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ABSTRACT

This paper discusses the development of concept maps for an entire veterinary curriculum, for each of the planned courses, and for each of the case-based exercises in each course, drawing on current efforts at the College of Veterinary Medicine at Cornell University (Ithaca, New York) to develop an integrated curriculum for use in a problem-based format. Increased use of problem-based approaches to medical education has highlighted the challenges of curricular revision and interdisciplinary development. Venturing beyond disciplinary boundaries can be difficult, despite a desire to create interdisciplinary courses and adopt new ways of teaching. Concept mapping is an effective tool for developing an integrated curriculum. Examples are given of concept maps that represent an entire veterinary curriculum, specific courses, and case-based exercises. It is argued that concept mapping is a valuable tool for curriculum development of any scope or discipline, but is particularly helpful for creating interdisciplinary courses and case-based exercises. Nine figures illustrate concept maps. (Author/SLD)

CONCEPT MAPPING FOR THE DEVELOPMENT OF MEDICAL CURRICULA

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Abstract

Increased use of problem-based approaches to medical education has highlighted the challenges of curricular revision and interdisciplinary development. Venturing beyond disciplinary boundaries can be difficult, despite a desire to create interdisciplinary courses and adopt new ways of teaching. Concept mapping is an effective tool for developing an integrated curriculum. Examples will be given of concept maps that represent a entire veterinary curriculum, specific courses, and case-based exercises. The author argues that concept mapping is a valuable tool for curriculum development of any scope or discipline, but is particularly helpful for creating interdisciplinary courses and case-based exercises.

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In the past decade, increasing numbers of medical schools have made efforts to improve and revise their curricula. Among the innovations is problem-based learning (Barrows & Tamblyn, 1980), a method that allows students to direct large areas of their learning, and encourages them to integrate knowledge relevant to a particular case without respect to disciplinary boundaries. Features of problem-based learning that have appealed to medical educators include its interdisciplinary nature, relevance to practical application, emphasis on problem-solving, and the integration of knowledge from basic and clinical sciences.

Increased use of problem-based approaches has highlighted the challenges of curricular revision and interdisciplinary development; developing curricula that achieve these objectives can seem deceptively simple. Faculty involved in curricular reform may find it difficult to venture beyond their disciplinary boundaries. However, erasing those conceptual boundaries is a necessary precursor to creating new interdisciplinary courses, and to adopting new ways of teaching. Our experience has shown that creating an interdisciplinary curriculum requires much more than compiling the syllabi of existing courses and editing composite lists of educational objectives. The problem our faculty face is how to reconceptualize the subject matter in a way that eliminates redundancy, creates a smooth transition between courses, and demonstrates the conceptual interrelationships the faculty hope students will develop as a result of integrated, meaningful learning.

This paper will address the problem of developing an interdisciplinary curriculum. It will propose the use of concept mapping (Novak & Gowin, 1984) as a valuable tool for developing curriculum of any scope, particularly curricula that integrates content from several disciplines. Drawing from the current efforts at the College of Veterinary Medicine at Cornell University to develop an integrated curriculum for use in a problem-based format, this paper

will discuss the development of concept maps for the entire veterinary curriculum, for each of the planned courses, and for each of the case-based exercises within each course. Examples will be given to illustrate the hierarchy and integration within each map and across the entire curriculum. The paper will also discuss the role of concept maps in facilitating the development of case-based exercises for use by student tutorial groups. To date, roughly two-thirds of the curriculum has been developed with the aid of concept maps.

Concept Mapping

Concept mapping is a tool for visualizing the interrelationships between concepts in an integrated, hierarchical manner. It has been used successfully in many disciplines, particularly in science (Willerman & Mac Harg, 1991; Starr & Krajcik, 1990; Heinze-Fry & Novak, 1990; Novak, 1990; Novak, Gowin, and Johansen, 1983) to promote meaningful learning and effective teaching. Concept maps can be used as a study tool, to evaluate learning, or to plan a lesson, course, or an entire curriculum. Based on assimilation theory (Ausubel, Novak, and Hanesian, 1968), concept maps facilitate meaningful learning (as opposed to rote learning) by making conceptual relationships explicit, serving as advance organizers to subsequent learning, and highlighting misconceptions and alternative frameworks.

Concept maps are not flow charts or outlines. Like these other organizational tools, concept maps illustrate hierarchical (linear) relationships. However, they also illustrate interrelationships from one side of the map to the other, and from the bottom to the top. Flow charts often illustrate causal relationships; concept maps illustrate conceptual relationships. Rather than answering the question: How does X cause Y?, concept maps explain how X relates to Y. Concept maps are context-dependent, and depending on the examples chosen and cross-links drawn, maps containing the same concepts can convey very different meanings

(Novak & Gowin, 1984). This feature has been particularly helpful in facilitating our efforts to create an interdisciplinary and multidimensional curriculum.

The theoretical framework from which concept mapping was derived is based on a constructivist epistemology. Consistent with this view, understanding is characterized by knowledge about the nature and structure of the material that is to be learned. That is, an understanding of not only facts, but of how the facts are organized, and how they relate to one another through more inclusive, superordinate concepts. This theory-driven approach to curriculum development is not common; often changes are made piecemeal or by adding and subtracting topics or assignments. By incorporating concept maps into the development of new courses, we hope to ensure that the conceptual relationships the faculty intend to express are clear to the students, and we hope to facilitate students' meaningful learning. Attention is being paid not only to how material is to be taught, but also to how it will be learned.

