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FROM BASIC SCIENCE KNOWLEDGE TO CLINICAL UNDERSTANDING

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ABSTRACT

The aim of the thesis was to expand our understanding of medical students learning of medicine through a longitudinal perspective on the medical curriculum. The development of medical knowledge was illustrated through mapping of two basic science subjects – anatomy and physiology – over the course of the curriculum. Thus, it was analysed in what sense these subject areas function as a knowledge foundation for later clinical studies. Interviews with first and fifth year medical students made up the main source of data used to analyse their experience of learning. A contrasting retention test was also given. The interviews were analysed according to the phenomenographic approach. The first study focused on how medical students learn anatomy. Three categories of description sum up their experience: Learning anatomy as *Memorising*, as *Contextualising* and as *Experiencing*. The second study dealt with anatomy from a clinical perspective. The retrospective view of anatomy yielded four categories: *Contextualising*, *Visualising*, *Selection* and *Anatomical Language*. In revealing the experience of the students, important content characteristics of the discipline were also found. The third study concerned medical physiology in a clinical setting. Medical students were asked to give an account of a scenario involving basic physiology and biochemistry. Three categories were outlined: *A chain of mutually interdependent physiological and biochemical sub-mechanisms*, *Juxtaposed physiological and biochemical mechanisms* and *Fragmented physiological and biochemical mechanisms.* The fourth study consisted of a contrasting analysis between phenomenographic categories and result on a retention test. Central characteristics of anatomy and physiology as well as medical students' approaches to learning were revealed. Concepts like memorising, understanding, causality and context feature as important components of the analytical frame of reference in addition to being enriched and clarified by the findings. The thesis adds to the knowledge about medical students learning through its comprehensive account of learning in anatomy and physiology; it adds methodologically to the research area of medical education through the consequent use of phenomenography; and it adds to the field of research on learning in general through its focus on understanding of complex systems.

LIST OF PUBLICATIONS

I. **Wilhelmsson, N**., Dahlgren, L.O., Hult, H., Scheja, M., Lonka, K., Josephson, A. (2009) The Anatomy of Learning Anatomy, Advances in Health Science Education. Published online 24th of June 2009. DOI 10.1007/s10459-009-9171-5

II. **Wilhelmsson, N**., Dahlgren, L.O., Hult, H., Josephson, A. (2010a) On the Anatomy of Understanding. Manuscript accepted for publication in Studies in Higher Education. In Press March 2011.

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IV. **Wilhelmsson, N**., Bolander Laksov, K., Dahlgren, L.O., Hult, H., Nilsson, G., Ponzer, S., Smedman, L., Josephson, A. (2010c) Retention and long-term understanding of basic science knowledge in medical students – A mixed method approach. Submitted manuscript.

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I. INTRODUCTION

This thesis is about learning medicine. More specifically, it is about learning anatomy and physiology as a foundation for clinical studies in a curriculum consisting of a preclinical and a clinical phase, from the perspective of medical students. It seeks to describe this learning from a longitudinal perspective, since alignment appears crucial in a long academic programme such as the medical one. To consider the effect on medical knowledge, it seems highly worthwhile to investigate the medical programme, for reasons ranging from the fact that students are investing important years of their lives as well as those of society. There will be no claim made to answer whether the time and money invested are worth it for the individual student or the tax-payers; it is more to justify the stance taken in the investigation: the longitudinal development of knowledge over the medical curriculum.

So, why focus on medical students' learning instead of the metabolic and genetic causes of diabetes? Medical education is special in one particular way; it is almost certain that, after such a programme, everyone will become a teacher in some way (Calman, 2007). Furthermore, changes in society towards reaching understanding of human practices and organisation in terms of knowledge management, are also mirrored in rapidly changing conditions for the health care system. These changes naturally have consequences for the practice of teaching and learning in medical school. From a larger perspective of learning, an enterprise like the present one may constitute one small piece of the puzzle and perhaps throw light on aspects of learning in essentially different settings. On a smaller scale, everyday life as a medical student has changed dramatically depending on new ways of functioning at university and in the hospital wards (Calman, 2007). Initially being learned as an apprenticeship, which to some extent it still is, clinical medicine is dependent on the clinical teacher, whose role increasingly has become increasingly more focused on output in terms of patient numbers and publishing instead of tutoring. On the other hand, the basic scientific foundation of medicine – the basic sciences – is taught by faculty primarily engaged in aspects of the life sciences far removed from the bedside (Cooke et al., 2006). No doubt, increased specialisation among faculty and practitioners is a good thing and follows a tendency towards the same in society, but the consequences for learning need to be addressed.

Another obvious reason to focus on learning is the explosion of knowledge within medicine and the other life sciences. As new treatment regimes develop faster, the knowledge handed over in medical school might very well prove out of date when the student leaves campus to adopt it. Modern medical education necessarily has to focus more on the ability to digest new knowledge than covering the whole area of body-functions, dysfunctions and remedies. Furthermore, it is arguable whether we can actually claim to know more about anything if there is no one there to explain it, or understand it. There is a need to emphasise equally both the knowledge about how medical students learn, and also enlarging the body of knowledge they need to master, as the latter will not be very useful if the former fails.

The starting point is the medical student, in more than one way. Primarily, everything that is being said is from their horizon; no attempt to characterise the medical studies from a curriculum or teaching point of view will be made. Secondly, the study also took off during my time in medical school. Thus, in a way, the thesis takes a medical student's perspective on medical students' perspectives on learning medicine. An interest in the pedagogical aspects of the medical programme took hold of me whilst I was in the Medical Students Union at Karolinska Institutet, which later developed into the project about anatomy studies. The experiences from the internship deepened my interest further as it provided a sort of immediate feedback as to learning in medical school. All graduate medical students are embarrassingly aware of the fact that they forget large amounts of important information they learned in medical school. At the same time, they are also aware that they somehow manage to function as a doctor, at times even a good one. When they are asked to describe this apparent contradiction a common answer is: 'I know in which book I need to look!'

What is the meaning of this notion? A kind of familiarisation with the field of medicine and a developing confidentiality regarding usefulness and relevant aspects of knowledge, appear to be the key. My personal experience of medical school and internship – influenced by others' – and my speculations about how medical knowledge develops were thus turned into a research project. The present investigation into longitudinal aspects of learning medicine is an attempt to account for the results.

An additional starting point for the present research project is the widespread concern of clinical teachers (Bolander Laksov et al., 2007) and clinical students (Bergman et al., 2008) that vital knowledge in the basic sciences is lost when the students enter the clinical phase of their education. This fact, also constitutes a reason to apply a longitudinal perspective. This central dividing line between two essentially different knowledge traditions goes back to the incorporation of medicine into the academic life of the university (Flexner, 1910; Cooke et al., 2006; Schaffner, 1986). It would turn out to be impossible to attempt an exploration of medical studies without addressing this issue. Indeed, the most extensive theoretical research endeavours into medical education have explicitly tried to bridge the gap between basic science and clinical medicine.

It would seem that continuity and knowledge transformation are key concepts in medical education and that the representation of basic science in later clinical training would be a fruitful approach in investigating the knowledge development. Hence, two of the most basic subject areas were chosen to exemplify the development: anatomy and physiology. They are both studied early in the curriculum as part of the pre-clinical stage. Traditionally considered as essential components of the medical profession, anatomy occupying the whole first year of old days medical curricula and physiology the second, they are nowadays taught in a more limited version still remaining core areas of the understanding of the healthy human body.

ANATOMY

The learning of the topographical structure of the human organism is a vast enterprise. It is the study of anatomical terms denoting the structures, the study of their complex interrelationship, and of their function (Eizenberg, 1988). The studious mapping of the anatomical inside of the human body for medical purposes can be said to start with Leonardo da Vinci's *A Treatise of Painting* (Keele, 1964). Here, the structures are depicted in a functional manner, as opposed to a strictly descriptive aim. During the centuries, the intimate link between the arts and medicine is especially clearly illustrated in the subject of anatomy. The renaissance anatomists took pride in depicting their discoveries in as detailed a way as possible, setting off in Vesalius' impressive *De Humani Corporis Fabrica* from 1543 (ibid.). This identity of comprehensiveness has become part of the identity of anatomy; every possible little groove, every branch of a vessel and every protuberance of a bone has a name. The medical student attempting to learn anatomy is faced by a flood of information and needs to develop instruments to handle it.

A number of pedagogical challenges are presented in the wake of the complete mapping described above and substantial restructuring of anatomy instruction in medicine has been undertaken to meet them (Leung et al., 2006). The scope has shrunk to about one tenth of the time in most modern medical schools, integration with other subject areas in the curriculum has become common, and new technologies in terms of computer aided learning and simulation are now widely employed. This is largely due to the emergence of new important areas of medicine and the recognition of anatomy as a primarily descriptive discipline. However, the completeness of anatomy makes it tempting to stuff the course with one too many details, resulting in the common problem of curriculum-overload.

PHYSIOLOGY

In the introductory chapter to one of the most read textbooks of medical physiology, the basic principles of the area are laid out: distribution of body fluid volumes in intra-, extracellular and interstitial matrix, osmosis and diffusion, functional morphology of the cell, structure and function of DNA and RNA, transport across cell membranes, the capillary wall, intracellular communication, homeostasis and aging (Ganong, 2001). It might seem a handy number of principles to apply over the processes of blood pressure regulation, digestion, heart function and neuronal activity. However, the principles are deceitfully straightforward. Depending on where to disbud younger fields such as molecular biology and neuroscience, physiology is as comprehensive as anatomy, albeit in a different way. Within physiology every process is connected with others in a complex network of intertwined cause and effect relations, regulated with feed-back and feed-forward mechanisms. It employs mathematical calculations applied to physiologic sub-systems and is essentially integrative (Michael, 2007).

The idea that all physiological processes can be learned and understood by applying a limited set of principles (Modell, 2000b; Michael et al., 2009) gives a hint as to the level of abstraction. The ability to use such a limited number of principles in a large

variety of settings, means transforming knowledge depending on the context and requires a substantial knowledge of detailed chains of events as well (Fyrenius, 2006). Thus, both in anatomy and physiology, careful study of details and general understanding of wholes seems important, despite other major differences. The study into medical students' learning of basic science and its representation in the clinical context should be well illuminated through examining these two disciplines.

OUTLINE OF THE THESIS

Following the introduction, an account of a number of research areas within higher education in general and medical education in specific will be presented. These areas of interest have been chosen as they relate to the description of knowledge transformation from the basic science stage to clinical setting under investigation. Subsequent to the background, the aims of the study will be presented. A more detailed review of the research tradition in which the study is situated, and in particular the methodological approach – phenomenography – will follow. This chapter contains a presentation of some early and contemporary work within the phenomenograpic movement of relevance for the cause. In addition, an account of the methodological characteristics of the present study is included. The thesis comprises four studies. The findings of these are summarised and presented in relation to each other and to the overall aims in a separate chapter. At the end, the studies are attached one by one, and they are referred to by the numbers I, II, III and IV in the findings and discussion chapters. Finally, a discussion of the findings in relation to prior research and the present approach is presented.

II. BACKGROUND

To be able to describe medical students' transformation of medical knowledge, a number of issues need to be addressed. The longitudinal perspective requires that both the knowledge possessed by the fresh medical student as well as by the experienced medical student are considered. Knowledge learnt in the early years needs to be brought up again in the later clinical practice. The issue of memory, or retention of knowledge must be taken into account, as the time gap between pre-clinical study and clinical application can sometimes exceed 5 years. Therefore, retention studies in medical education will be presented first in this chapter. Furthermore, the relation between the nature of the knowledge arrived at and that which was learnt is of interest; the sense in which we can make statements about the latter in terms of the former deserves clarification, as this is a central aspect of the investigation. Hence, a general outline of transfer of knowledge is given. Problem-Based Learning (PBL) forms a major part of the context in one of the studies. This educational philosophy features the integration of basic science and clinical medicine as one of several central elements, and a brief introduction to these ideas is also presented. As the clinical understanding medical students arrive at is the main target both for the individual student and for this research project, some aspects of the clinical reasoning process will subsequently follow. Prior research regarding medical students learning of anatomy and physiology that relates to the approach employed here is summarised to capture the specific nature of knowledge transformation in these disciplines. Finally, an introduction to the conception of knowledge used throughout this thesis is introduced through the description of the research tradition from which it stems.

The research field of medical education has seen a substantial increase in productivity during the last two decades (Albert et al., 2007) and with it, a new orientation and reflection concerning its own methods and goals has emerged (Eva, 2009; Bordage, 2007; Cook et al., 2008). It is a rampant methodological ground (Norman et al., 2008) with influences from a variety of different research traditions both from within medicine itself and from research on higher education in general. Both quantitative and qualitative approaches are used, which enriches the flora of questions asked and, consequently, the resulting knowledge is colourful and multi-layered. The great diversity of methodological approaches also makes the findings dependent on the ontological assumptions behind the respective approaches (Bordage, 2007).

This thesis' focus – the longitudinal perspective on medical studies – is by no means a novelty within the research community of medical education. Continuity over the lengthy medical programme has been strived after ever since Flexner (1910) published his report about medical education in the United States and Canada. The report was commissioned to serve as a foundation for restructuring the system for medical education; at the time, an abundant variety of medical schools frequently offered little or no training in the basic sciences. It was suggested that both medical students and future patients would profit from a more scholarly education in basic biology, chemistry and physics, and that this was to be achieved by incorporating introductory "pre-clinical" years into science courses at university. For many decades, the medical curriculum has – with recent exceptions – upheld this division between the basic

sciences and clinical training. Although the intention was to root the medical training more firmly into science (Cooke et al., 2006), the division subsequently amounted to problems of alignment when a gap was created between pre-clinical science and clinical knowledge. The fact that this gap was not just about moving from laboratory to hospital, but that it created two different cultures of knowledge, has been recognised as a concern in several different settings ever since (Cole, 1932; Lewis, 1956; Miller, 1962; Prince et al., 2000; Faigin et al., 2007).

Indeed, the majority of themes occupying the minds of researchers in medical education during the last three or four decades, can be linked to the aim of successfully connecting basic science with clinical application. With varying degrees, all these themes share aspects related to bridging the gap. It was already acknowledged back in 1932 that the two cultures of basic science and applied clinical knowledge needed attention:

"I remember vividly the feeling of relief with which I turned to clinical medicine when I had passed the examination in anatomy and physiology. I had been told that these subjects are the basis of medicine; but the relationship seemed a vague one, and during the next seven years physiology (as I had learnt it) appeared to have only a remote connexion".

(Cole, 1932)

The mere length of the educational efforts put in by both medical students and teachers has brought the issue of retention to the fore. Numerous inquiries into how much basic science knowledge medical students are able to retain have therefore been undertaken (e.g. Donovan et al., 1969; Kennedy, 1981; D'Eon, 2006) at different stages of undergraduate and postgraduate education. The retention studies report the amount of the material learnt, that which has been remembered over a certain period of time. The time span measured generally includes the transition from basic science learned in a preclinical setting to clinical skills learned in a hospital setting. This creates a situation of knowledge transfer (Chen, 1995; Gentner et al., 2003) that needs to be addressed, since the context of acquisition differs from the context of application (Norman & Schmidt, 1992; Prince et al., 2000). Educational efforts to facilitate the transition for the basic sciences into the clinic include the introduction of Problem-Based Learning (PBL) curricula (Barrows & Tamblyn, 1980). In emphasising meaningfulness, self-directedness and problem-solving skills, this educational initiative has been utterly influential in medical education (Hmelo-Silver, 2004). Recently, theories concerning how expertise develops in medicine (Schmidt & Boshhuizen, 1993; Boshhuizen & Schmidt, 1992; Norman, 2005) have been put forward, including ideas about clinical reasoning and encapsulation of basic science into illness scripts (e.g. Schmidt & Rikers, 2007; Rikers et al., 2000). To a certain extent, all the themes within the field of medical education mentioned above contribute to our understanding of this thesis' topic; they will be elaborated upon accordingly. They all attempt to investigate medical students' learning in relation to the continuity of the medical programme. They also represent different ways of measuring learning, and consequently differing views on learning, i.e. what learning is.

