cardiologist for Acyanotic Congenital Heart Disease.*



students and house officers. It is divided into 16 chapters, each chapter dealing with a separate "disease", eg Atrial Septal Defect, Ventricular Septal Defect, etc. Each chapter has basically the same sub-structure, viz embryology, anatomy, haemodynamics, clinical application, differential diagnosis.

The clinical features are therefore subsumed under broader pathological concepts. The common clinical features around which the clinician organises his thinking, are embedded in the detail within each chapter. The common clinical grouping into acyanotic and cyanotic congenital heart disease *is not evident in the chapter headings.*

Textbooks intended to facilitate clinical learning, need to demonstrate a clinically orientated structure

In Figure 1 we have tried to show in diagrammatic form the major organising concepts which were derived from a practising paediatric cardiologist in his daily work, focusing only on acyanotic congenital heart disease. It could be termed a hierarchical concept map, and was drawn up by listening while he was discussing actual cases with undergraduate and postgraduate students. This is obviously a highly abstract representation, which does not attempt to represent the dynamics or the richness of interconnections of such a schema. Connected to each organising concept is a host of clinical, anatomical or pathological information.

It is again clear from this diagram that *the task structure is the reciprocal of the classical textbook structure.* Where the classical structure starts with diseases, (ie the diagnosis) the task structure ends with them. This seems self-evident, as the whole diagnostic process moves from the known (the clinical information) to the unknown (the diagnosis). This process is, however, not represented in medical education, where it is assumed that knowing the classical textbook structure is a sufficient prerequisite for practice.

Textbook and task structures in nephrology

The WHO Committee on Renal Disease has proposed a detailed classification of renal disease based primarily *on histological findings.* Walker and Solez[14] consider this organisation to be "... of limited value to the clinician who is presented initially with an undiagnosed type of renal disease with no histological information for guidance to the correct diagnosis". In order to develop a diagnostic approach they consider it to be more helpful to take the major *modes of presentation of renal disease* and to develop a systematic approach to these findings. The modes of presentation which they outline in their chapter can be categorised as:

- The Proteinurias
- The Haematurias
- Oliguria and Acute Renal Failure
- End stage Renal Disease
- Functional disorders of Renal Tubules
- Renal Calculi

If these modes of presentation are compared to those proposed by Black, the similarity is obvious, although Black is more consistently clinical in his choice of terminology. It is therefore clear that nephrologists have defined certain classical patterns of clinical presentation of renal disease and are using these in their textbooks as the basis of the organisation of knowledge. They are therefore attempting to bridge the gap between textbook structures and task structures.

Teaching medicine upside down

If the information in the clinician's memory is structured in an upside down manner vis-a-vis the textbook structure, the following questions now arise:

i) Should students not be taught in the same manner rather than first being taught the classical structure and then having to transform it into a task structure through experience?

ii) Should the instructional design not be based on the same principle? It seems reasonable to postulate that if instruction is designed taking into account this upside down structure, then students will not experience the frequently documented problems at the bedside of recalling textbook information. If this is so, medical education may not only become more effective, but also more pleasant.