Developing a Problem-Based Curriculum: Student-Centeredness

According to Gowin (1981) and Schwab (1978), the four commonplaces of educating (teacher, student, curriculum, and governance or social milieu) are inextricably linked. Therefore, change in one affects the others. Developing an entirely new curriculum should also involve analysis of methods (of teaching as well as evaluation), the needs and interests of the learners, as well as the broader educational and institutional environment. Development and implementation of a problem-based curriculum requires the adoption of new teaching methods, new assumptions about the relationship between teacher and student, and decisions regarding the extent to which students will be responsible for identifying content and pursuing areas of interest. Larger issues relating to authority and power, conceptions of truth, and professionalism underlie the more mundane tasks of curriculum planning. It is paradoxical

that the design of a curriculum that aims to be student-centered requires such extensive faculty planning. By using concept mapping (or any another form of planning) the faculty are engaged in the process of delineating the information students will "discover" on their own. O'Loughlin (1992) raises a valid critique of planners of "student-centered" curricula relative to authority, culture and power in the classroom:

> Who decides on the pedagogy and curriculum of the constructivist classroom and in whose interest? . . . Are students better off in the apparently more amenable social and intellectual milieu of a constructivist, student-centered classroom if the epistemological messages they receive about themselves and their world are identical to the messages they would have received in a traditional didactic classroom? . . . The challenge . . .is to theorize how to define a pedagogy that is truly empowering rather than one that merely gives the illusion of power. . .. (pp. 806-8)

In his book Educating, Gowin (1981) places great emphasis on empowering the learner and characterizes the shared of meaning of curricular materials between student and teacher as "cracking the code". This shared meaning or mutual understanding empowers the student by accentuating his or her ability to construct knowledge. Gowin describes the use of indirect teaching methods such as the Socratic method or problem-based learning as heuristic teaching, because they lead to understanding and encourage "the student to discover for himself" (p.67). The rationale for such methods, according to Gowin, is that by having the student reconstruct scholarly knowledge under the guidance of a teacher, her or she will have greater control over subsequent experience and learning:

> The student's power to control better his later experience is grounded not so much in the teacher's authority as in the student's understanding of how educative materials enhance and enlarge the range of experience. The teacher's responsibility is to see that what the student takes from the educative materials does in fact help the student in this increased understanding. (Gowin, 1984, p.81)

Concept maps are effective tools for making the structure of knowledge explicit, and our hope is that by using them in our planning and case development, the material will be

more accessible and more easily integrated by the students. Because concept maps are heuristic devices that have already been incorporated into some of our faculty's teaching, (including some forms of student evaluation) we plan to monitor the effectiveness of our efforts to construct a curriculum that is "conceptually transparent" (Novak, 1991) and the quality of our students' subsequent learning.

There are many variations of problem-based curricula implemented at medical schools around the world, and many of the differences among them concern the degree of freedom students have in determining what and how to learn (Blumberg, Michael, and Zeitz, 1990; Branda, 1990). The variations range from schools that offer case-based exercises with no other formally structured activities such as lectures or laboratories, to schools that offer a combination of structured experiences, to those that use problem-based methods within more traditionally structured courses or programs.

The extent to which faculty identify specific content to be learned is an important element in the development and implementation of such a curriculum, as are the extent to which the content is organized by discipline, and how skills and attitudes are integrated with disciplinary knowledge. Because concept mapping requires the identification and prioritization of key concepts and principles, constructing maps has helped the faculty at Cornell to determine main areas of emphasis while suggesting new interrelationships. Identification of concepts that are key to more than one discipline has helped interdisciplinary groups of faculty to move beyond their disciplinary boundaries. In the development of the new veterinary curriculum, concept maps have been used for planning purposes only; they will not be distributed to the students. This is to protect the students' role in constructing an understanding of the material that truly builds upon their individual prior knowledge and experience, while encouraging them to pursue areas of interest.

Part of the challenge of developing a problem-based curriculum is that it is more open-ended and interdisciplinary than a traditional curriculum. While the faculty will not be able to anticipate all of the ways students will shape what they learn (nor do they wish to), there are some principles and interrelationships they do hope to highlight. Integration of basic and clinical science knowledge is the most obvious of these, but the interpersonal, technical, and social dimensions of veterinary medicine are also important educational goals the faculty have identified. Our faculty have struggled with the task of planning for such multidimensional teaching (and learning). A major impetus for changing the traditional curriculum was to highlight aspects of veterinary medicine the faculty thought were important, but were not accommodated by a traditional format. Articulating these important dimensions of veterinary medicine and tracking them through the development of new courses has been an important part of the planning process.

Concept Maps for Curricular Development

Because the entire veterinary curriculum is being revised (implementation is scheduled for the fall of 1993), our use of concept mapping has occurred on several levels. The goals and broad conceptual themes of the curriculum have been derived by the faculty as a whole; subcommittees have further refined these themes and have developed concept maps to represent portions of the curriculum. Additional groups of faculty and students have used these maps to create additional concept maps for particular lectures, laboratories, and case-based exercises. Each concept map serves as a kind of road map, guiding the writing of cases, clearly illustrating areas of redundancy and omission, and reassuring faculty about content coverage and curricular coherence. We are in the process of producing a conceptually integrated problem-based curriculum that can be represented through a series of hierarchical,

or "nested" concept maps. Rather than summarizing the curriculum through a series of outlines, the concept maps illustrate the dynamic network of conceptual relationships, and emphasize important themes. This approach to curriculum development has provided a conceptual framework and theoretical basis for implementing an innovative approach to medical education.