RETENTION

There is a widespread belief among practising doctors that close to nothing is remembered of what was learned in the first years of medical school (Custers, 2009; Kennedy, 1981), despite medical knowledge being an obvious goal of medical education (Verhoeven et al., 2002). A retention study therefore asks: 'How much of what was learned is remembered?' The idea of describing knowledge development (or rather, decrement) as a function of the time elapsed, goes back to Ebbinghaus (1966), who used himself as a subject in trying to remember nonsense syllables. His resulting retention curve exhibits an initial steep decrease in retained information, followed by a level off as more time elapsed.

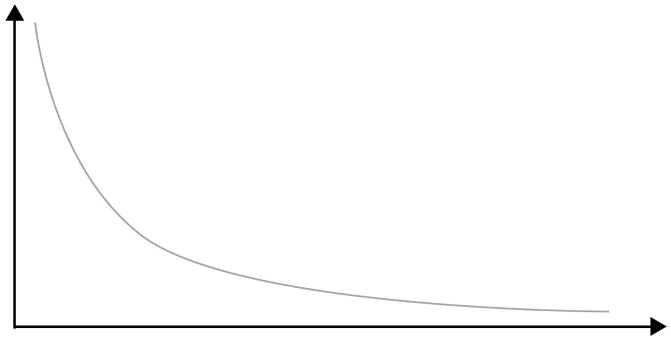


Illustration 3. Example of retention curve.

The shape of the retention curve has been confirmed by a number of studies within medical education (e.g. Donovan et al., 1969; Rico et al., 1981, DuBois et al., 1969), however, the levels of retention are more ambiguous. Whilst some studies show a very limited loss of retention of just a few percent (Kennedy et al., 1981; Swansson et al., 1996), the majority point towards more serious losses of around a third of the material (Miller, 1962; Rico et al., 1981; D'Eon, 2006; Donovan et al., 1969), and in some severe cases, what remains is not above the level of chance (Sinclair, 1965). As would be expected, these studies exhibit the loss of retention to be dependent not only on the length of the retention interval but also on the degree of non-use during it (Rico et al., 1981; Kennedy et al., 1981; Hojat & Veloski, 1984; Swansson et al., 1996; D'Eon, 2006). With time, medical students – and people in general – forget what they learned, especially if that specific knowledge is not used. The differences in whether a subject area is lost or retained follow a pattern where, not surprisingly, fields inherently offering a close clinical connection are better retained than subject areas with a less obvious relation to clinical medicine. Pathology, pharmacology and, to some extent, physiology belong to the former category, while anatomy, biochemistry and microbiology belong to the latter (e.g. Kennedy et al., 1981; Swansson et al., 1996). These differences can be quite substantial; the subject of anatomy, for example, suffering from decrements of around 50% (Sinclair, 1965; D'Eon, 2006), while physiological knowledge only decreases by around 20% (D'Eon, 2006) or is even virtually intact (Kennedy et al., 1981). Although few clinicians would deny anatomy and biochemistry their respective place in the curriculum, on the basis of these findings, the amount of space they occupy has been debated. Even though recall of biochemistry falls to levels well under "passed" after just one year (Rico et al., 1981), the subject of

anatomy has been proven especially hard to remember (Sinclair, 1965; Kennedy et al, 1981), seemingly regardless of whether it is being taught with dissection of human specimens or not (Sinclair, 1965). This fact calls into question whether the place of anatomy is really among the basic sciences, as some central aspects of it are more related to clinical medicine (Wilhelmsson et al., 2009).

As has been pointed out, courses that later show a bad retention level have either generated less initial learning or not been reinforced enough (D'Eon, 2006). This fact brings to the fore the issue of measurement and delimitation of the basic sciences. It is crucial to acknowledge the type of questions asked, and to define what is basic science and what is clinical medicine. This is shown by the considerable variation in results (e.g. Donovan et al., 1969; Kennedy, 1981; Sinclair, 1965). Naturally, the mode of assessment will influence the results depending on the degree to which the knowledge has been transformed into something new. Regardless of what has been measured, the majority of studies attribute the lack of recall to the lack of reinforcement, or non-use, during the retention interval (Hojat & Veloski, 1984; Swanson et al., 1996; Rico et al., 1981; Kennedy et al., 1981), thus assuming constancy in the integrity of the individual disciplines. The importance of the idiosyncrasies of the area has also been found when the order of the subject areas has been manipulated (Rodriguez et al., 2002). For example, when the clerk-ships internal medicine, surgery, psychiatry, gynaecology were ordered according to a different rotational sequence, internal medicine proved immune to knowledge loss independent of order due to its general characteristics shared with many other areas of medicine (Hojat & Veloski, 1984).

While inter-subject differences seem to be a major factor influencing the level of knowledge recall, inter-individual characteristics have not been found to correlate with delayed performance (Rico et al., 1981; D'Eon, 2006), again pointing towards the importance of assessment (Wilhelmsson et al., 2010c). Interestingly, not only the basic sciences seem to suffer from knowledge decay. Feigin and colleagues (2007) found a rapid decline in medical students' ability to discriminate radiological structures after a pre-clinical course in radiology, even though the relevance of the subject ought to have increased their ability as the studies progressed to more clinical areas. The question then arises; should the basic sciences be brought to the bedside or should clinical thinking enter the laboratory? Over the years, the forgetfulness of medical students – and faculty – has been connected to the divided curriculum and the two resulting cultures, with scientists preaching the importance of the base, and clinicians campaigning for its application (e.g. Dornhurst & Hunter, 1967). Once the division was there, it didn't matter if courses were prolonged or new subjects were added to the curriculum. Some have attributed the problem to the resulting "de-contextualisation" of medicine following the early introduction of scientific thinking (Dornhurst & Hunter, 1967), whilst others have argued for the need of a "brotherhood" between physiologist and physician (Cole, 1932). Ways to integrate the two cultures have been sought after since the division was observed. By offering medical students and residents reinforcement courses in basic sciences, Dubois and colleagues (1969) found that one such delayed reminder every third year helped considerably in maintaining decent levels of knowledge. The problem of knowledge transfer between settings has been taken seriously, but context in terms of physical surrounding does not facilitate recall in a medical setting (Koens et al., 2003).

Ultimately, whether these results are good or bad news is a matter of interpretation, since what is use and what is non-use is most often hard to say. Imagine a group of students studying the mechanisms of a swollen leg. Some students use this approach and others use another. What prior knowledge they apply to arrive at an understanding is largely individual, so that some will use basic science and others will not. Most situations in medicine can be understood from complementary perspectives. One young doctor sees pain, anxiety and denial in a patient entering the emergency room with a red, swollen leg, whilst another one sees the patient's age, risk factors and a third sees the venous branches of the lower limb.

The perspective of a retention study is backward-looking. One looks for what remains of what was (assumingly) there and what is left of it in terms of its original shape, taking subsequent "reinforcement" of material acquired earlier into account. The point of view has already been chosen: that of the basic sciences. A forward-looking perspective – which is employed in this thesis – implies that the knowledge has been reorganized and changed identity; its shape or representation in the clinical context is distinctly different from its appearance in earlier years. Therefore, relying too heavily on retention measurements considering medical knowledge of medical students will not provide more than a fragment of an answer, since they are based on unusable assumptions. A recent review of retention studies in medical education (Custers, 2009) concludes that approximately 25-35% of the knowledge is lost during the first year, followed by further loss in the second year, arriving at under 50% by the end of the second year. Seen from such a single-minded point of view, medical school may seem like a giant waste of time, since so little knowledge is retained. If more efficient methods of instruction could be found, it would even be tempting (theoretically) to shorten the curriculum. One might not feel very tempted to accept any kind of treatment from a medical practitioner who has forgotten half of what she or he is supposed to know. At the same time, most of us do accept treatment without asking for the doctor's grades from University first. Furthermore, the most acute problem of the health care system is not an abundance of doctors unskilled in the basic sciences. Finally, all medical universities believe that they produce knowledgeable graduates able to serve future patients with adequate care. It seems a large part of the puzzle is still missing after the retention studies exhibited the disintegration that is the destiny of basic sciences not adequately integrated, since it is unclear exactly what knowledge is retained and what is lost. Thus, it would appear that Ebbinghaus' exclusion of the meaning of the learning task was a mistake, since this appears to be crucial.

TRANSFER

It seems evident that a transitional effort needs to be carried out if students are to retain knowledge learned in a pre-clinical setting and apply it in a clinical setting (Prince et al., 2000; van Gessel et al., 2003). From a psychological perspective on learning, this is called the problem of transfer (Bolander Laksov, 2007). It comes about in the act of making use of prior knowledge to meet the demands of a new situation, which has been shown to be a complicated process (Chen, 1995; Schmidt & Norman, 1992). Several different interpretations of the transfer problem are possible. Transfer from a

metacognitive perspective is about applying knowledge in a situation different from the context of learning, while transfer from a situated learning perspective is about person-world relations, since learning according to this view is heavily bound to situational and environmental factors (Bolander Laksov et al., 2007). According to the latter, the question is not about the degree of similarity between situations, but whether it is possible to transfer knowledge between situations that are distinctly different. If every new learning experience is unique, and if that which is learnt is dependent on that experience, then transfer of any kind of knowledge is not a meaningful concept (ibid.).

If one assumes there are certain similarities between situations and that transfer can occur, the degree to which it is possible is dependent on several factors including similarity between source situation and target situation and the time elapsed before retrieval. Context has been found far more critical than time interval between acquisition and application (Catrambone & Holyoak, 1989). Furthermore, transfer can be described according to its features; it can be either specific or unspecific, depending on whether it is specific content knowledge or general principles that are being transferred, it can be positive or negative, depending on whether learning is facilitated or not, and it can be distal or proximal depending on distance (Schönborn & Bögeholz, 2009). Horizontal transfer describes knowledge generalised on the same level of complexity, vertical transfer denotes a shift in level of abstraction (Gruppen & Frohna, 2002; Schönborn & Bögeholz, 2009).

In several of the experimental situations used in investigating the problem of transfer, the design is set to decipher how subjects achieve analogical encoding between a source analogue and a target analogue (Chen, 1995; Gentner et al., 2003; Catrambone & Holyoak, 1989), i.e. their focus of attention when comparing two situations. Spontaneously, this seldom occurs since subjects rely on direction to point them to the relevant aspects of the source analogue (Catrambone & Hoyoak, 1989). When learners, especially un-experienced ones, are left without guidance in this respect they tend to focus on superficial similarities, and successful transfer is more likely when surface features are shared amongst target analogue and source analogue (Chen, 1995). In investigating the transfer between schematic pictures and a problem-solving task, Chen (1995) found that superficial and procedural similarity between the two analogues determined performance.

Analogical problem solving refers to the comparison of two situations or problems with respect to their similarities. An underlying assumption is the fact that new knowledge is incorporated into the learner's experience of previous similar examples. Catrambone & Holyoak (1989) found that although transfer between dissimilar situations is harder, it is possible to achieve. Help with emphasising abstraction and a focus on structural features of the target situation facilitates learning, as does increasing the number of examples. Hints regarding the applicability of a former analogue also increase transfer. They conclude that transfer is mediated by the representation of the commonalities between situations, and cues in the target analogue activate certain features of the prior situation. Students should therefore be instructed to focus on the relevant aspects.

From the point of view of medical education, a problem of transfer can be seen to arise when an un-experienced medical student encodes a specific situation in a "superficial"

way, that is, according to surface characteristics. Since the clinical situation – to which knowledge is presumably transferred – is so different in context, transfer will be difficult, even though the fundamental content is very similar (Gentner et al., 2003). Thus, a very small change in perceived surface identity risks shattering the transferability of knowledge. According to this line of thought, it is more likely that students, when presented with a new problem, focus on superficial details when connecting to prior knowledge.

To summarise, novices focus on surface characteristics that they are familiar with, rather than central concepts important for realising similarity with a prior example. Instruction should then be about helping learners to focus on structural similarities to facilitate transfer. With increasing experience, novices become better at encoding structural instead of superficial similarities (Gentner et al., 2003). There is also evidence that learners who are presented with two cases are better able to transfer solutions between them, than if just one problem is presented in which transfer is supposed to take place from prior knowledge (Catrambone & Holyoak, 1989; Gentner, 2003).

PROBLEM-BASED LEARNING

One of the most influential measures used in overcoming the division in medical education is Problem-Based Learning (Barrows & Tamblyn, 1980). This educational idea came about due to widespread concern within and outside the medical education community regarding the appropriateness of the heavily loaded medical curriculum, which often resulted in passive students (Rahimi, 1995; Fyrenius, 2006). Its goals can be seen as an attempt to remedy the problems of the time, and can be expressed as follows: Problem-Based Learning (a) increases the integration of basic science and clinical knowledge (flexible knowledge); (b) facilitates the development of clinical reasoning skills (problem-solving ability); and (c) fosters self directed learning in students (e.g. Hmelo et al., 1997; Fyrenius, 2006). From the start, the basic ideas were expressed as an educational philosophy, but it has acquired an identity of an instructional method since then (see Rahimi, 1995 for a comprehensive account of its foundation). Through using student activation in the basic educational "unit" – the tutorial group – self directedness in all the phases of learning is strived for; the students confront a scenario, identify facts and areas for further study, create hypotheses about possible solutions and finally embark on a mission to search for the knowledge. Also in a curriculum perspective, the aim has been to foster understanding of complex clinical scenarios through the integration of clinical subject areas into early medical training. Thus, a longitudinal progression comprising rehearsal of basic science subjects during the subsequent training, is supposed to give the student more powerful instruments to connect and transform knowledge.

In addition to the three goals mentioned above, other important aspects with support from psychological theory have been hoped for, such as collaborative skills and motivational skills, but despite extensive research on the effects of PBL, much remains undetermined (Yew & Schmidt, 2009). Unlike the properties of knowledge and abilities to handle learning tasks that PBL is supposed to provide students with, these other

aspects of PBL have not been evaluated as thoroughly (Hmelo-Silver, 2004). Some evidence in terms of self rated inter-professional competence and ability to handle acutely ill patients, suggests a positive effect of PBL on the former and no effect on the latter when compared to more traditional curricula (Faresjö et al., 2007). When examining conversations taking place over one learning cycle within a tutorial group, Yew & Schmidt (2009) found collaborative processes between students common, while self-directed and constructive processes were less frequent than expected.

Assumingly, such emphasis on careful integration would increase students' ability to connect different knowledge areas, but in terms of coherent explanation studies are dissentient (Albanese & Mitchell, 1992), some reporting positive effects (Hmelo et al., 1997) and others negative (Patel et al., 1993). In terms of knowledge, retention studies are likewise ambiguous (Norman & Schmidt, 1992), pointing towards no difference at all (Herzig et al., 2003) or less recall (Patel et al., 1993). When Indian medical students were studied during an implementation of a curriculum reform, the PBL-group showed significantly higher scores on deep and strategic approach to learning, than did the non-PBL-group (Abraham et al, 2008). In a meta-analysis, Dochy and colleagues (2003) report slightly negative effects on knowledge, especially in the first years of medical school, but a better retention of that knowledge. They also found positive effects on skills. Some studies have reported that students taught according to PBL perceive deficiencies in their own basic science knowledge (Prince et al., 2003), an interesting finding suggesting differences on meta-cognitive levels. However, in a basic subject area like anatomy, no difference in retention (or perceived retention) depending on instructional method was found among the eight Dutch medical schools (Bergman et al., 2008).