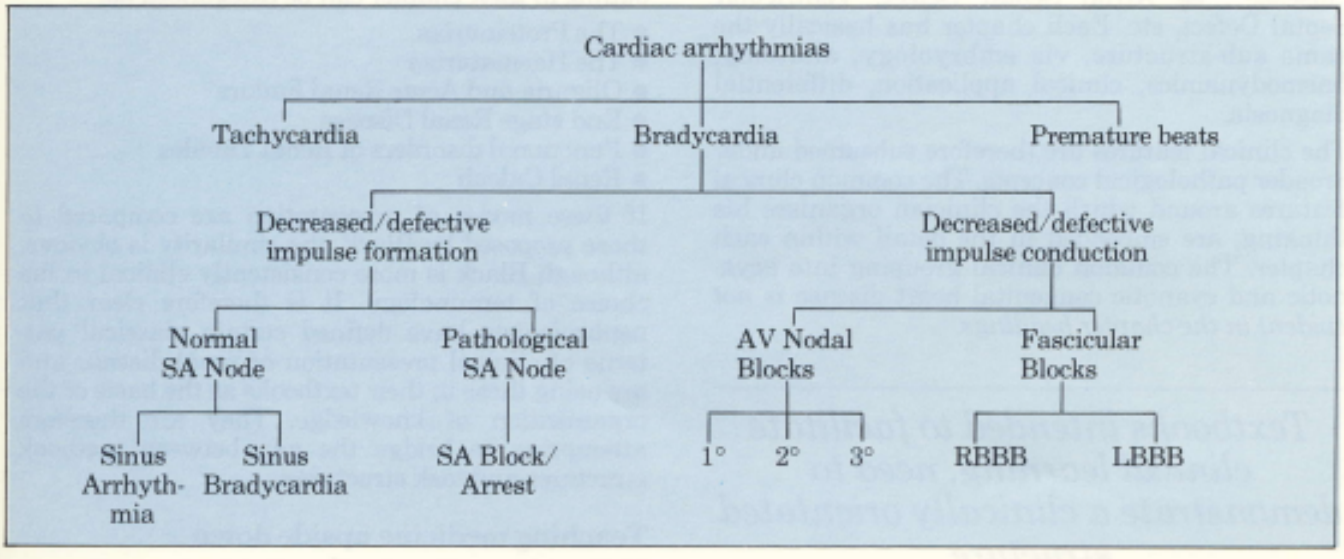
Doctors do not solve problems; they recognise patterns or prototypes of clinical features

To refer again to the concept of Taylor[8]: if a task structure is the reciprocal of the textbook structure, is it not possible *for the reversal to be mediated by the teacher and the learning material* rather than waiting for it to take place through a hit-or miss process of medical experience? The contextual learning