The overall structure of the new veterinary curriculum has been modelled after the New Pathway at Harvard Medical School. It consists of six Foundation courses that will be scheduled consecutively in blocks of time. A seventh Foundation course ("Animals, Veterinarians, and Society") will run longitudinally across the curriculum, optimizing students' exposure to animals and clients, and offering many opportunities for ethical, social, technical and professional issues to be integrated with students' consideration of the clinical cases. The Foundation courses represent approximately 70% of the veterinary curriculum. The remaining courses will be offered during annual Distribution periods, and will allow students structured choices from clusters of more specialized areas. The Foundation courses are interdisciplinary (as are some Distribution courses) and bear titles such as "Function and Dysfunction", "Genetics and Development", and "Host, Agent, and Defense".

A faculty subcommittee was established for each of the Foundation courses. Working with the College Curriculum Committee, these Curriculum Design Groups (CDGs) are responsible for determining the scope of their course, creating a concept map that represented its major conceptual themes, developing educational objectives, planning each week in some detail, and estimating the necessary faculty and teaching support staff necessary to implement such a course. In addition to these tasks, the faculty planners developed a concept map representing the entire veterinary curriculum (Figure 1).

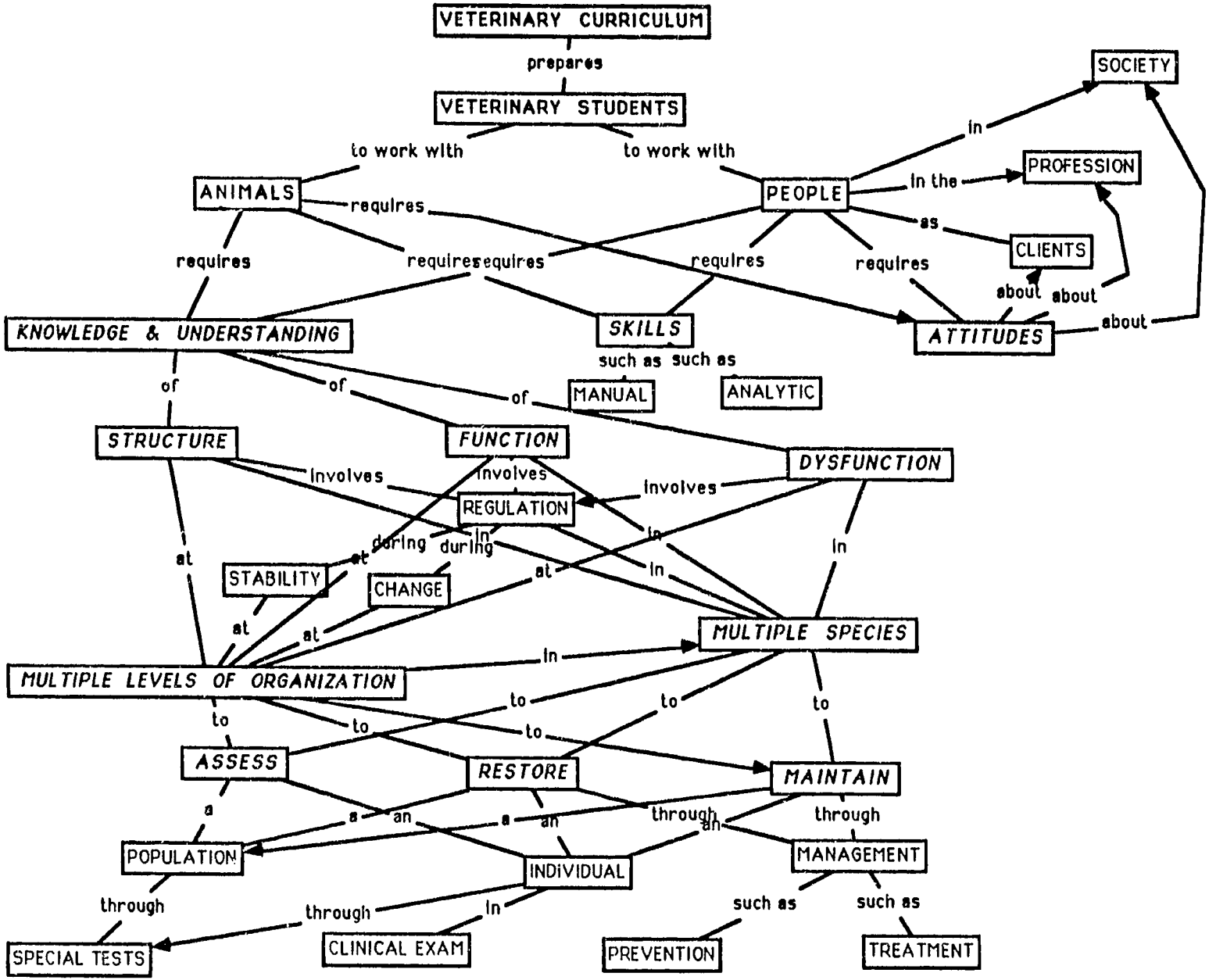

Figure 1: Concept map of the entire veterinary curriculum.

Insert Figure 1 Here.

This map is necessarily broad, in order to be inclusive of a large amount of information. What is important about this concept map is the fact that it reflects new areas of emphasis over the traditional curriculum: skills and attitudes are depicted as important as knowledge and understanding, maintenance of health is placed higher in the map (therefore of higher priority) than treatment, reflecting another shift. The prominent position that clients and other professionals have in the map expresses the importance of communication and interpersonal skills. Despite its brevity, the map expresses important educational goals the faculty hope to instill in their students. For example, the faculty want their students, no matter what the specific example, to consider structure, function, and dysfunction occurring at multiple levels of organization in multiple species.