Some have argued that the evaluation of PBL must not only regard the level of knowledge students exhibit after their training, but also take into account the pure cognitive and problem-solving abilities since these measures are basic goals of the approach (Hmelo et al., 1997). Students seem to enjoy their studies more in medical schools employing PBL (Rahimi, 1995), while general medical competencies measured by peer-rating further into professional life did not correlated with type of curriculum (Norman et al., 2008). A basic feature of PBL is the reinforcement of hypothetico-deductive reasoning (Rahimi, 1995; Patel et al., 1993); an initial hypothesis about diagnosis is the starting point of learning, but whether this is a facilitating or inhibiting factor is unclear. There is a sound theoretical base about the possible positive effects of PBL (Hmelo-Silver, 2004), but it is still open to discussion whether studies have been able to capture the differences. A recent literature review on studies of PBL in academic health education reports more favourable results of PBL-interventions in more traditional curricula, compared to studies comprising whole PBL curricula, suggesting that the orchestration and dosing play important roles (Polyzois et al., 2010). Some findings have indicated that PBL does not constitute an exhaustive foundation for a successful unification of the basic sciences with clinical practice (Prince et al., 2000). However, a recent study of results on final examination during internship among Swedish medical graduates depicts a stable positive trend in terms of number of successes and failures (Östergren et al., 2009). It is probable that the most powerful effect of PBL is a raised and focused attention on educational and pedagogical issues within medical education (Dahlgren & Norman, 2008).

CLINICAL REASONING AND MEDICAL EXPERTISE

A major area of research dealing with the development of diagnostic skill in medicine is clinical reasoning. The representation of basic science is examined here, in the light of the ability to assess medical data and to process it in order to arrive at an accurate diagnosis (Norman et al., 2002). Research in clinical reasoning has been established as a field defined as a sub-area in a more general research programme about expertise (Patel & Groen, 1991). Viewed in this way, medical expertise as exhibited in expert clinical performance to state a diagnosis, is an example of a general problem-solving ability. The main theoretical assumptions governing many of the interpretations made are derived within a cognitive "paradigm" (Gruppen & Frohna, 2002), in which variables such as mental problem representation and evaluation patterns are examined. Amount of accrued knowledge, and organisation of that knowledge is considered the foundation of expertise, which is described with reference to structures such as categories, prototypes, schemas and scripts (ibid.). Other epistemological perspectives are also represented, resulting in a variety of conceptual frameworks and, at times, divergent conclusions about basic characteristics of the reasoning process (Norman, 2005). Expertise has also been described as a developmental process in which action is conducted according to rules for the novice, and according to situational understanding for the expert (Dreyfus et al., 1986). With increasing experience, the learner is able to "read" the clinical situation without having to rely on formulas for solving tasks. This is called clinical intuition, and is the hallmark of expertise in medicine (Carraccio et al., 2008). To be able to describe the relation between basic science and clinic medicine as regards clinical reasoning, a general outline of this field is presented.

As has been mentioned, the research into medical expertise has drawn extensively on expert performance in other areas, but it is a mutual relation; medical expertise has informed the view of the general expert as much as the opposite (Patel & Groen, 1991). In the traditional cognitive research programme – in which the major part of the work has been carried out – level of expertise and amount of knowledge possessed are closely related. A large number of studies in this domain have included some kind of recall measurement as a constituent in the definition of the expert (Norman, 2005). It is therefore necessary to address the issue of knowledge development within this area, since the basic sciences are embedded therein.

Within medicine, interest was directed to the superior performance of a few diagnosticians in a programme designed to capture the essence of expertise in medicine (Elstein et al., 1978). Although the investigation focused on experts nominated by peers, it failed to show any difference between these diagnosticians and the more average "typical doctor" in diagnostic ability or cognitive processes. Subsequent work has been re-oriented to the laboratory in order to refine the experimental conditions, with consequences for the kind of results obtained (Ericsson, 2007). In a series of such studies, Patel and colleagues (Patel & Groen, 1991) let participants of differing levels of expertise read clinical cases, account for the content after a time interval and provide a diagnosis. The relationship between level of expertise (experience), level of recall and diagnostic ability was thus studied. Another agenda has studied clinical problem

solving in real time, focusing on diagnosing (Schmidt & Rikers, 2007), thus paying more attention to contextual factors. Yet another orientation studies clinical experience, as a non-analytical phenomenon, which appears automatic and based on prior examples in long-term memory (Norman et al., 2007). All these directions of research have, to an extent, diverted from the original quest: to examine expert diagnostic performance, as it is carried out in real time and in a clinical context, and the factors associated with it. At the same time, emphasis has shifted from studying expert behaviour, to the study of the development of expertise along the continuum from junior medical student (novice) to experienced clinician (expert) (Ericsson, 2007).

It was found early on that one essential characteristic of clinical reasoning was a variant of the hypothetico-deductive method (Elstein et al., 1978; Patel & Groen, 1991; Rahimi, 1995). According to this method, a scientific hypothesis always precedes data, which in the clinic means that the clinician works against one or a limited number of differential diagnoses, and gathers medical information in support (or opposition) of them as reasoning proceeds. The alternative approach is an inductive way of reasoning, in which data is tentatively gathered without any predetermined goal of justification. A variant of the hypothetico-deductive model has been called backward reasoning (Patel & Groen, 1991) or top-down reasoning (Rahimi, 1995), referring to the direction in which the line of argument goes. Theoretically, this approach should be safer, since the induction problem (have all the symptoms been included?) is limited and false premises are avoided, but it is also slower and more strenuous as new information needs to correspond to the goal. Consequently, this approach is seen when knowledge of the subject area is limited, such as in novices' clinical reasoning, while expert reasoning is characterised by forward reasoning, a fast and more risky way of reasoning because of its requirements of robust subject area knowledge and lack of checks of the inferences made (Patel & Groen, 1991).

The basic ongoing activity in both forward and backward reasoning is analytical. They are both step-by-step procedures where each new stage depends on the former. Independent of direction (forward or backward), they are sensitive to causal miscomprehensions along the way. To arrive at a correct initial diagnostic hypothesis is crucial since this biases the analytical information process (McLaughlin et al., 2008). In changing the focus from the analytical procedure of the medical mind to more pattern recognition aspects, Norman and colleagues (2007) have proposed an alternative framework: non-analytical reasoning. The fundamental idea is here is that diagnostic reasoning is primarily based on similarity to a prior example, as opposed to analytical reasoning. In a series of experimental studies involving both novices and experts, participants were influenced by a prior essentially irrelevant case in the diagnosing task (e.g. Hatala et al., 1999). This led the investigators to the conclusion that central parts of the reasoning process are "reflex-like"; verbal or visual stimuli (based on experience) result in a corresponding diagnostic hypothesis in a process not open to retrospection or introspection. Familiar symptoms also had a substantial impact on the diagnostic reasoning, suggesting a more holistic process (Young et al., 2007). Expertise consequently develops with the growing bank of similar cases in long-term memory, and should be fostered by teaching with multiple examples, and complemented with analytical aspects to un-bias the hypothesis.

Non-analytic reasoning can be said to constitute an alternative to the viewpoint that clinical medicine has very little to do with the basic sciences altogether. Even though this latter stance seems counterintuitive, it has been suggested that clinical information cannot be embedded in basic science explanations (Patel et al., 1988; Rikers et al., 2005). Another influential theoretical model to account for the connection between basic science and clinical medicine is the theory of knowledge encapsulation (Schmidt & Boshhuizen, 1993). According to this model, biomedical knowledge becomes encapsulated as the student's level of experience progresses towards expertise. It was found when first year medical students (novices), advanced medical students (intermediates) and experienced physicians (experts), were all studied as they solved clinical problems. In contrast to what would be expected, intermediates recalled more pathophysiological material of the test cases than did both novices and experts, while experts were more accurate and faster in their diagnosing (e.g. Rikers et al., 2000; de Bruin et al., 2005). This intermediate effect was interpreted to represent the encapsulated biomedical knowledge embedded in the experts' processing. The encapsulation process comprises a transformation of causal networks of biomedical knowledge into clinical concepts of a higher level of abstraction (Schmidt & Rikers, 2007). This summarised information forms an illness script, integrating basic science but also containing more contextual clinical information such as enabling factors. As expertise develops in the novel clinician, encapsulation becomes increasingly important (Rikers et al., 2004) as it represents a more coherent knowledge structure and is thereby more easily accessible than basic science concepts (van de Wiel et al., 1999).

The fact that the two worlds of basic science and clinical medicine are connected, is doubted by only few researchers and even fewer medical practitioners, although how the link is best described is still open to debate (Norman et al., 2007; Patel et al., 1993; Woods et al., 2007a and b; Donnon & Violato, 2006).

A NEED FOR A NEW ORIENTATION IN MEDICAL EDUCATION

As has been accounted for, several different approaches to picturing medical students learning have been, and are used. This variety no doubt renders the area powerful means to move research forward. However, as pointed out early in this chapter and by others (Bordage, 2007; Ericsson, 2007; Myopoulos & Regher, 2007) this variety may also result in diffused goals when competing research programmes work in different directions as a result of unclear definitions and aims. As for the traditions based in educational psychology, all theoretical models put forward have in their own way enriched one or several aspects of the area, although none has hitherto managed to explain the complex relationship between information processing, expertise and diagnostic performance (McLaughlin et al., 2008). The investigation into expert behaviour as "routine-experts" instead of expert-performance approach (Ericsson, 2007) has been criticised because of its lack of ecological validity. Studying typical clinical cases does not reveal the difference, it is argued, since the differences between the expert and the non-expert are to be found in the extraordinary. Adaptive expertise (Myopoulos & Regher, 2007) better captures expert behaviour, through a continuous intentional engagement of problems in the domain in order to gain re-understanding.

Also, the different qualitative approaches used complicate the picture and may contribute to confusion when results obtained from alternative fields are compared. Results reached within a certain methodology cannot immediately be transferred to the next, and risks deploying the variety of qualitative approaches of their epistemological basis (Lingard, 2007). It is not just a matter of different terminological use, it is a matter of what exactly is regarded as knowledge.

Retention of knowledge as a measurement, is problematic as the contextuality is not addressed, and because the quantitative conception of knowledge fails to capture the whole entirety of the learning (Dahlgren, 1997). This thesis can be seen as an attempt to clarify important aspects of learning medicine through shifting towards a qualitative understanding of medical students learning, with a focus on their longitudinal knowledge development. It is argued that qualitative investigations can be used to remedy some of the problems experienced by researchers through broad explanations of central features. Clinical reasoning has a focus on the process of learning. The processing of different learning tasks is treated as though they were all subjected to the same handling by mental structures. Our approach is to focus on outcome: that which can clearly be observed by the senses.

LEARNING ANATOMY AND PHYSIOLOGY

The previous sections have dealt with general schools of thought regarding learning among medical students. They have been elaborated on here, as they all shed light on the present investigation, albeit from quite different horizons, and because they mark out the theoretical terrain. Yet, the two other areas of anatomy and physiology remain, and some key findings will be presented to complete the picture. Medical students' learning of anatomy has been characterised in many ways. Generally, not much about the specific nature of learning anatomy is known. Most statements concerning its role in the medical curriculum are based on anecdotal and historical evidence (Pandey & Zimitat, 2007). As explained in the section about retention, anatomy is the subject of much anxiety for medical students, primarily on issues of memory. It has a reputation for being insurmountable, which is reflected in the perceptions of the students (Krontiris-Litowitz, 2009; Bergman et al., 2008; Smith & Mathias, 2009). The major concern has been to avoid root-memorisation, as this results in suboptimal learning if not combined with other approaches (Wilhelmsson et al, 2009; Miller, 2000; Rizzolo et al., 2006). Instead, meaningfulness in terms of relevance (Wilhelmsson et al., 2010a, Smith & Mathias, 2009) and adequate horizontal and vertical integration with clinical subjects (Wilhelmsson et al., 2009; Wilhelmsson et al., 2010a; Bergman et al., 2008) appear to be the most crucial measurements.

Eizenberg (1988) described medical students' approaches to learning anatomy ranging from memorisation of isolated parts to comprehension of the whole site, in terms of gradually more holistic approaches. The category system obtained stands in a qualitative tradition that captures the content of learning; however, a basic distinction between memorising and understanding seems central to the learning of anatomy, as several inventories report strong correlations between approach to and outcome of learning (Smith & Mathias, 2009; Pandey & Zimitat, 2007). This points towards the

major duality students experience when approaching anatomy (Wilhelmsson et al., 2009; Wilhelmsson et al., 2010a).

Learning physiology, however, is demanding in a quite different sense. Due to the nature of the discipline, it requires conceptual understanding involving several interrelated systems (Fyrenius, 2006). This fact opens up a potential for the formation of misconceptions, when students develop knowledge according to situational descriptions rather than underlying principles (Modell et al., 2000; Fyrenius et al., 2007a). Such misconceptions have been seen in a number of sub-areas (e.g. Michael et al., 2002; Michael et al., 1999) and appear resistant to change once established (Morton et al., 2008), making it an issue of major importance to deal with early in medical training. The risk of oversimplification of content and memorising is obvious. Students' difficulties in grasping core content of medical physiology has led to suggestions concerning the basic principles underlying many of the body functions involved (Modell, 2000; Michael et al., 2009). Fyrenius and colleagues (2007a) found students' understanding to depend on conditions of transferability and differentiation in the area of blood pressure regulation, suggesting that such generality is worth exploring in the teaching.

LEARNING AND UNDERSTANDING IN HIGHER EDUCATION

As the stance of the present inquiry draws on a literature about learning developed within the domain of higher education and not specifically within medical education, an introduction to this body of research will be offered here. It regards the nature and outcome of student learning with a particular emphasis on approaches to learning and understanding. A more detailed account of the specific methodological perspective will be outlined in the following chapter.

A central and important finding within this area is clarifying the different approaches according to which students take on their learning (Marton & Säljö, 1976a and b). Deep- and surface approach represents a starting point for a research programme, investigating student learning in terms of qualitative differences in approach and outcome. Parallel dichotomies had been obtained in other traditions, such as the cognitive notions of students' different levels of processing (Craik & Lockhart, 1972), and meaningful learning contra rote-learning (Ausubel et al., 1978) from a cognitive perspective. The distinction marks a point of departure for the research programme in which the differences are the central focus point – phenomenography. Mapping the variety of approaches used by students in higher education and treating these as an important part of their learning is also an example of a broader orientation within research in higher education. Drawing on the categories obtained by Marton & Säljö (1976a and b), Biggs (1979) described the study processes of students in tertiary education using three distinct dimensions: utilising, achieving, and internalising. Another set of approaches akin to these were introduced by Entwistle and Ramsden (1983) when they described three learning orientations: reproducing, strategic and meaning.

The labels ‘deep-approach’, ‘internalising’ and ‘meaning orientation’ describe features of learning related to the search for a holistic understanding in analysing and critically evaluating the learning material closely dependent on an inner motivation for the task. The surface approach, utilising and reproducing refer to an emphasis on memorising the learning content for purposes of accurate reproduction, in contrast to an individual construction of knowledge, and are associated with external motivation, such as demands from the learning environment. The intermediate approaches, achieving and strategic, denote the tendency to tactical adjustment of assessment practices in order to obtain excellent grades, and lack a corresponding equivalent in the deep- surface dichotomy. Depending on the nature of the learning task, an achieving or strategic orientation can be described as either deep- or surface approach (Fyrenius, 2006).

The central aspect of motivation as a determinant for learning quality, as launched by these studies, has been further developed. A somewhat broader notion of learning orientation (Beaty et al., 1997) point to the intrinsic vs. extrinsic motivation students have in engaging with their studies. How such orientations affect the ways in which students interact with course work has also attracted attention (Scheja, 2002).

The differing approaches to learning that students employ have also led to substantial research on the distinction between memorising and understanding, since these two, to a large extent, seem to be the result of the approaches when applied to a learning task (e.g. Marton & Säljö, 1997; van Rossum & Schenk, 1984), although not being intimately linked (Marton et al., 1997). This central relation emerged from studies on students’ conceptions of learning (Säljö, 1979; Marton et al., 1993; Marton et al., 1997), which revealed five central conceptions.