model suggests an appropriate course and curricular format, but what about the structuring of information in textbooks and lectures?

Reorganisation of textbook structures

It is interesting to note that Black already mentioned in 1972 that "textbooks of renal disease

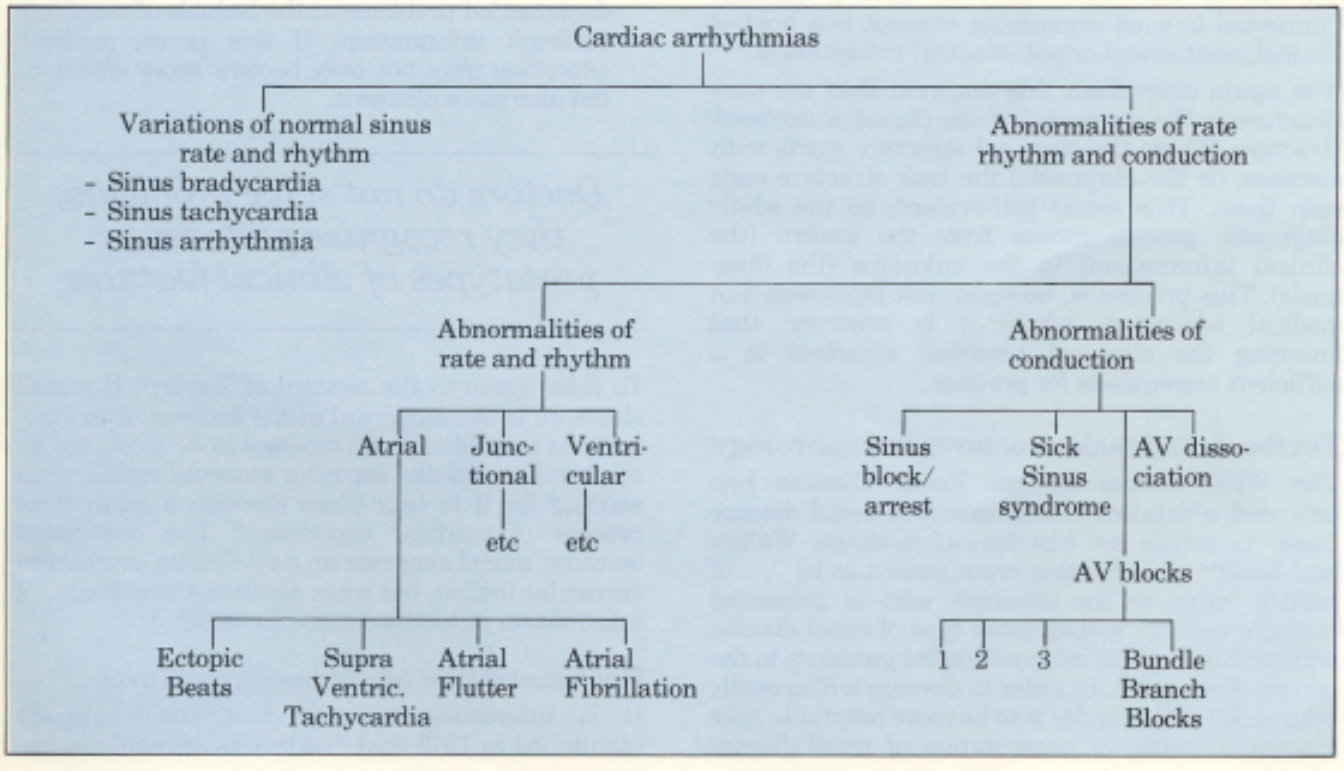
Figure 2: *A possible task structure for the teaching of arrhythmias. (Based on Harvey, Johns et al: The Principles and Practice of Medicine).*