With this map as the most inclusive, many other concept maps have been generated to express more detailed aspects of each course, each case-based exercise, and several planned lectures and laboratories. The concept maps become increasingly detailed, but continue to reflect the major goals of the curriculum while emphasizing themes particular to each course. As mentioned above, each CDG developed a concept map for their course. These maps have served, quite literally, to map out the conceptual territory of the course. The concept maps representing courses 1 and 2 ("The Animal Body" and "Genetics and Development") are shown in Figures 2 and 3.

Insert Figures 2 and 3 Here.

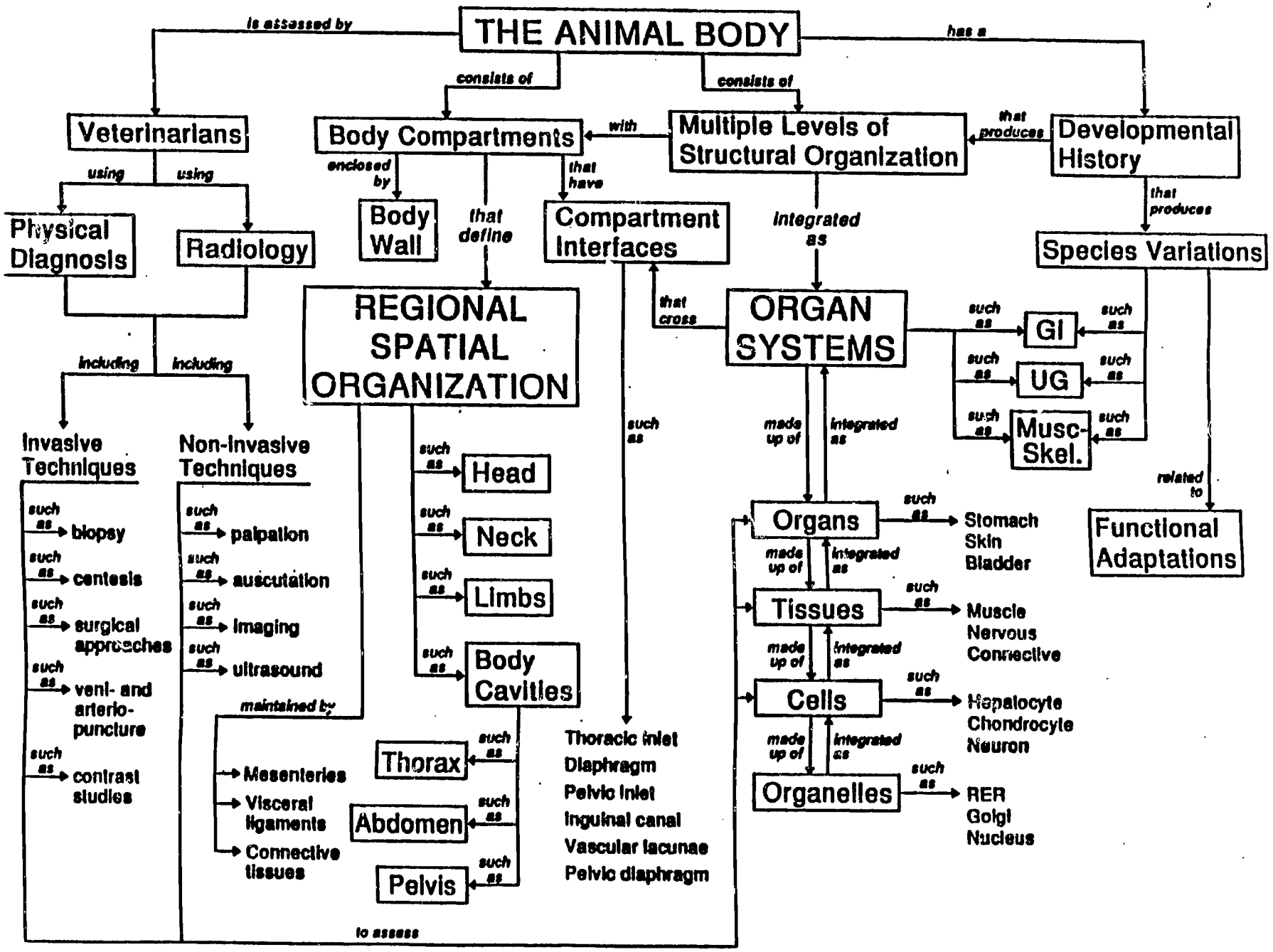

Figure 2: Concept map of "The Animal Body" Foundation course.