A set of five distinct categories was found by Säljö (1979), in which students conceptualised learning as (a) an increase in knowledge, (b) memorising, (c) acquiring facts and procedures for instrumental purposes, (d) an abstraction of meaning, and (e) an interpretative process aimed at understanding reality. To these five a sixth was later added – changing as a person (f) – and the whole category system was rearranged according to the central distinction between memorising (words or meaning) and understanding (meaning or phenomenon) but also comprising temporal aspects (Marton et al., 1993; Marton et al., 1997). Thus, learning was conceived of in terms of acquiring, knowing and making use of (Marton et al., 1997).

In an attempt to explain what has been known as the “paradox of the Chinese learner”, Marton and colleagues (2005) clarified the distinction between memorising and understanding further. The paradox is constituted by two stereotypes: firstly, that learning by repetition is a predominant feature of the Asian learner, and secondly, that the brainy Asian successful in academic studies, also by western standards (e.g. Kember, 1996). If repetition implies memorisation, it appears counterintuitive that it should lead to quality learning. However, it was found that students gradually abandoned a sequentially ordered conception (starting with memorising in order to understand later on) as higher education proceeded. Memorisation and understanding were thus seen, not as mutually exclusive, but as simultaneous and complementary, with repetition serving the purpose of remembering the material more easily, and variation in learning facilitating understanding (Marton et al., 2005).

As the nature of the understanding achieved has been left unexamined in many studies, a parallel undertaking into this question was attempted. Taking the deep and surface approach as point of departure, the understanding arrived at during the time of completion of final degrees was explored (Entwistle & Entwistle, 1991). Understanding was conceived of in terms of *meaning, coherence* and *connectedness*, rendering a feeling of *satisfaction* and *flexibility* and *confidence* in adapting and explaining the knowledge. These findings were extended in the description of "knowledge objects" (Entwistle & Marton, 1994), a kind of tightly structured visual understanding resulting from intensive study. The term "object" denotes the level of integration reached, as some aspects bring up other closely connected aspects of the object, and the tactile experience of knowing the object so well that it takes on sensory features. Their formation involves memorisation of details as well as understanding (Entwistle & Entwistle, 2003).

Within medical education, students' approaches to achieving understanding have been described as *Sifting, Building, Holding* and *Moving,* building on the classic dichotomy (Fyrenius et al., 2007b). The latter two denoting deep-level processing, mark a distinction between understanding, reached for the purpose of holding on to, or, as a constantly proceeding learning activity. Another rather special approach preferred by medical students in particular is the professional orientation to studying (Lonka & Lindblom-Ylänne, 1996). This concerns a selection of the kind of knowledge directly applicable in professional life, in the vast amounts presented during the studies.

III. AIM AND OBJECTIVES

The present investigation has a longitudinal focus on medical students learning. *The aim is to describe the knowledge development over time, how it is structured, and how that structure changes as new knowledge is incorporated, i.e. how it transforms.* This also means investigating in what way the final structure arrived at towards the end of the medical programme is related to the one initially constructed during basic science studies. It may be expressed as if and how medical students' conceptions of learning in medical science change between the basic science years and the clinical context.

The specific objectives of the thesis – with references to specific articles in brackets – are:

How students learn anatomy. (I)

How students develop anatomical understanding. (II)

How medical students transform physiological knowledge between the basic science and the clinical stage, and in what way this is related to the curriculum, as well as whether it can be investigated with a phenomenographic analysis. (III)

How retention of basic science and understanding are related in a clinical setting. (IV)

IV. METHOD

Learning can be studied from a variety of perspectives. A first rough line of division can be drawn between quantitative and qualitative methods. The former is about how much knowledge a person has acquired, while the latter deals with what has been learnt and how this was learnt (Dahlgren, 1997). In view of the questions posed in the introduction, a qualitative approach was chosen since this would enable a broader description of our topic: medical students' longitudinal development of knowledge in anatomy and physiology. Furthermore, differences were expected regarding students' conceptions of learning, approach to the learning task and outcome of learning. A research approach taking such differences into account would most likely render a rich and thick account of the students' experience of learning. The two subject areas under study, anatomy and physiology, also represent some of the most challenging tasks in medical school. They present the student with vast amounts of knowledge, that may often change depending on new research, and will eventually make up the necessary foundation on which a professional competence is to be based. The most predominant difficulties are presented in two ways: how to adapt a large amount of detailed factual knowledge into a coherent system (anatomy), and how systems interact to maintain human biological functioning (physiology). These difficulties are well known to medical students, as is the awareness of the fact that each student differs in how well they overcame the difficulties, i.e. how well they do. Being a medical student myself at the time of the planning of the study, the assumption that all medical students perform very differently in anatomy and physiology was made early in the process. In order to understand why some students do better than others, we need to understand what they are doing differently and, hence, we should focus on the differences.

Phenomenography was chosen as the approach to the problem. This research specialisation targets the qualitatively different ways people experience phenomena around them (Marton, 1981) and would therefore provide a powerful tool when answering the questions. The roots of this research approach, its ontological and epistemological assumptions, and its usefulness in researching learning in medical students, will be elaborated below.

Another important distinction in relation to the perspective of the present study concerns the objects of research. As a research area, medical education is a sprawling ground with a number of methodological approaches used by researchers with educational backgrounds of considerable variation (e.g. Bolander Laksov, 2007). It might therefore be useful to initially sketch the ontological positioning of the study, leaving the detailed accounts of this to later sections of this chapter. Most medical research is conducted around phenomena considered representations of real objects in the real world, for example high blood pressure. The existence of this one common real world, which stands independently of the observer or researcher, and is one and the same for everyone, is implied according to this rationalistic view. If one is uncertain about the nature of the relation between the phenomenon and the "real object"(i.e. between how the object appears and what it is really like), focus is directed to phenomena as perceived through our senses. Following this constructivist line of thought, the existence of the real world is not taken at face value, but might differ

depending on how we choose to see it. The stance of the present thesis is a perspective from the individual medical student: what he or she learns is dependent upon how he or she understands that which is to be learned, i.e. the approach, no matter what the learning task "is really about". (As will be outlined later, it is arguable whether the learning task can be said to mean something in itself, disconnected from a learner). Investigating differences in this area has, furthermore, great potential for adding valuable knowledge to the field.

It is important to keep in mind that we are dealing with two epistemologies here. On the one hand the medical student's world is about what he or she understands medicine to be about, i.e. his or her view of the world. This "epistemology" is a personal one, and all personal epistemologies are equally good as long as they serve the purpose of learning. The student struggles to understand what the world (of medicine) is like. The present research project on the other hand studies learning from a phenomenographic perspective, which implies a non-dualistic ontology. This means that there is only one world, the world which we experience, and hence, that is what we can make statements about (Marton & Booth, 1997).

DESIGN

The present thesis is based on qualitative research interviews, with a supplemented quantitative retention test in study 4. Most of the interviews were conducted at the medical programme at Karolinska Institutet (KI) in Stockholm. In the third article, data from the medical programme at Linköping University was also included to broaden the perspective in a discussion around alignment in educational programmes. The work leading up to this thesis comprises two projects: an anatomy project and a physiology project. The results from the anatomy project are presented in studies I & II, while the physiology project is accounted for in studies III & IV.

Study 1 explores how medical students learn anatomy. It is based on interviews with second year medical students, conducted three to four months after they had finished their anatomy studies. Eight of these students were interviewed once more in their fourth year of medical school – during their surgical rotations – in order to get a clinical perspective on anatomy. These interviews make up the empirical material in study II.

Understanding basic physiology from a clinical perspective was investigated in studies III and IV. Three data sets were used to examine the issue: ten interviews with students from KI, ten interviews with students from the problem based learning (PBL) medical programme at Linköping University, and a quantitative retention test given to nineteen KI students. The results of the retention test and the part of the qualitative data set comprising the KI students' interviews make up study IV. Study III comprises these same interviews, as well as the ten interviews from Linköping University.

PHENOMENOGRAPHY

How do we gain knowledge about the world? This question has occupied the minds of philosophers – and in the last centuries also psychologists and educational researchers – ever since the days of Plato when Socrates tried to guide his disciple Meno into and out of a search for the meaning of the concept of virtue. The resulting discussion led them to a paradox: you can not set out to find something if you don't know what you are looking for because if you were to find it, you wouldn't know that you had found it; and if you knew from the start what you were trying to find then you wouldn't have to try because you would already have knowledge about it. Hence, knowledge about the world is impossible to gain. And yet, we learn (from Marton & Booth, 1997).

This paradox has been answered in a number of ways all found to be inadequate by later generations of researchers. Roughly divided into differing schools of thought, the rationalist tradition states that knowledge ultimately comes from within, while the empiricists claim that it comes from "outside". In the first group we find Plato himself, Descartes and Kant, and in the other line of thought Bacon and Locke (Nordin, 1995).

Ebbinghaus studied the memory by making himself recall increasingly lengthy lists of pairs of nonsense syllables (Ebbinghaus, 1964/1885). This memorising act can be said to deal with learning as a function of repetition, although the experimental setting hardly allows for an attempt to answer the question posed above. Later, psychological research into learning from a cognitivistic perspective has oriented itself around the division between the outer reality and the inner construction of it in the form of internal representations and other hypothetical mental structures. This failure to combine the "outer" with the "inner" seriously hampers the psychological cognitivists' explanatory power in answering the question of how we develop knowledge (Uljens, 1996; Marton & Booth, 1997). The key is a pragmatic one: the world from the learner's perspective is the world he or she experiences. There is not….

"...a real world "out there", and a subjective world "in here". The world is not constructed by the learner, nor is it imposed upon her; it is constituted as an internal relation between them. There is only one world, but it is a world that we experience, a world in which we live, a world that is ours". (Marton & Booth, 1997, p.13)

In an era when much of the research into learning was carried out from a quantitative perspective, in which most testing consisted of measuring the amount of knowledge acquired, a new approach – phenomenography – was focusing on the qualitative aspect of learning. In a quantitative study, the result – or outcome – of the learning process is expressed as *how much* has been learned, while the qualitative study tells us *what* has been learned. The difference may also be formulated as a shift from a horizontal description of alternative points of attention in the learning material onto which educational efforts can be imposed to direct the learner, to a vertical description of a distribution of attention, revealing the true content of learning (Dahlgren, 1975).

The Content of Learning

In marking a distance towards the prevailing research tradition in which the activity of learning was referred to psychological structures of dubious ontological status, the strive for describing the outcome of learning in terms of its content became the phenomenographic creed. In search for the content of learning, the quest had to consist of a description of what is happening in the interaction between the learning individual and the learning task. This meant performing two seemingly contradictory acts at the same time: a focusing of attention on the learning act (*how* the actual learning is best described) and taking a step back to consider the whole possible range of learning activities (*what* kind of learning is actually taking place in a specific situation). These two central aspects of learning will be elaborated on later.

The straightforward way of conducting such an enterprise was to talk to the subjects and let them describe their learning from their own horizon. The shift of perspective from the quantitative measurement "from outside" the individual, to a qualitative view "from the inside" could describe the learning from the learner's point of view. An influence from Piaget's research into children's thinking can be detected here, as he also described the development of knowledge from the perspective of the learner (Piaget, 1952). Another central assumption that inspired early phenomenographic studies is the individual's search for meaning in the learning material, put forward by the Gestalt school of thought (Gurwitsch, 1964). When it comes to learning, this meaning is not to be found in the text itself; it is to be created.

The focus of investigation was thus directed towards the learning individual, how he or she set about learning and what they understood the learning task to be about, i.e. the approach to learning. Since most learning in educational settings is about reading, the experimental layout adopted in the first studies was an individual text reading session followed by an interview. In one such study, the concept of study skill was empirically studied (Svensson, 1976). Study skill was functionally defined as the organisation and adoption of a specific activity in order to reach a postulated learning goal. The author found cognitive approach to be the most important factor in the development of study skill, super-ordinate to knowledge of terminology, concepts and study technique. Two alternative approaches were found: a holistic and an atomistic, the former related to an overall understanding of the message of the text and the latter to a focus on parts of the text and the whole as a combination of these parts. Although a holistic approach was related to academic success, several courses did not demand such knowledge; in fact, much of the schooling system seemed to foster an atomistic approach (Svensson, 1976). By their nature these findings could not be measured on a quantitative scale, instead they referred to qualitative differences and had to be dealt with as such.

Qualitative Differences in Learning

Results of several studies into student learning pointed towards the importance of evaluating learning with qualitative parameters, as opposed to the free-recall paradigm used by Ebbinghaus and others (Tulving, 1964; Marton, 1970), as this methodology delimits the field of investigation to a narrow range of predetermined facts up for

testing. In the field of psychology, the level of processing a learning task (Craik & Lockhart, 1972) had been introduced to describe differing mental solutions for dealing with knowledge. Although constructed in another ontology, deep and surface levels of processing were found suitable to assign to students' approaches to learning. As this dichotomy points to a variation in a qualitative rather than a quantitative dimension, the outcome of learning must be described in a similar way (Marton & Säljö, 1976a). The relation between level of processing – or approach to – and outcome of learning was investigated in another experimental trial which focused on manipulation of the subjects, either to deep level or surface level processing (Dahlgen, 1975). Students were randomized into two groups and given a text to read. The experimental group had questions about the meaning bearing elements interspersed in the margin of the text. Paradoxically these students performed inferior to the control group students on a following test of understanding. When reading the next unprepared chapter they did, however, outperform the controls on the following interview. Even without manipulation, it was found that a deep approach to reading the text was associated with understanding of its intended message, whilst a surface approach was associated with miscomprehension (Marton & Säljö, 1984). Thus, not only the approaches to learning, but also the outcome of learning could be described in terms of qualitative differences.

In another study about text comprehension, Säljö (1975) found that experimental manipulation by means of imposing different kinds of questions to different groups of subjects after reading sections of a text resulted in qualitatively different outcomes, and he also described the functional relationship between level of processing and level of outcome. Students directed towards a surface approach in the experiment relied more on reproduction in their answers, while their deep approach counterparts showed a more conceptual understanding. On a recall test immediately following the experiment, a surface approach proved functional as students from this group answered some questions more accurately, but on delayed recall deep approach students achieved far better results.

A similar design – a text with directed questions after each chapter for experimental and control group – was used by Dahlgren (1975), in examining students' conceptions of basic concepts in Economics. Likewise, these students were found to hold conceptions about economic principles according to diminishing complexity: distinct qualitative levels of outcome depended on the number of factors considered during the reading of the text. As in several of these studies mentioned above, a worrying observation was the widespread prevalence of misconceptions after the experiment, which led to a criticism of the schooling system fostering such a superficial approach to learning. As a solution to the problem, it was suggested that close attention was to be paid to the respective learning content of different subject areas and to focus research into learning on these contents (Dahlgren, 1975).

The studies referred to above formed the basis of what was later to be called phenomenographic research, coined and consolidated by Marton (1981). Although many of the later studies carried out under it's label differ in terms of basic assumptions and mode of analysis (Hasselgren & Beach, 1997; Svensson, 1997) they all share the same basic outline: to map the qualitatively different ways in which a certain group experience a certain phenomenon. The fact that the outcome of learning may be seen

as a function of how the learning task is experienced – and therefore tackled – has been repeatedly confirmed in several settings (Säljö, 1982; van Rossum & Schenk, 1984; Martin & Ramsden, 1987; Fyrenius et al., 2007) and also accounts for its popularity. As more and more studies explored how people conceive or experience different phenomena, it appeared that they did so in a limited number of ways (Marton, 1996).

Experience and Conceptions

The unit of analysis in phenomenography is conceptions, or ways of experiencing. The quest is to discover the conceptions held by the person regarding a specific question of interest and to describe them as faithfully as possible (Francis, 1996). The data arrived at is of a second order perspective, which means that it is the subjects' understanding of the phenomenon which is investigated rather than the phenomenon itself. The second order perspective relates to ontological and epistemological assumptions within the phenomenographic perspective. The rationale is that the conceptions held by a certain group of people regarding a phenomenon help define that phenomenon as an internal relationship between the phenomenon and the person who experience it (Fyrenius, 2006). Knowledge is then to be found in the internal relationship between the learner (experiencer) and the world (the experienced) and learning about that world is to experience it in a different way compared to before, i.e. a change in conceptions (Booth, 1997).