in any language, now lay great emphasis on the syndromes of Renal disease". This emphasis has not however influenced the *formal pattern of teaching* in most medical schools, where the classical textbook structures dictate the pattern of teaching. However, several textbooks have been reorganising the information in a manner suggestive of the pattern we are recommending. Baughman and Guzman[16] discuss cardiac arrhythmias under the three clinical headings of bradycardia, premature beats and tachycardia. In figure 2 we have given a hierarchical concept map of their information regarding bradycardia. Teaching arrhythmias from such a clinical perspective leads to greater understanding by students.

Figure 3 shows the classical textbook arrangement of the same information. Although the arrangement is quite logical, the clinical information is embedded in the most distal part of the map in a jumbled fashion, ie ectopic beats, bradycardia and tachycardia are all found mixed together on the same hierarchical level. Students who have learnt

Figure 3: *A typical textbook structure of the organising concepts of arrhythmias.*



this type of categorisation have great difficulty in retrieving relevant information in the clinical situation.

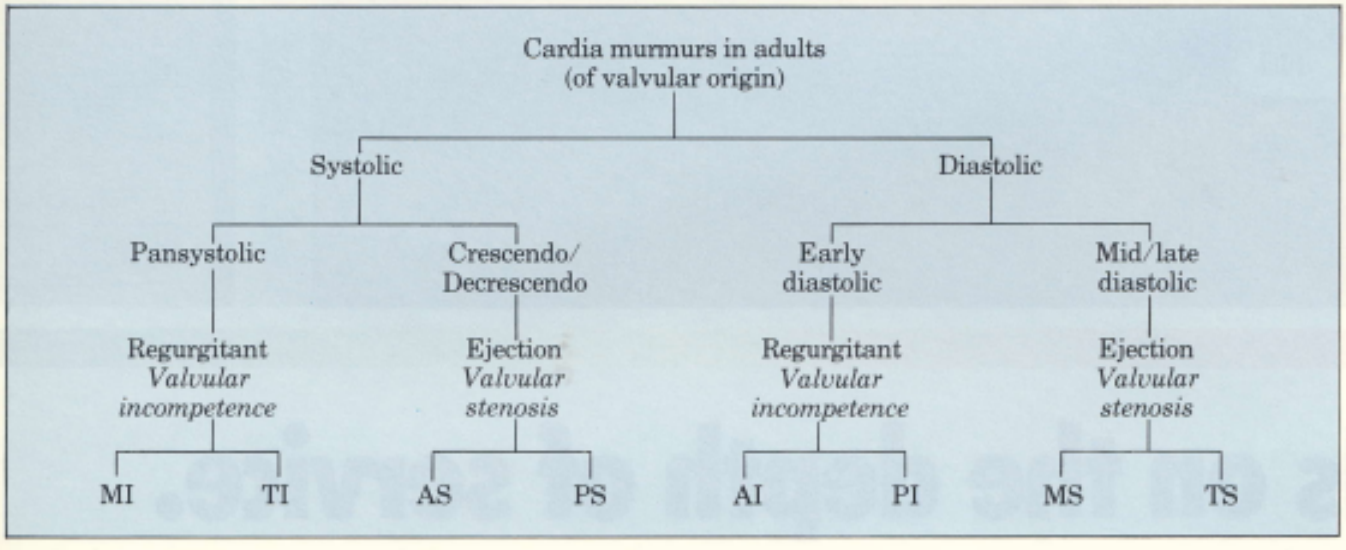
However when Baughman and Guzman[15] discuss the various lesions that can affect the heart valves, they revert to a pathological approach and discuss lesions such as mitral stenosis, aortic regurgitation, *separately from the murmurs* that are the clinical indicators of these lesions. An integrated framework such as suggested in figure 4 leads to a greater understanding by students. The point of this diagram is that the clinical pathological and aetiological information regarding these lesions, should be given in the context of the murmurs. The two clusters of information should not be separated.

assumed to be a copy of reality. The assumption is that such knowledge is quantitative in the sense that the more of it that can be memorised, the more expert the person will become and the better he will be in applying his knowledge.

In contrast to this view, it is contended that knowledge (thus also medical knowledge) is a cognitive construct and that a number of different constructs of the same information are possible depending on the purpose or purposes for which the knowledge is to be used. One such construct is the classical knowledge framework found in clinical textbooks in which information is organised around disease processes.

This same information base is constructed to a

Figure 4: *Organising concepts (task structure) regarding cardiac murmurs in adults.*



Students need guidance in the reorganisation of the knowledge organisation of textbooks. Kriel and Hewson[2] have argued that textbooks intended to facilitate clinical learning need not only be shorter than the textbooks used for scientific communication and information storage purposes within a discipline, but need overtly to demonstrate *a clinically orientated structure* or task structure. In the light of Coles' proposed contextual learning model[18], the possibility should be investigated of developing *textbooks* that overtly demonstrate the features of the contextual learning model, including an upside-down task structure.

Task structure and meta-learning ability

Medical education is presently based on what could be called a behaviouristic set of assumptions[19]. According to this view the learner has to commit to memory a vast amount of abstract information prior to its application at a later date. This objective and external knowledge is considered to be represented in textbooks in what has here been called the classical knowledge structure and is

different task structure in the memories of clinicians for purposes of clinical application and decision-making. Although task structures are idiosyncratic (ie they differ from person to person) they probably always use *clinical concepts* as the organising principles or entry points for their knowledge frameworks.

This constructivist view of knowledge thus implies that knowledge is not pre-packaged, but can be reorganised into various packages depending on the practice to which it is to be related. This constructivist view of knowledge has important implications for learning and teaching.

John Biggs[19] has shown that a crucial factor in effective learning is what he calls the students' *meta-learning ability*. This refers to students' insight into learning processes and the ability to choose those approaches to learning from their range of cognitive options that are most likely to bring about the sort of learning outcome that is desired. Insight into structuring of information for purposes of clinical application could possibly be

seen as a form of meta-learning ability. The same may be true of the ability consciously to relate theoretical material to inclusive but concrete exemplars of that material.

It is therefore reasonable to postulate that if students are assisted to develop the cognitive skills of restructuring information along the lines suggested by the contextual learning model, then recall will be facilitated and clinical practice improved. The challenge before medical education is therefore not only curricular and textbook adaptation in line with modern developments in learning theory, but also the development of the meta-learning ability of medical students and practitioners.

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