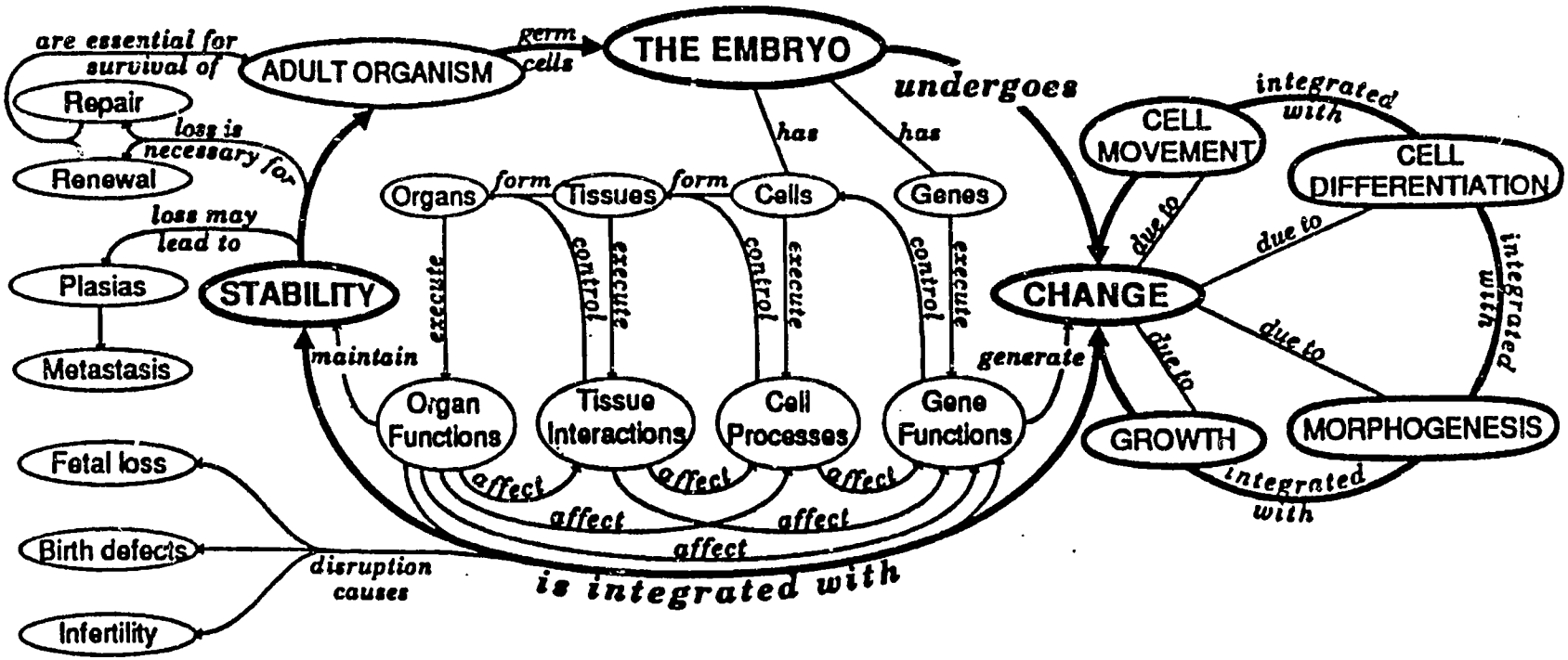

Figure 3: Concept map of "Genetics and Development" Foundation course.

While each map represents a distinct body of knowledge, the maps share certain themes (e.g. multiple levels of structural organization) that should facilitate students' integration of knowledge within each course and from one course to the next. The concept map for "The Animal Body" (Figure 2) includes an emphasis on body compartments with regional spatial relationships, and organization at multiple levels, but also as having important developmental histories. Specific techniques (invasive and non-invasive) will be learned as part of physical diagnosis, which will be integrated with anatomical structures and imaging techniques. The concept map for "Genetics and Development" (Figure 3) carries some of these themes forward, while adding the complexity of oncogenesis as an aspect of growth. The remaining Foundation courses are mapped out in a similar fashion. The concept maps have helped the faculty to ensure coherence across the curriculum, to remain focused on the major themes they hope to convey, and to continue their planning to greater depth without feeling lost in a sea of facts. As one professor put it: "We have released ourselves from trivia." These concept maps have been helpful in guiding case selection, but also in developing supporting materials, and in choosing topics for global lectures.

Within each of the Foundation courses, case-based exercises have been written that highlight major conceptual themes. Because the faculty wanted some control over the open-endedness of the cases, we have also used concept maps to develop the case-based exercises. We have relied heavily upon veterinary students to help with case writing, and our use of concept maps in this way started as a way of monitoring case development. As it has progressed, the mapping has become a useful method for anticipating the range of related learning issues any case may generate.

Each case is based on two concept maps, a list of case objectives, and a medical record. The first concept map focuses on the disease entity, its pathogenesis and treatment,

clinical signs, etc. The second map illustrates the learning issues related to that case arising from multiple disciplines. Figures 4 and 5 are examples of two concept maps developed for a case of manx cat syndrome. These maps, taken with the overall concept map of the course, case objectives, and the medical record, guided the case writer in making decisions about whether to emphasize, de-emphasize, or even omit parts of the case.

Insert Figures 4 and 5 Here.

While the cases will permit students great flexibility in identifying and pursuing learning issues, occasional details such as drug dosages or extensive lab reports that show no abnormal findings may be omitted, depending on where in the curriculum the case will be used. For example, if the clinical pharmacological aspects of a case are truly peripheral to its main (basic science) objectives, a specific dose may be omitted but the drug name or family will be included. Conversely, if the concept maps indicate that the case provides a natural introduction to another related area (such as ethics or principles of genetic inheritance), pertinent information might be carefully documented in the case, or raised in the context of a structured laboratory experience or global lecture. By mapping out the entire conceptual territory addressed by a case, future case modifications (or changes in emphasis) will also be facilitated.