The ontological status of the conceptions has been a subject of debate (e.g. Säljö, 1996; Hasselgren, 1996). Since most phenomenographic studies are founded on data obtained from interviews, it is crucial that the conceptions are securely identified in the discourse between the interviewee and interviewer. The conception is not regarded to be ready available for the researcher to bring out from the mind of the interviewee. Rather, the conception is there as an internal relation between the person and the world embedded in the conversation between them. More of an attitude than an opinion, it is sometimes implied and often unarticulated (Svensson, 1997).

Bowden (1996) has argued that the basic delimitation between a conception and the category of description within which the conception is found is that the category of description describes, as faithfully as possible, the conception(s) it refers to i.e. the category comprises a label to characterise a conception and a description thereof. In the interview situation, the conception is seen as "unarticulated", or "implicit", and is brought into awareness by the mutual reflection of interviewee and interviewer. It is a matter of levels of abstraction: if the conception is the interviewee's way of thinking about something, then the category of description is the researcher's way of describing that conception (Marton, 1996).

By making the conceptions – or ways of experiencing – the focus of investigation, the problem with a dualist view of learning (a real outer world perceived by the inner human mind) is avoided (Marton, 1996). One does not need to account for the transforming of the outer world to be experienced in the human mind, since there is only one world, not two (one experienced and one "real"). Instead, the origin of the conceptions becomes the centre of attention.

Ontology and Epistemology in Phenomenography

As already mentioned, inspiration from older and more established schools of thought can be detected in the theoretical apparatus of phenomenography. The view of learning as defined by its content draws on Piaget's (1952), Vygotskij's (1978), and Gestalt psychologists' writings, the structure of awareness draws on Gurwitsch's (1964) concepts of theme, thematic field and margin; as in the latter case, most terminology originates from phenomenology. However, phenomenography takes its starting point, not in deduction of meta-physical statements from other theories, but from reality. Focus is on the empirical situation at hand and the necessary tools to deal with it come second (Svensson, 1997). The learner's experience of the world has priority over theoretical constructs.

As has already been touched upon, phenomenography marks a distance to other representational cognitivistic theories through its non-dualistic ontological stance (Uljens, 1996). The dualistic view implies the existence of at least two different worlds, one populated by objects, and one made up of mental models of those objects. Some kind of connection between the object in the real world and its representation in the mind is furthermore necessary to be able to judge the accuracy of an experience of the outside world. However, this evaluation of whether the experience corresponds to the outside world or not, needs to be performed from an independent viewpoint (the homunculus problem). Since no such "third part" can be found in a dualistic ontology, we are left with a problem about how we are supposed to find anything out about the world. In other words, it becomes impossible to reunite person and world after they have been separated (Marton, 1996).

The phenomenographic alternative is a world, which is both constituted by one's own experiences of it, whilst at the same time it is one and the same for all – a merging of the dualism. Everyday objects do exist, but they do so through our experience, and not by virtue of their own. This position is a kind of combination of the rationalistic view of the world (existing independently of our view of it), and the constructivistic view (an individually constructed world on the basis of our experience of it). It means that there is only one real world, and we only have access to it through our experience of it. It is therefore nonsensical to talk about it in a way that does not take the experience – or descriptions – of it into account, since the description, the describer, and that which is described can not be separated (Marton, 1996; Marton & Booth, 1997). This is referred to as the internal relationship between the person and the world, and is defined as a dual relationship in which one part is no longer the same once its counterpart is missing. The person experiencing the world could not be the same without it because her actions in it must be based on how she perceives it; neither would the world be the same, given that it is understood as the sum of all possible ways of experiencing it (Marton, 1996). Here also lies the fundament of why we must trust what the interviewee says: it seems impossible to act in the world in a way other than according to one's experience of it. And, similarly, the way we talk about the world – or any phenomenon within it – reflects our experience of it. This experience cannot be true or false. It is one aspect of the world as perceived by someone, and therefore, one active attempt to understand it and participate in it.

In relation to phenomenology, the phenomenographic view of the world marks a contrasting standpoint regarding the ontology as well as purpose of investigation, while displaying an essentially akin one regarding our possibilities to gain knowledge about it (Abrandt, 1997; Marton & Booth, 1997). This latter idea has to do with the notion that the nature of the world needs to be examined through human experience of it. Taking the point of departure in people's experience of phenomena in the world around them thus unite the two approaches, although they do it in slightly different ways. While in phenomenology the search for the true essence of a certain phenomenon is undertaken, a phenomenographic study would focus the critical differences in experience. In phenomenology, an objective reality, independent of the learner is accepted. In phenomenography, the existence of an objective world comes second to the world as perceived by a learner. The study of reality has to start with our experience of it.

In the non-dualistic ontology, the ontological question is related to the epistemological question. Since the way we gain knowledge about the world is essentially dependent on how we experience it, and our experience of the world represents the internal relationship that constitutes it, then our experience of the world (epistemology) and the world (ontology) have become one. This is reflected in the nature of conceptions: a conception or a way of experiencing something is essentially relational (Svensson, 1997); the person and the world are ontologically connected through their internal relationship.

The pragmatic feature of phenomenography is connected to its ontology. For educational purposes we are forced to deal with learning situations depending solely on how people experience them. It is not so much a question of what the learning task is about since it is unavoidable that people will learn according to their view of what they are learning about.

Variation in Learning

Recent development within the phenomenographic movement has taken a more theoretical direction. This was partly due to internal criticism (e.g. Säljö, 1997) regarding the mode of obtaining data in relation to the object of research; whether interviews capture the experiences or elements of contextualised discourse; in other words, whether the second order perspective can be used to make statements about the phenomena as *actually* perceived by people. What makes us trust the interviewee's utterances as reflecting true experience and not just discursive elements of jargon? This increased emphasis on methodological awareness among phenomenographers led to intensified work around the structure of awareness and, in connection to that, the birth of the theory of variation.

Since focus is directed towards qualitatively different ways of experiencing, the question regarding reasons for this fact comes naturally: why is it that people experience things in a limited number of different ways? This is explained with reference to the structure of awareness (Marton & Booth, 1997) and underpinned by Gurwitsch's (1964) concepts of theme, thematic field and margin. The theme is the

object of focal awareness, that towards which the mind is directed. But it is always related to its context:

The appearance of a theme must be described as emergence from a field in which the theme is located occupying the centre so that the field forms a background with respect to the theme. (Gurwitsch, 1964, p. 319)

In a learning situation, the thematic field is constantly changing depending on aspects of relevance in relation to the theme, bringing about a continuous rearrangement. The theme might mean one thing to the learner if it is seen to have emerged from one specific thematic field, or something completely different if emerged from another. For example, one thematic field is the geographical surrounding in which the learning is taking place, another is the educational demand on the learner, a third is defined by what relevance the knowledge might have in the future, and so on.

Another terminological distinction used to define the object of research in phenomenography is the internal and external horizon of the phenomenon. The internal horizon of the phenomenon denotes its constituent parts and the relations between these parts, as well as its defining contours. The external horizon denotes the surrounding from which it is discerned, including its contours. For instance, the internal horizon of the phenomenon of anatomy is the whole human body as defined by its outer contours and internal relationships between organs. Its' external horizon is the background from which it appears, the surgical scenario in the operation theatre or the clinical examination situation in which a certain muscle is examined. The external horizon and the thematic field are thus connected in their shared aim to define the background from which the phenomenon is understood. These are all qualities of the phenomena and our awareness of them that make it possible to experience the phenomena in qualitatively different ways.

According to a phenomenographic view of learning, a third feature of our awareness is the intentionality of the mind. This line of reasoning owes inspiration from Brentano (Uljens, 1996) and states that every mental act is directed towards something beyond itself. In learning about anatomy, for example, my mind is directed towards the subject of anatomy as I experience it. It is considered impossible – or at least, pointless – to view learning as something detached from its content. It comes with the intentionality of the mind that learning can be divided into a what-aspect and a how-aspect, an idea, which has been present in this tradition for decades. But, since that to which the mind is directed and the actual object of learning are not necessarily the same, the how-aspect can be said to consist of the act of learning and to that which the learning act aims at. This latter part of the how-aspect is called the indirect object of learning, and takes into account differences in the quality of the act of learning.

Similarly, experience is said to have a referential aspect, denoting it's meaning – or what is experienced – and a structural aspect, describing how it is experienced. The latter is subdivided into the internal and external horizon of the phenomenon. It is possible to understand the concept of intentionality (learning) with the corresponding how and what aspects of learning as complementary to the structure of awareness (experience) comprising a structural aspect and a referential aspect (Harris, 2010).

Learning from a phenomenographic perspective is about a change in the way of experiencing a phenomenon. Learning has occurred when the same phenomenon (be it anatomy, physiology, speaking a language or playing the cello) is experienced in a qualitatively different way than before. As explained above, our ways of experiencing differ depending on what we focus on, what we bring out as important in a given situation. These critical aspects of the phenomenon that are present in focal awareness is what define an experience.

What has been discussed so far is primarily the variation in different people's ways of experiencing a certain phenomenon and, secondly, the variation of critical aspects of a phenomenon brought up to result in the specific experience. These two theoretical elements have been referred to as "the two faces of variation" in phenomenography (Pang, 2003). Understood from this horizon, phenomenography can be said to have dealt with variation since the start. Hence, it is a matter of discernment. The ability to discern aspects or features of a certain phenomenon in a given situation determines what kind of learning is possible. Which aspects are discerned is a matter of variation, since every aspect of the phenomenon is experienced in a dimension of variation (Runesson, 2006).

Phenomenography in the Present Study

In the first two studies of this thesis, phenomenographic analysis is used to describe how medical students learn anatomy (Wilhelmsson et al., 2009), and what they perceive anatomical understanding to be about from a clinical horizon (Wilhelmsson et al., 2010a). In studies III and IV, this involved stretching the method to its limits. As we shall see, these studies investigated senior medical students' understanding of a basic science concept explained in a setting involving several consecutive events. Given the amount of knowledge that was required, it was necessary to guide each student with different degrees of probing questions. This steering converted the interview into a dialogue, where every statement made by the informant had to be interpreted in the light of what had just been said by the interviewer.

Participants in studies I and II were recruited according to a stratified sampling procedure. To achieve spread among students and thereby comprehensiveness in the data material, all students were chosen from three strata dependent on their result in the examination. Thus, all the possible conceptualisations were more likely to be brought up. All the interviews were performed by the present author, as were the first set of transcriptions. This enabled a close relation to the data and facilitated the primer analysis through detailed knowledge about the interview transcripts. In all, twelve students were chosen to be interviewed for study I, which was considered a sufficient number. The questions around which the interview evolved regarded the approach to and perceived content of studying anatomy (see appendix for the set of questions). Study II focused on the understanding of anatomy from a clinical horizon and the questions were consequently more oriented towards usefulness and relevance (see appendix).

Phenomenographic analysis of interview transcripts has been described in great detail (Dahlgren & Fallsberg, 1991; Abrandt, 1997) and consists of capturing the qualitatively different conceptions experienced of the phenomenon under investigation and ordering them into groups that later become the categories of description. In all four studies reported in the findings chapter, the following description captures the procedure specifically. The interviews are first subjected to *familiarisation*, in which the researchers acquaint themselves with the content. This is necessary to ensure that the transcribed interview corresponds to the recorded one. A *condensation* of the material is then undertaken in order to delimit the meaning-bearing elements. The decision concerning what should be considered a significant part of the answer was made according to a formula suggested by Rahimi (1995); significant utterances are those, which are mentioned early in an answer, those that are mentioned several times and those that are elaborated upon spontaneously. The next phase consists of a *comparison* between the selected sections with respect to similarities and differences. This step requires the identification of the central aspects of the phenomenon that are in the informant's focus. When the variation between these aspects has been made clear, the answers are *grouped* into what is to become the categories in the next step. At this stage, the researchers contribute to the refinement of the category by *articulating* its content. Up until this point, all content has been made up of verbal expressions of the interviewee. In the researcher's articulation of the group of answers constituted in the previous step, the group becomes a category of description. In stages 3-5, (comparison-grouping-articulating) an iterative process takes place, as the boundaries of each category are established. The categories are then *labelled* according to their respective content, and finally *contrasted* against each other to determine each category's respective placement in the total outcome-space.

In study III, the same methodological procedures as described above were applied. However, the nature of the question demanded an unorthodox handling of phenomenographic interview technique. The task consisted of producing an elaborate explanation to one single question, and put great demands on the interviewer seeking to expose all angles of this complex physiological scenario. The amount of steering – or probing – involved in the informant's process of arriving at an answer was consequently included in the analysis. The nature and impact of probing strategies have been described as: repeating, request for clarification, request for elaboration, request for confirmation (Abrandt, 1997), ordered by increasing input from the interviewer on the interviewee's reasoning. The three interviewers used in this third study were experienced senior clinicians, but none of them an expert level physiologist. The fact that different interviewers performed the interviews gave a valuable opportunity to compare different interview transcripts regarding the role of the interviewer.

The transcripts were analysed with the help of phenomenograms (see appendix) depicting a compromised version of each explanation. The boxes represent coherent, self-sufficient sections of knowledge taken charge of by the interviewee in order to answer the question. They are causally linked or juxtaposed, indicated by the arrows (causal link) or lines (juxtaposition) or not linked at all, but mentioned. When the phenomenograms had been constructed, the explanations were assessed depending on depth, breadth and stringency.

In study IV, a mixed method approach was used in contrasting the categories of description denoting the various ways of understanding physiological fatigue with retention of basic science. The test consisted of basic science questions from several subject areas, such as biochemistry, histology, anatomy and physiology. It consisted of two parts, each comprising a situational theme with questions associated. The participating students had taken all four parts three years earlier, as part of their pre clinical examination. The test was subjected to analysis by the revised Bloom's taxonomy.

TRUSTWORTHINESS IN QUALITATIVE RESEARCH

Phenomenography is a qualitative research approach. This means that it makes use of the researcher in the researching process in an integrative way; he or she is not regarded to be an observer independent of the phenomenon researched. While quantitative methods test hypotheses and predict the outcome when a specific set of variables is changed, qualitative methods seek to describe and understand a certain topic by rich descriptions (Denzin & Lincoln, 1994). Different methods provide alternative ways of approaching the problem and are judged by their ability to contribute something substantial to human experience of the world. Quantitative criteria of rigour are replaced with other more appropriate ones, and some are abolished completely; objectivity, for instance, is not an aim in itself in qualitative research. Such replaced principles include internal validity, which is replaced with credibility, in which a transparent description of the data gathering and analysis ensures truthfulness of the findings. Instead of objectivity, confirmability is used to display a neutral and solid connection between data and findings (Larsson, 2004). Generalisability is also replaced by transferability; by situating the research in its right context and interpreting the findings within the same context, the extent to which the findings depend on the context are elucidated. The term "moderatum generalisations" has been suggested to clarify the delimitation against total generalisations used in physics and chemistry, as well as statistical ones used in, for instance, epidemiology (Williams, 2000). These are not given by the laws of nature, or expressed with a mathematically calculated certainty. Instead, the transferability of the findings is dependent on the degree to which one is able to identify aspects of the findings that "can be seen to be instances of a broader recognizable set of features" (Ibid.).

Within medical education, four critical characteristics to ensure trustworthiness in qualitative studies have been suggested; participant selection, appropriate method, comprehensive data collection process, and findings corroborated through member checking or comparison with theory (Giacomini & Cook, 2008). In the present study, this is accomplished in the following way. Careful selection of medical students has been carried out, acknowledging the specific features they need to exhibit in view of the research objectives; the group interviewed was composed to secure breadth of experiences regarding the phenomenon. Furthermore, not one student lacking the necessary experience was interviewed. The method chosen is well established in educational research and medical education. It targets differences in approach and experience, and delivers useful results on a high level of abstraction. The use of semi-structured interviews allowed for rich and robust descriptions of the findings, and it is

unlikely that any central aspect of the phenomenon has been left unexamined. Finally, the analysis of all four materials was performed within the research group comprising expertise from educational research, medicine and medical education. Furthermore, as the analysis has proceeded, findings have constantly been compared with emerging theoretical proceedings within the phenomenographic movement.

V. FINDINGS

The present investigation comprises four studies. They are all concerned with the longitudinal perspective employed here, but they also emphasise different research questions. Study I represent the start of the project and is an inquiry into second year medical students' learning of anatomy. In study II the understanding of anatomy from a clinical point of view is emphasised; the same students that were interviewed in study I give an account of what they perceive anatomical understanding to be about, three years after they completed their anatomy studies. The last two studies are focusing on physiology and are based on interviews with final year medical students about a basic science problem. Study 3 examines in detail the accounts of the basic science problem of twenty medical students, ten from the conventional programme at Karolinska Institutet and ten from the PBL curriculum at Linköping University. Study IV focuses on the relation between understanding of a basic science problem analysed according to the phenomenographic approach, and result on a retention test. Below, summaries of the findings in the four studies are presented.

STUDY I. LEARNING

This study describes medical students' learning of anatomy from a phenomenographic perspective (I). The interviews targeted what the students perceived they had learnt while studying anatomy, i.e. what the study of anatomy is really like or the *referential* aspect of it, and, secondly, how they learned what they learnt, i.e. how they set about learning or its *structural* aspect. In other words the questions posed to the participating students were directed in order to arrive at an answer to what it means to learn anatomy. Following the phenomenographic perspective, the students voiced not just their experience of learning anatomy, but also essential characteristics of anatomy as a discipline, its approachability, its appearance to the learner.

The students described how they created meaning in their study of a subject area that does not offer many meaning-rendering elements itself. A variety of difficulties were heard, all pertaining to a central duality of anatomy as a subject area: the two faces of details and whole. By its nature, anatomy has a splintered identity represented by the human body of anatomical parts conceived as a whole on the one hand, and a detailed list of all its constituent parts, more resembling a telephone directory than an integrated system, on the other. This central identity coloured the students' conceptions of learning anatomy and was held crucial for comprehending it.

The categories describing the conceptions held by the students about learning anatomy also bear witness to the duality of anatomy as they are all influenced by it, especially the first two. Three categories of description were found: (i) *Memorising*, (ii) *Contextualising*, and (iii) *Experiencing*. The latter two have sub-categories indicating the richness and variety of the students' experience. Contextualisation was achieved through (a) intra-anatomical linkages, (b) trans-disciplinary linkages or (c) professional linkages. In the third category, experiencing, anatomy was approached either through (a) visualisation or (b) reality-anatomy.

Learning anatomy as *memorising* is a straightforward rote-memorising approach in which anatomical Latin terminology plays a crucial role. This way of conceiving of anatomy often resembles learning a new language, where the syntax was initially impenetrable. The scope of the anatomical enterprise as it has developed through history – the detailed naming of all body parts of relevance (and also those without relevance) for reasons of completeness – represents a huge task if learning anatomy is conceptualised this way. As was expected, most difficulties with anatomy as a subject area were voiced in connection to this feature, but a positive side to it is also traceable. The grammatical side to anatomy can after a certain point also facilitate learning in providing the necessary framework.

Often, *memorising* anatomy was seen in connection with various sorts of imposed structure on anatomy, the frequent use of mnemonics being the most obvious one. The use of imposed structure points towards a basic lack of meaning bearing elements in the subject area itself. Had there been an accessible knowledge structure for the learning of anatomy, no such other imposed structure would be called for.

The second category – *contextualising* – denotes rather the reverse of its prior neighbour. As opposed to the first category, in which the single anatomical structure is treated as a self contained entity, this category emphasises learning anatomy as set in a context that provides its meaning. Conceptions about the importance of contextualising anatomy were frequently heard during the interviews. The contextualisation was often performed through reference to the close surrounding area of the anatomical structure that was to be learned – *intra-anatomical contextualising*. That particular site was treated as a whole and its constituent parts rendered meaning through inter-relations. By necessity, conceptions found here are globally oriented rather than towards particularities and give priority to grasping wholes over detailed knowledge. However, it does not have to include the whole human body. The three-dimensionality of the human body is likewise emphasised, as such a view is the inevitable path to its comprehension as an inter-related system.

An additional way of contextualisation was to create connections between the anatomy and other areas of medicine – *trans-disciplinary contextualising*. The anatomical site is here comprehended in relation to its role in a biological reality, in interaction with physiological or pathological processes. This way of contextualising anatomical knowledge establishes a frame for interpreting its *raison d´être* in a specific location through its function. The notion of function was held central to learning anatomy in general, and is captured most clearly in this category. Contextualising across disciplines also lends the anatomical part to a greater whole, thus injecting it with meaning. It was found that although the interviewed students had very limited clinical experience, there were numerous spontaneous references to clinical situations in connection with anatomy; pathological dysfunction was as present as physiological function. The clinical reality of a practising physician treating patients is the focus of the third form of contextualising – *professional contextualising*. The references to the clinic made above are a core conception here, resulting in a frame of relevance and motivation in learning

She	**L**ikes	**T**o	**P**lay	**T**ry	**T**o	**C**atch	**H**er
Scaphoideum	**L**unatum	**T**riquetrum	**P**isiforme	**T**rapezium	**T**rapezoideum	**C**apitatum	**H**amatum
1	2	3	4	5	6	7	8

Illustration 4. Anatomical sketch over the bones in the hand illustrated by a mnemonic.

anatomy. Anatomical function is related to diagnosis and patient care, rather than an instrumental view of the human body.

A third category emphasises richness of real-life anatomy instead of theoretical and functional aspects – *learning anatomy as experiencing anatomy.* In the experiencing lies the implied use of perceptual senses, through which anatomy is perceived. The first way of doing this is by *visualising* an anatomical site, either through dissection or with the help of mannequins or textbooks. By studying such representations an inner picture was created, serving the purpose of creating a whole. Not only the understanding of the whole was facilitated this way, but recall of detail was also reported to be more fluent. *Reality anatomy* is a second aspect of this category, describing the various features of realness experienced. It is contrasted with mannequin anatomy or textbook anatomy, which are not considered to have as much "reality value"; even though these can be helpful in learning, the true anatomy is revealed in the meeting with dissection, and medical imaging. Insomuch as the anatomical aspects of physical examination are present, there is no clinical application to be found; the anatomical experience is more of an end in itself, and less of a means to provide a basis for clinical medicine.

It was found that the interviewed students prime concern in learning anatomy was the creation of meaning. The categories of description should be seen as different attempts to do so. Achieving meaningfulness in the area of anatomy seemed to be a great challenge due to its disciplinary characteristics: completeness at the expense of comprehensiveness. Furthermore, the architecture of the area results in a duality when it is approached from a learner's perspective: the two faces of details and wholes. Because of the power of this duality and the risk of a uni-dimensional apparition, variation in learning is suggested as a means to reaching a qualitative understanding. The entirety of anatomy is deceptive; constructing anatomy as a self-contained subject area might be risky, since it seems to be experienced in close relation to other areas. Another perspective is called for; as the field of anatomy itself is organised according to biological principles, the knowledge about it is organised around principles of learning.

STUDY II. UNDERSTANDING

In study II, the field of anatomy is revisited in a clinical context (II). A retrospective view is set when the same medical students that were interviewed in study II, give an account of anatomical understanding. Understanding was in focus because of the outline of medical education, in which understanding of basic science areas like anatomy might be assumed to evolve later on in medical training, but also since anatomy provides a sound foundation to describe the relation between memorising and understanding, as seen in study I. Investigating the development of understanding in an area which is inherently difficult to create an understanding of, appeared to be a promising and fruitful undertaking. To a large extent, the findings from this study represent surrogate understandings, as an anatomical understanding defined solely in terms of anatomical knowledge could not be traced in the interviews. The kind of anatomical understanding referred to in the interviews has developed in relation to

other areas of medicine and was not established during the anatomy course. It stands in close connection with concepts like causality, meaningfulness and relevance.

Four categories of description depict medical students' understanding of anatomy from a clinical point of view: (i) *Contextualisation*, (ii) *Visualisation*, (iii) *Selection,* and (iv) *Anatomical language*. The first category is an echo from study I, but bears a somewhat different meaning in this setting. Seen through the experience of four years of medical training, contextualisation is described as the degree to which anatomy has been integrated in a more general understanding of the mechanisms of health and disease. To view an anatomical structure as part of a more comprehensive whole implies a change of perspective, which was brought up as an important means to achieve understanding. Depending on how much "anatomical identity" anatomy was left with when a clinical understanding was to be construed, the contextualisation was either *horizontal* or *vertical*, the former describing the enriching of other areas by anatomy, and the latter emphasising contributions by other disciplines to an understanding of anatomy. In horizontal contextualising, the time factor is important. As subsequent areas of medicine add knowledge during the medical curriculum, the meaning of anatomical understanding is found in relation to these neighbours. Anatomy is not a well-defined entity anymore. In an act of vertical contextualisation, the same essentially relational character of anatomical understanding is acknowledged, but the integrity of the field is preserved. Other areas bring up aspects of anatomy and provide instruments for understanding.

Visualisation reappears as a category of description in a clinical context. It is still distinguished by its central inner picture, which creates a frame of provisional wholeness to enable understanding. Both real surgical scenarios and representations in textbooks are mentioned. Similar to vertical contextualisation above, this category allows for anatomy to be comprehended within its internal horizon, as anatomy is delimited and defined by its borders to other disciplines. This is not the case when it comes to horizontal contextualisation, since not only the borders, but also the content of the phenomenon of anatomy is described in terms of other disciplines.

The obvious fact that the perspective is a retrospective one is thoroughly taken charge of in the third category. *Selection* describes the perceived usefulness of anatomy, its relevance for the clinic, and promotes a longitudinal view of knowledge refinement. As when a gravy is left to simmer and reduce so that it acquires the right texture and intensity, so is anatomy reduced down to the essentials. Only the relevant parts of what was learned are left. Active selection takes place when anatomical knowledge is retroactively prioritised through aspects of it being brought to the fore by clinical circumstances. Passive selection is the absence of such prioritisation and results in an omitting of sections of knowledge. Anatomical understanding is the tightly connected body of knowledge that is the result of the selection process.

Finally, the semantic feature of anatomy is the basis of the fourth category – *anatomical language*. This category too, is an echo of the memorising category from study I, and – as visualisation – still reminds of the same core trademark. Viewing anatomy as a language is here provides a means to connect it to understanding through its linguistic features. Although still an inadequate way of achieving a thorough

understanding, it was reported to help recall. If anatomical language was characterised as a foreign language by the memorisation category, this category rather has the features of a functional mother tongue to it.

STUDY III. TRANSFORMING

In the third study, interest is directed towards the learning of physiology, but it is done in an indirect way. In exploring the representation of basic science in medical students' clinical practice, a clinical case was chosen and the basic science content of the students' understanding of that case investigated (III). The question posed to the participants was: *Imagine a person on an exercise bicycle. Why is it that the onset of fatigue is so sudden when the workload is increased gradually?* The students produced lengthy accounts of the chain of events that are embedded in the scenario and were encouraged to explain it in terms on physiology. As explained in the method chapter, the analysis of the transcripts included careful attention paid to the role of the interviewer, as one sole question was in focus. In the interview situation, the technique required extensive probing of the core question and substantial knowledge of clinical and preclinical medicine. Some aspects of the methodological procedure will be presented in this section, as they constitute findings albeit on a more theoretical level.

The phenomenographic analysis of the transcripts resulted in three hierarchically ordered categories of description. This means that the content of a category of lower complexity is implicit in a higher category. The categories found represent decreasing completeness as to the basic science content, and focus on qualitatively different aspects of the phenomenon. Due to the nature of this phenomenon – muscular fatigue – the categories are labelled according to their content rather than to a specific aspect. As opposed to the categories obtained in studies I and II, these are personal in the sense that a whole interview is assigned to only one category. The nature of the question made this necessary, since all interviews had to be analysed as a whole. Because of the existence of a correct answer to the question, it should also be emphasised that the analysis focused on the students' different ways of understanding a physiological phenomenon, and did not assess it according to a preconceived template.

A successful explanation of the situation is presented in the first category: *A chain of mutually interdependent physiological and biochemical sub-mechanisms* (A). The sub-mechanisms referred to are areas of physiological processes considered in order to cover as much as possible of the field. The interdependency of these represents the central causal nature of the category; the disposition of the answer is designed to account for the causal linkage between all areas included, in order to achieve alignment. Naturally, the nature of the linkage or interdependency, apart from being causal, is also stressed in this category. This is true because a causal relation not only accounts for a dependency, but also invites a description regarding in what way the dependency results in changes of the systems involved. Notions put to the fore in this context were threshold and equilibrium. These concepts describe the consequences of the causal connection and are central to the category. The fatigue experienced on the exercise bicycle was conceived of in terms of a displaced equilibrium. Since focus is directed towards the governing principles in the chain of events, those aspects

displacing the equilibrium are arrived at first, while other aspects come second. However, answers found here do not lack completeness in terms of preciseness, rather, it seems that the elaborate account of the principles resulting in the experience of fatigue also carry the relevant details.

The second category is denoted: *Juxtaposed physiological and biochemical mechanisms* (B). As opposed to the first category, where connecting sub-systems were the path to a final answer, this category emphasises the completeness of the reported systems. The same systems are accounted for respectively in roughly a similar way, but the causal link is missing, or at least not in focus and never of a two-way type. One system might affect another, but the counter-effect is not taken into account. Earlier, the equilibrium was displaced due to the reaching of a threshold; here the same process is described as a fuel tank gone empty. The reason the fatigue set in, is that the system run out of combustible substrate. The answer is arranged to incorporate as many factors as possible leading to the fatigue, at the expense of their internal relationship. As the preoccupation is with juxtaposing factors affecting the system in the same direction, not taking into account the balance so crucial for the human organism, this category represents a simplified answer.

In the third category, explanations are found which are in most ways unable to account for the full complexity of the situation. It is labelled: *Fragmented physiological and biochemical mechanisms* (C). As a consequence, it represents an inversion of the prior two categories. Characteristic of explanations found here include sparseness and ambiguity in terms of medical diction; precision is lacking and general expressions without medically relevant terminology are used to explain complicated processes. As the label indicates, there is a certain compartmentalisation of the knowledge. Reasoning is at times correct, but there is a limitation as to the range. The boxes depicted in the phenomenogram are not connected, but fragmented. Clinical medicine was often taken charge of in filling the gap created when the basic science could not be mobilised. An example of such a reasoning is shown by the different "kinds" of fatigue the person on the bicycle could experience: a muscular fatigue in the legs, being "short of breath" in the lungs, and a "heart" fatigue felt as a pressure over the chest. These are clinical signs, observed to guide the physician in the differential diagnosing of ischemic heart disease, and crucial as such, but of very limited relevance in explaining the situation at hand.

Through the approach outlined in the methods chapter, it was possible to use phenomenography to depict the qualitative content of the students' understanding of a physiological scenario, and the differences between these understandings. This required a careful analysis of the steering necessary for the student to arrive at an acceptable answer, and includes the use of several different probing techniques. Thus, the interview evolved into more of a conversation between peers, since the target of the question was always crystal clear. Contrastingly to most phenomenographic interviews, where the aim of the question can sometimes be perceived of as vague by the interviewee, this situation carried no uncertainty as to the right answer. It also highlights the importance of an appropriate composition of the analysis group, as several perspectives on the issue under investigation are preferable in order to evaluate the respective contribution of interviewer and interviewee.