The interrelationships and transitions between cases and courses have been carefully planned by the faculty. Attempting to discourage compartmentalization of students' learning, the faculty hope that the transitions between cases and courses will be seamless to the students. The longitudinal course ("Animals, Veterinarians, and Society") will play an important role in integrating the students' developing knowledge, skills and attitudes across

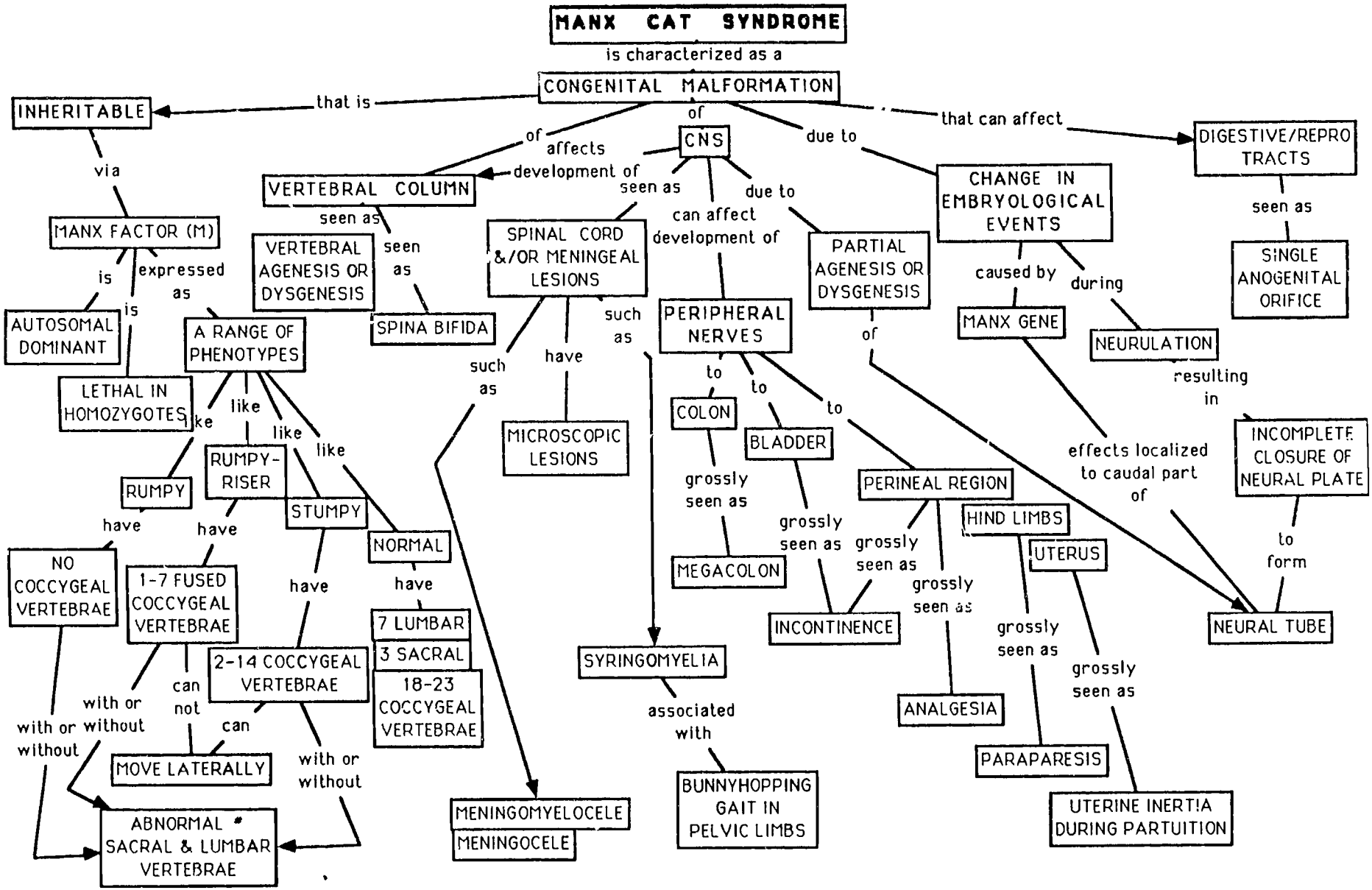

Figure 4: Concept map of the pathogenesis of manx cat syndrome.