STUDY IV. FORGETTING

In the last study, the categories obtained in study III are contrasted with a retention test given to a group of final year students at Karolinska Institutet (IV). This was done in order to relate the nature of the findings in study I, III, and III to the practice of assessment in medical school and other research areas. Since the conduct of phenomenographic analysis had been carefully considered, an analysis of the test according to the revised Bloom's taxonomy was also performed. The group (n=19) was found representative of their whole year cohort through comparison of initial results on the examination that was used as retention test. Average retention was approximately 60%. Depending slightly on the definition of the questions, this result is similar but in the lower segment when compared to other retention studies. Level of retention differed substantially between students, with individual losses ranging from 28% of initial result to 105%, as one student even improved.

The results mean that only one student would have passed the whole examination had it been given again. Of the nine students that were interviewed after the test, one was assigned to category A, two to category B, and six to category C. Interestingly, there was no correlation found between initial result and level of retention. Furthermore, there was no apparent connection between initial result and the level of understanding arrived at during the phenomenographic interview. There were even signs pointing to a negative correlation; all three students who achieved the highest result on initial examination provided answers belonging to category C in the phenomenographic interview. The difference between retention and understanding suggests that great care needs to be put into designing adequate assessment, but also highlights questions about what the kind of knowledge is that is fostered in medical school.

VI. DISCUSSION

In order to see what knowledge remains after a longer period of studying like medical school, the representation of knowledge of any subject area can be explored. This has been done in the present investigation. The perspective is one of transformation; basic science has been looked at *as* basic science, but through the lens of a clinical context. This delimits this project from the perspective of the retention study, which lacks the ability to account for the integration. The reason for the introduction of a retention measurement in study four, was to contrast the phenomenographically discovered categories of description with a measure more resembling common assessment practice in medical school. The perspective also differs from psychological research into clinical reasoning, mostly in that it focuses on the content of learning.

As was set out in the objectives-chapter, the enterprise of this thesis has been to describe medical students' learning with a longitudinal and content oriented approach using the perspective on their learning provided by themselves. The categories obtained represent the varying ways in which the students experienced learning anatomy and physiology. The qualitative perspective employed was used to allow for an exhaustive a description as possible in grasping the completeness of the experience. In that sense, all four studies establish themselves in a broad tradition of studies of learning from the learner's point of view (e.g. Marton et al, 1984; Scheja, 2002) with a focus on the qualitative differences in approach and outcome (Dahlgren, 1997). It distinguishes itself from the majority of studies in medical education (Norman, 2005; Regehr, 2004; Bowen, 2006) through its qualitative features of detailed and deep description. This major line of research in medical education is often oriented around intervention studies of a certain variable (Fyrenius, 2006). It is based in a predominantly psychometric quantitative epistemology in which the mental structures involved in the process of learning are of major interest, and the content of the learning in terms of structure and meaning are less so. Contrastingly, this work focuses on the content of learning. A major underlying assumption is that learning is a complex phenomenon that needs to be dealt with in a way that allows for a large number of aspects to be included. This is the reason for the use of open-ended interviews as the major source of data generation. It is also the reason behind the basic methodological approach centred in the experience of the individual student. One could argue that the abundance of approaches and theoretical frameworks, in themselves, point towards the complexity of learning, as different attempts to capture its essence have led researchers in such diverse directions. The research area of medical education is also rather young, and influences from several different traditions are just to be expected. A number of recent studies have attempted to merge several perspectives to strive for greater clarity regarding the theoretical framework (Mylopoulos & Regehr, 2007; Mylopoulos & Woods, 2009), but there is also confusion lurking in the wake of a methodological "smorgasbord" (Lingard, 2007; Norman 2007a and b; Regehr, 2004).

Qualitative studies, in general, have a major strength in their ability to generate results simultaneously detailed and general. This is due to their ontological position and means that they are likely to capture critical aspects of the investigated phenomenon. Focusing on a comparatively small number of individuals, monitoring their actions, thoughts and

explanations closely, renders the data a substance generally not accessible using quantitative methods. The findings are thus limited and general at the same time, and may play an important role in defining research questions and generating hypotheses. In view of the methodological variety within medical education, qualitative methodologies have an essential role to play.

In relation to a "pure" retention study, the studies reported here (I-IV) take their starting point in the qualitative nature of the knowledge at a specific point in time, while the former defines that knowledge which is left in terms of what was (presumably) learned earlier. If a comprehensive account of an individual's knowledge of some sort is what is aimed for, then this seems to be a problematic approach since there are a number of questionable assumptions. If the question posed is about quantifying an amount of knowledge, the totality must have been defined. In a retention study, this totality is often taken to be the same as the course objectives. Generally, what is achieved in the examination is what has been learned. As has been pointed out (IV), results on examination and retention-test bear little resemblance to level of understanding. Furthermore, the student might have learned something not measured at all in the formative assessment.

Similarly, the four studies presented in the prior chapter (I-IV) complement psychological research into learning from the same ontological starting point. While psychologically based research into, for example, clinical reasoning is carried out, focus is on the mental structures and processes of learning (e.g. Gruppen & Frohna, 2002; Custers & Boshuizen, 2002; Schmidt & Boshuizen, 1993). With this comes an experiment situation in which one parameter is permitted to vary while remaining sources of influence are held constant. This necessarily means a reduction in the number of variables taken into account relative to the experiment. On the contrary, a setup used in the reported phenomenographic studies (I-IV) allows for a totality of the learning experience to be captured, without the constraints imposed on the experiment situation in order to achieve reproducibility. Thus, statistical generalisability is lost, but robustness in terms of detail and depth is gained.

ON CONTEXTUALITY, CAUSALITY AND UNDERSTANDING

In view of the findings from all four studies collectively, three notions stand out as they recur in several shapes. In order to understand medical students learning from the perspective chosen here, contextuality, causality and understanding feature as especially important. The first two appear as central categories of description resulting from the phenomengraphic analysis; contextuality in studies I and II, and causality in studies II, III and IV. Understanding is the main topic in study II, while it is also addressed explicitly in study IV, and features as an overarching and implicit theme in the remaining two. All three notions are also related, as they sometimes make up constituent parts of each other (II; III).

Contextualising anatomy was found to be a major way of creating meaning in a discipline apparently without a wealth of connecting aspects in itself (I; II). The notion of context bears several facets when employed to describe students' intentions with and

approaches to learning anatomy. Both the immediate surroundings of an anatomical site (in anatomical terms), its theoretical environment (neighbouring disciplines), as well as its role in a wider professional reality are included (I). Contextualisation was also used to describe the role of anatomy seen from the perspective of the totality of the whole medical curriculum (II). The notion of context can take on several alternative meanings in different research traditions (Scheja, 2002), and it is important to delimit the use of the term. Within medical education the concept of context has been identified to comprise three different dimensions: a physical dimension, a semantic dimension and a commitment dimension (Koens et al., 2005). In the present research, the emphasis is on the content of learning; here, too, contextualisation is to be understood as an individual construction of meaning. Hence, it is a theoretical approach to the learning material referring to the physical environment of the curriculum, the coherent abstraction of the anatomical site, and the more general framework of relevance.

IMPLICATIONS FOR TEACHING

In addition to giving medical students learning a theoretical base, the findings also suggest implications for teaching practice. Although the explicit aim of the thesis is an improved understanding of medical students' learning of anatomy and physiology, certain implications for educational practice follow from the set of categories obtained. It is possible to view the categories of description from different theoretical points of departure, which in turn make them useful in different ways. Phenomenography was chosen to provide the methodological tools helping the enterprise forward. It has shaped everything from the construction of the interview questions to the final analysis of the results. Hence, the results are to be viewed, primarily, as phenomenograhic results. This is not to say that the theoretical frame within which the results have been obtained is of no importance for any conclusions drawn. Nor is it saying that a general qualitative analysis is implicit when conducting phenomenographic research. It does mean, however, that the lessons learned from the investigation are useful even if one does not accept all the assumptions that come with the phenomenographic approach. In addition, the question about where the phenomenographic enterprise ends is also subject to discussion (Bowden, 2000; Marton, 1986).

Primarily, the categories of description depict what the students understand learning to be about and how they approached and carried out the learning tasks. The perceptions students have of different aspects of the teaching and learning environment are important in any educational setting. In phenomenography, this is made the object of research. The views students have of the subject matter clearly influence the approach to and outcome of learning. For instance, students conceptualising anatomy as contextualising the knowledge treated the study of anatomical details in a different way from students displaying an orientation towards memorising (II). For the individual student, it might be appropriate to learn anatomy as memorising, as the study must be related to the demands of the course and teachers, but most often a focus on the detailed structure of the discipline seems a suboptimal way of learning (III). As has been shown, the interplay between details and the whole is complicated as memorising and understanding are not mutually exclusive (Marton et al., 2005; Fyrenius, 2006) and largely dependent on subject area (II; III). However, the students' conceptions of

anatomy and physiology are also crucial information in the construction of the curriculum as the presentation of any subject area to the learner heavily influences the learning outcome (Calman, 2007). Therefore, a pragmatic standpoint is to acknowledge the categories as the different ways in which medical students understand anatomy and physiology, adapting the teaching to reinforce certain aspects, and letting other aspects fade away. For example, it seems that causal connections between biochemical reactions and organ systems are important for understanding physiology, while there is a risk that a deficit in linkage results in compartmentalisation of the knowledge (III). By recognising the categories as the students' attempts towards understanding, a conscious instructional strategy can be essential in guiding the student away from more limited approaches to better understanding.

Phenomenographic research is about revealing the possible ways people understand a certain phenomenon. Phenomenographic pedagogy is consequently about the change in the ways of understanding something (to a qualitatively more complete one) that can be brought about by good teaching, resulting in the learner's ability to do something differently. It has been argued that there is no single generally applicable teaching method based on a phenomenographic view of learning (Marton & Booth, 1996). This should be understood as connected to the basic characteristic of phenomenography to describe learning in terms of its content; as contents naturally differ across the range of subjects, so does educational content and, thereby, the suitable pedagogical tools. There are, however, practical implications for teaching. Booth (1997) has described four principles to govern a teacher's conduct. Primarily, the teacher should be aware of both the content and the acts of learning. Secondly, educationally critical aspects must be identified. Thirdly, the learner's experience of learning should be revealed and subjected to reflection, in order to open the way for a change in understanding. Finally, the learning task must be integrated into the world that the learner experiences.

The teacher, thus, has to identify the *how* and *what* of learning (structural and referential aspect) both in terms of what they are in any given situation, and what they should be to ensure quality learning. The learning task should be analysed in its educational context, with focus on how this context is experienced by the learner to achieve congruence. Furthermore, it is essential that the students be brought to make their various conceptions conscious. As other ways of understanding are reflected on by the student, a change in understanding is stimulated. The teacher should also attempt to facilitate the integration of the learning task into the world of the learner. The level of relevance must amount to a change in the learner's understanding of the world (Booth, 1997).

On a more general level, the activity of phenomenographic research also influences the way we think about educational practice and development. Not only are the varying ways of understanding a phenomenon important to reflect on by the student; they are also likely to raise attention amongst teachers and educational developers, as awareness of the students' ways of understanding can be used to develop our own understanding. In determining which conceptions are present and how they relate, the way is paved for a constructive development of them (Dall'Alba, 2000).

A recent branch, sprung from the phenomenographic movement regards variation, not between people's conceptions, but pertaining to the inner structure of a conception (Pang, 2003). This approach has been called variation theory and builds to a large extent on classical phenomenographic ideas. It deserves to be brought up because of its explicit pedagogical nature. It takes its starting point in the awareness of the learner, which is constituted by the simultaneous discernment of the critical aspects of a phenomenon (Runesson, 2006; Marton & Booth, 1997). The anatomy of this awareness is the underlying pattern resulting in the different ways people experience any phenomenon (Marton & Trigwell, 2000); the reason why people's experiences' differ is because we constantly discern and focus on a different set of aspects (we are not able to focus on all aspects simultaneously). The two intertwined aspects of each conception, the referential and the structural, are the basic elements through which the phenomenon is present to the learner. The referential aspect denotes the meaning of the object, while the structural aspect is constituted by the specific set of features focused on (Marton & Pong, 2005). As variation in the structural aspect can be achieved through attending to certain critical features of any phenomenon, this stance has substantial educational potential.

According to this idea, the categories of description concerning anatomy (I; II) consequently contain a certain number of aspects focused on and varied. The conceptions found in the categories denoted *Memorizing* and *Anatomical Language* focus on the linguistic features of anatomy and varies them as learning proceeds. The conceptions regarding contextualisation are about focusing and varying the integrity of anatomy in relation to other areas of medicine. Similarly, the conceptions constituting the categories *Visualisation* and *Selection* also have certain features in focus corresponding to a dimension of variation. When understanding of physiological fatigue was examined (III; IV), the students focused on equilibrium and causality in the category denoted "*A chain of mutually interdependent physiological and biochemical sub-mechanisms"*, they focused on juxtaposition and finite amount of fuel in the category *"Juxtaposed physiological and biochemical mechanisms"*.

Variation theory can be regarded as an instrument for identifying the critical aspects necessary for learning (Runesson, 2006), but can also be used in formal instruction in planning the teaching. Drawing on the present study (III), physiology teaching would include addressing the conceptions of equilibrium and causality and give varying examples provided in the dimension of variation at hand. In the subject of anatomy, similar dimensions of variation are open to elaboration within each conception.

METHODOLOGICAL CONSIDERATIONS

Researching one's own area can be a risk (Larsson, 2004). That risk is about not acknowledging the preconceived ideas that are brought into the investigation through the background (professional, personal or other) by the investigator. It cannot be eliminated completely through structural initiatives, but must instead be constantly addressed during all steps of the study. If such factors that might otherwise bias the results are not carefully considered, important aspects of the phenomenon under study may be lost due to a too rigid frame of reference. This is true especially in explorative

studies like the present one, where a broad and open perspective is essential. On the other hand it is important to realise that all qualitative studies are always conducted with the specific aim of illuminating a certain set of aspects. The perspective chosen with the aim in mind will necessarily influence the study, as well as the results. One such assumption that follows with the phenomenographic approach is that there are differences to be found in the understanding of a certain phenomenon. It might seem not a very controversial one, but it will nevertheless colour the following research. In many situations, having access to the inside of a particular professional practice is an advantage, and sometimes a necessity, in order to capture nuances in the social environment. In the present study, such access was achieved through the interviews being performed by me as a medical student in studies I and II, and by medical practitioners with a thorough understanding of the issues brought up from a clinical horizon in studies III and IV. Using several interviewers could potentially result in bias, as each interviewer will influence the interview in his or her own way. However, it can also serve to illuminate aspects of the interview situation and of the informants' reasoning that might otherwise have passed unnoticed. In study III, great attention was given the interplay between interviewer and interviewee, and the differences could thus be used in a constructive way. In all studies, the analysis was performed in cooperation with expertise from several areas.

The second order perspective employed throughout this investigation offers the opportunity to make statements about how certain phenomena are perceived or experienced by people, and not about the phenomena themselves. Would it not be more desirable to make statements about the phenomena themselves? It is argued here that the first and second order perspectives are complementary, and that it depends on the kind of research question which perspective to choose. Most scientific questions in medicine require methodologies allowing for predictions and causal reactions that are generalisable over large populations. In such a case, a first order perspective is worthwhile. However, in learning, not only the phenomenon is of interest, but also the relation between the phenomenon and the learner. This is the central pragmatic feature of phenomenography; since the quality of learning is so dependent on approach to the task, there is simply no other way than to analyse and facilitate learning in terms of experience. Marton and Booth (1997) describe this as a bracketing of the person-phenomenon-relation in the case of a first order perspective, in which an object is described as it really is, and a bracketing of the object in the case of the second order perspective, in which the relation between the person and the phenomenon is described as it really is. In other words, learning as an activity is situated between the learner and the world, because there can be no learning without something being learned and someone learning.

The conceptions held by the interviewed students form the basis of the categories of description reported in the prior chapter. This relates to the wider question regarding the categories' status as constructed or discovered (Walsh, 2000). It is possible to understand the analysis process as a researcher driven construction of categories made up of elements of the subjects' experience, especially since some phenomenographic enterprises have resulted in failure to replicate the findings of others (Johansson, 1996). It is important to notice, though, that the aim of phenomenographic studies is often closely connected to educational practice (Bowden, 1996). Hence, the fact that results

differ depending on context is not only to be expected, but is also a positive effect, as it may increase the applicability of the findings. Contrastingly, others have argued that the categories belong to the field of discoveries (Marton, 1996). If viewed as such, they are not results obtained solely through analysis of data; therefore, recognised criteria of validity and reliability are not applicable. Instead, reliability as interpretative awareness has been suggested (Sandberg, 1997), to account for the researcher's intentional approach in analysing the subject's experience.

For anatomy and physiology as subject areas, the ontological non-dualism of phenomenography has important implications. As Larsson (2004) noted, these are on an individual and a collective level. The true nature of, for instance, physiological fatigue has to remain bracketed, as explained above, and instead we are dealing with the pedagogical question how the phenomenon of fatigue is experienced. For the individual learner, this means acquiring a gradually more complex way of conceptualising the phenomenon. On a general level, the implication is that all phenomena are subject to a flexible and proceeding handling by the collective awareness, and, as explained in the method chapter the phenomena are all we have access to. The phenomena themselves are changing as we are experiencing them differently.

The phenomenon of anatomy is experienced in the ways denoted by the categories: memorising, contextualising and experiencing. If there is no other way of experiencing anatomy than the ones captured by the categories (and that appears unlikely), then the categories not only imply central characteristics of the interviewed medical students' conceptions of learning anatomy, but they also suggest critical features of the phenomenon of anatomy itself. Thus, the categories embed information about the experiences and the phenomena. Similarly, in categorising medical students' experiences of physiological fatigue, their conceptions are analysed, and the phenomenon of fatigue is also researched.

From this line of reasoning, and in view of the categories in the four studies, some conclusions follow about anatomy and physiology in medical education. Anatomy has an inherent duality – that of details and the whole – which can easily be perceived as an obstacle, and result in root memorisation. A major part of the subject's identity seems to be constituted in relation to other subject areas. Furthermore, the experience incorporates an emotional aspect, which becomes manifest as the real-life anatomy is revealed through the senses. Physiology, on the other hand is intimately linked to the causality of body functions. A careful study of the governing processes in the body does not amount to a substantial understanding if the causal relations are not focused on.

One of the major problems within medical education can be traced back to a fragmentation of the curriculum. This thesis represents an attempt to deal with the problem from a qualitative, content-oriented and longitudinal perspective. The contribution is of a conceptual kind in providing important characteristics of medical students learning in anatomy and physiology, as well as of those disciplines. In analysing subject areas of this sort, important general features of learning in higher education have also been highlighted. For the individual student, medical education has

always been a challenge – and should remain one; the ultimate goal is to put the emphasis right and challenge where there need to be challenge, and support that which needs to be supported.

VII. APPENDIX

Interview questions Study I.

What is most important when you learn anatomy? (What is difficult/easy?)

How would you describe anatomy studies for someone who has no prior knowledge of it? (In the beginning and in the end of the course)

What advice would you give to someone who is about to start to study anatomy? (What do you need to be prepared for?)

What was the examination about?

How did you go about studying anatomy? (Why did you go about it the way you did? Did it change during your study?)

Interview questions Study II.

How do you view anatomy now?

What does it mean to understand anatomy? (Do you understand it better today? If so, why? Do you feel you can grasp it?)

Is anatomical knowledge important for the understanding of surgery, and vice versa?

What is most important when you learn surgery?

Do you have a specific way of studying? Did you always study like that?

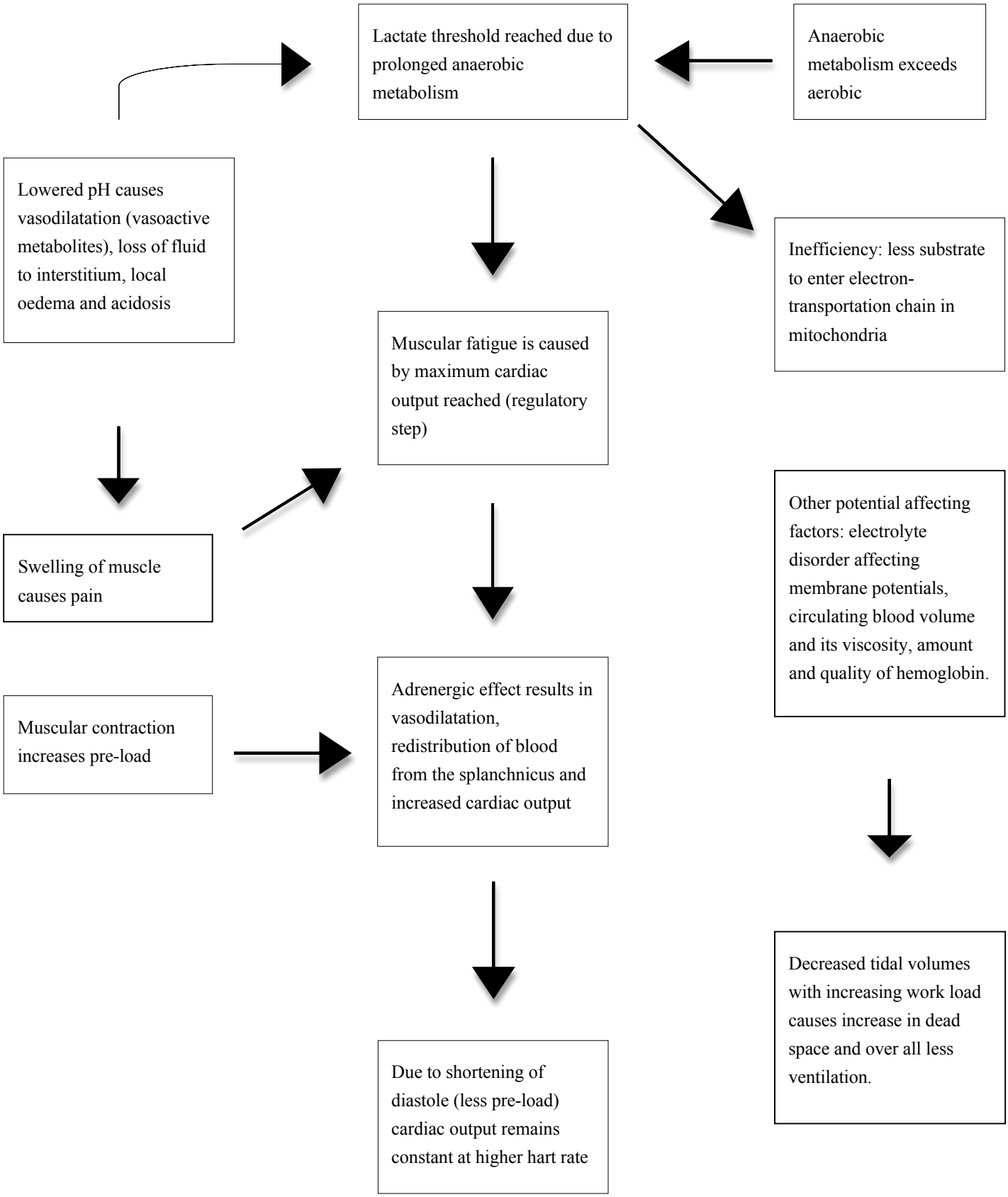
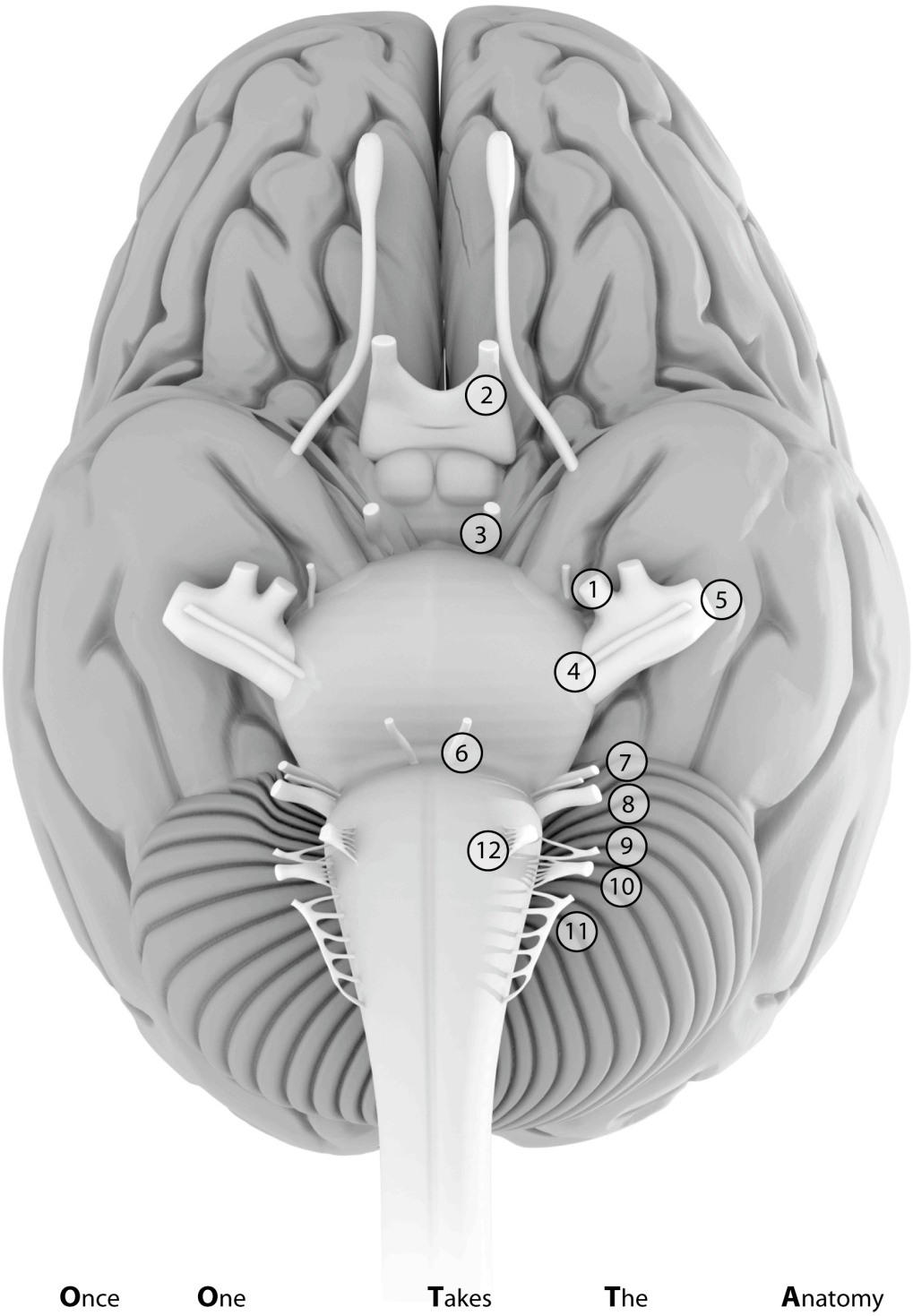


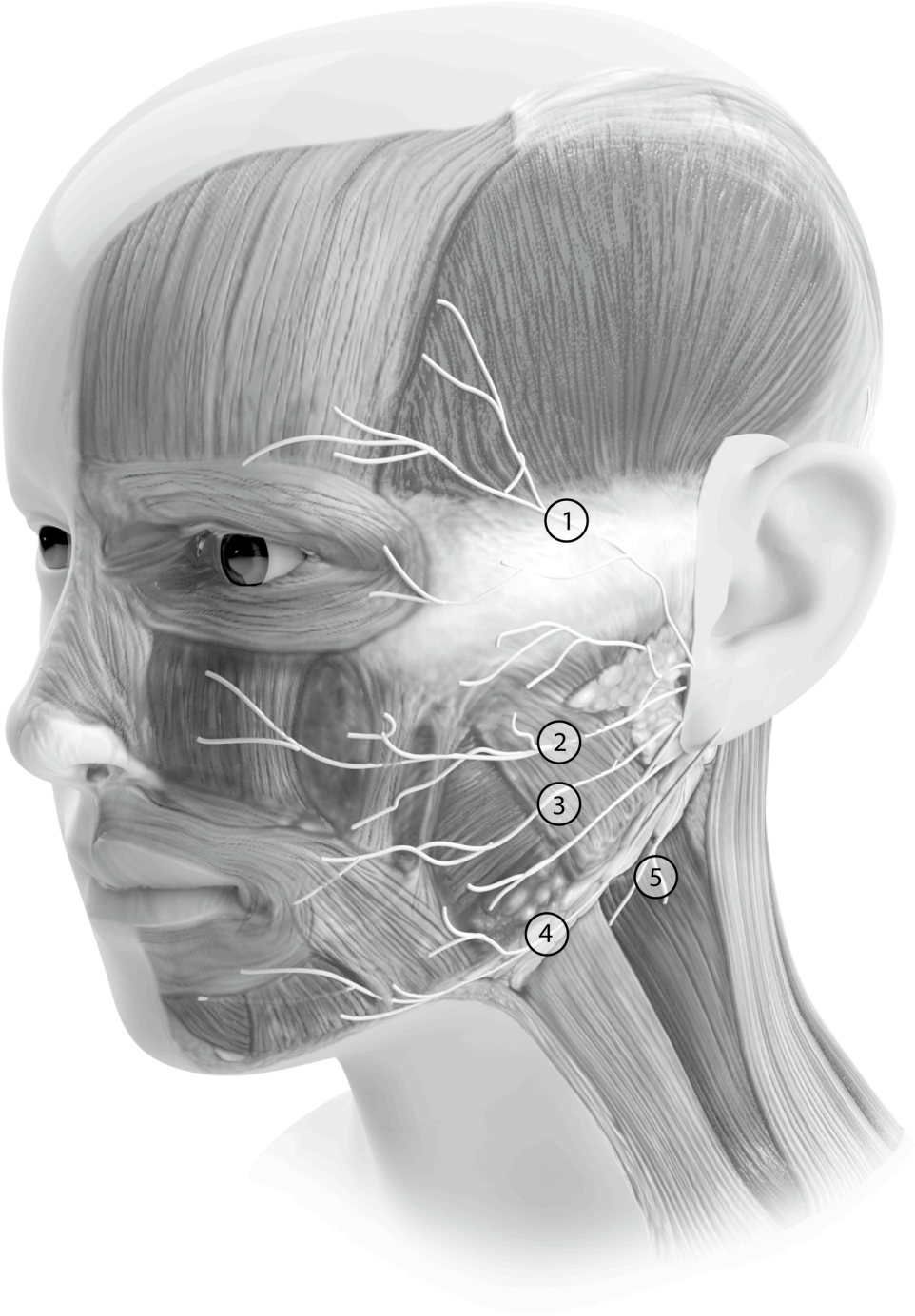
Illustration 5. Example of Phenomenogram used in Study III.



Oh	**O**nce	**O**ne	**T**akes	**T**he	**A**natomy	**F**inal
Ophtalmicus	**O**pticus	**O**culomotorius	**T**roclearis	**T**rigeminus	**A**bducens	**F**acialis
1	2	3	4	5	6	7

Very	**G**ood	**V**acation	**A**ppears	**H**eavenly
Vestibulococlearis	**G**lossopharyngeus	**V**agus	**A**ccesorius	**H**ypoglossus
8	9	10	11	12

Illustration 6. Cranial nerves I-XII with corresponding mnemonic. Inferior view.



To	**Z**anzibar	**B**y	**M**otor-	**C**ar
Temporalis	**Z**ygomaticus	**B**uccalis	**M**arginalis mandibularis	**C**olli
1	2	3	4	5

Illustration 7. Branches of the Facial nerve (VII) and mnemonic.

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