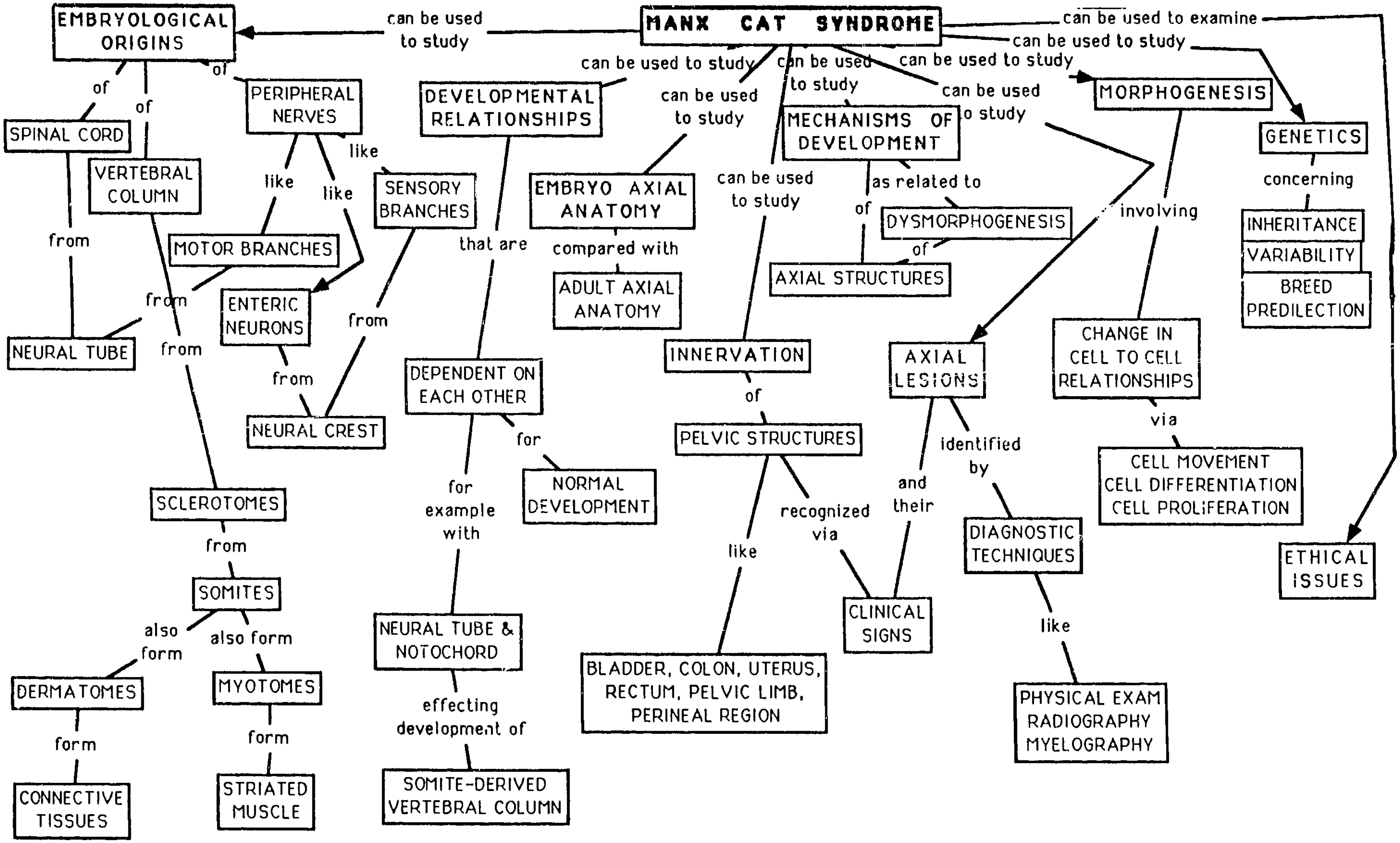

Figure 5: Concept map of potential learning issues raised by a case of manx cat syndrome.

the curriculum, and it is to the integration of the components of the curriculum that the focus of this paper will now turn.

Integration Across the Curriculum: Two Examples

One way to understand the intended integration of the planned curriculum is to take a vertical slice through time and consider the curriculum as the students will experience it. During the first course ("The Animal Body", Figure 2) students will work through cases designed to highlight anatomy, radiology and other imaging techniques, and approaches to surgery. Concurrently, they will engage in the longitudinal course which has been planned to correlate to each of the other Foundation courses. For example, the first case the students will encounter concerns a dog with pneumothorax. The concept maps summarizing the pathogenesis of pneumothorax and potential learning issues for this case are shown in Figures 6 and 7. During that same week in the longitudinal course ("Animals, Veterinarians, and Society"), students will learn to perform elements of a physical exam and related diagnostic procedures that relate to the thorax and respiratory system. These are illustrated by the concept map shown in Figure 8.

Insert Figures 6, 7, and 8 Here.

As illustrated in Figures 6 and 7, the pathogenesis of this particular disease is relatively straightforward, but it leads into many rich learning issues relating to anatomy, clinical evaluation, and surgical procedures. Comparison of these maps with Figure 8 reveals different areas of relative emphasis, but many concepts in common. The maps are complimentary without being redundant. They represent three different ways of thinking about

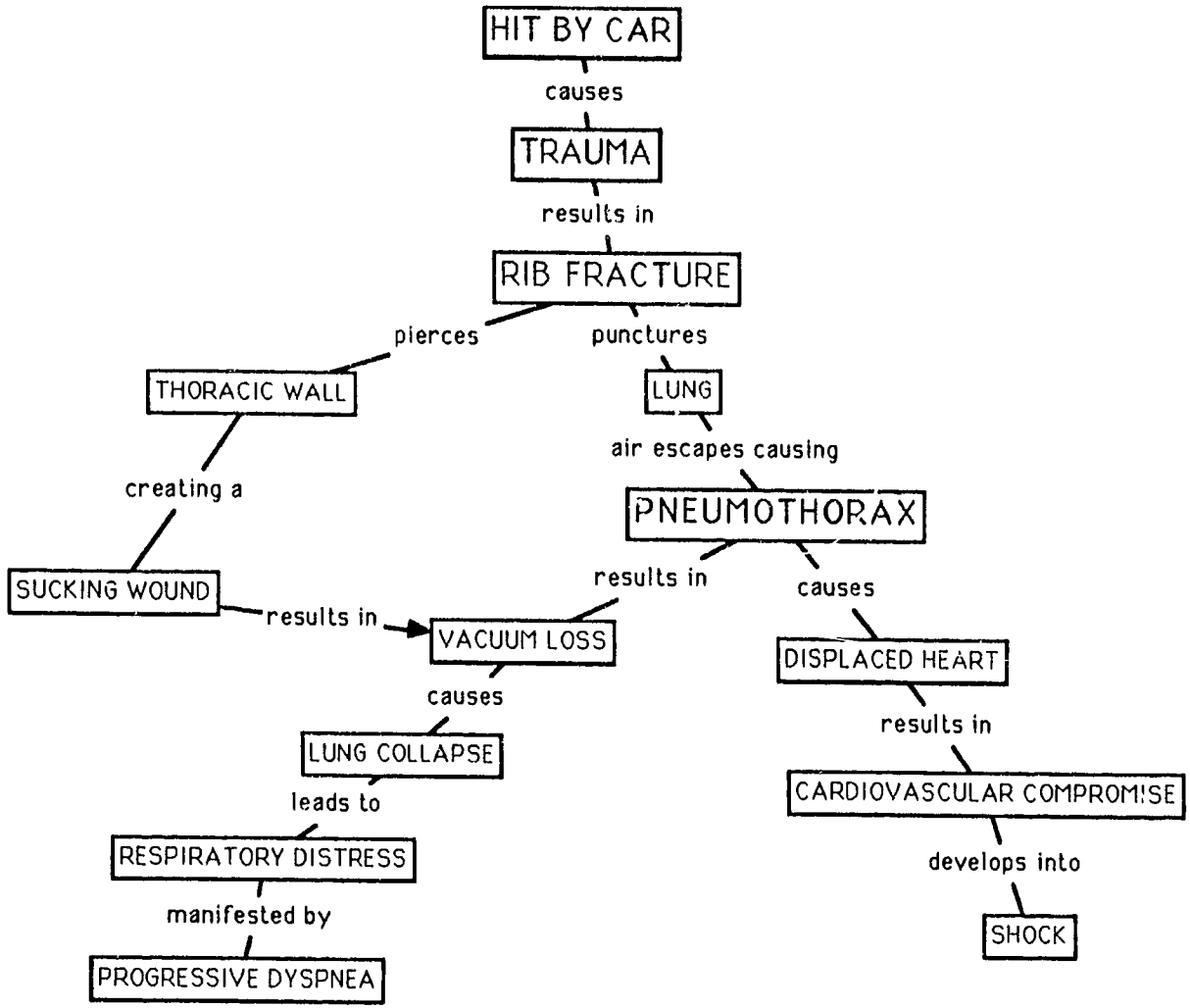

Figure 6: Concept map of the pathogenesis of pneumothorax.

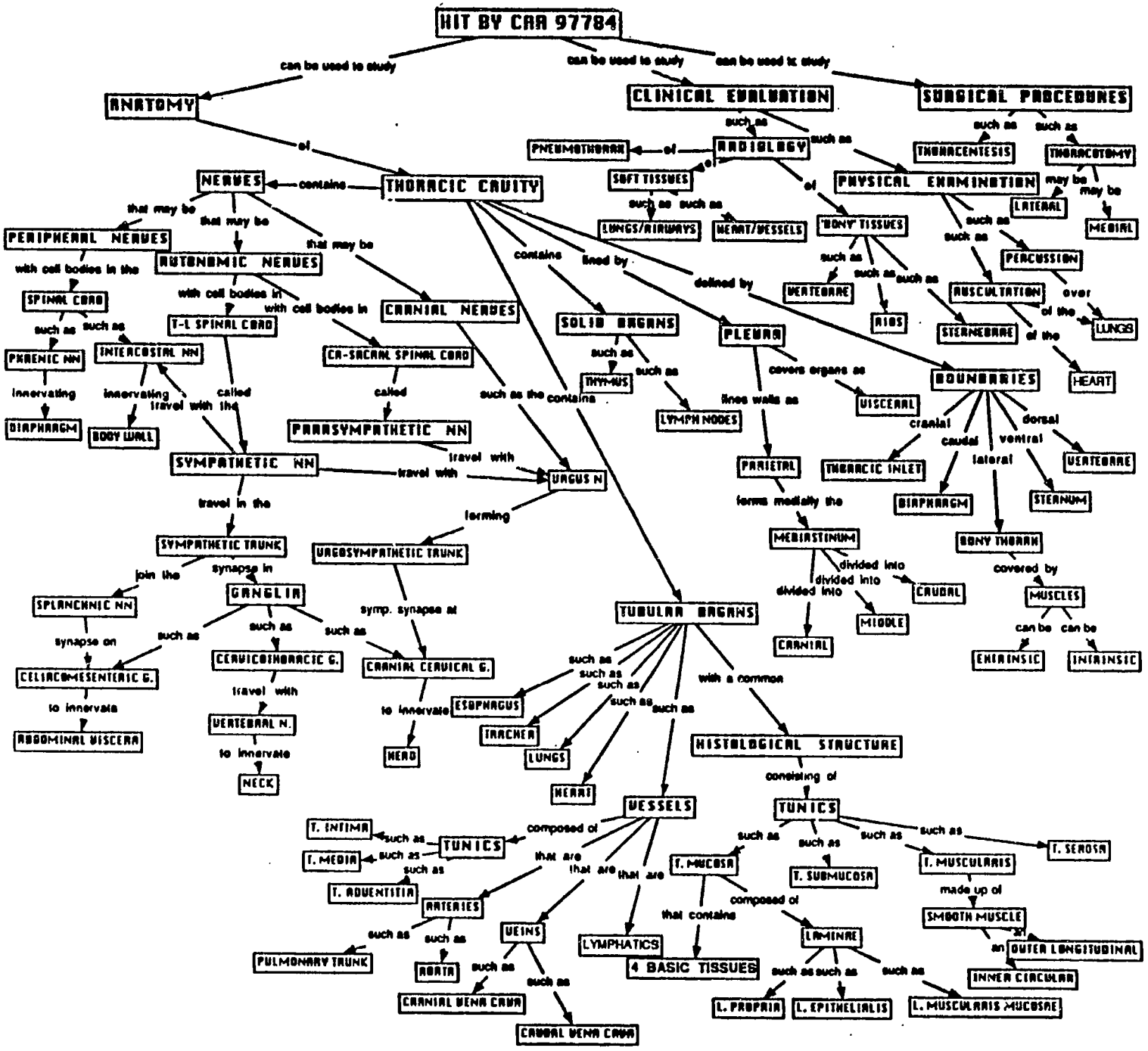

Figure 7: Concept map of potential learning issues raised by a case of pnemothorax.

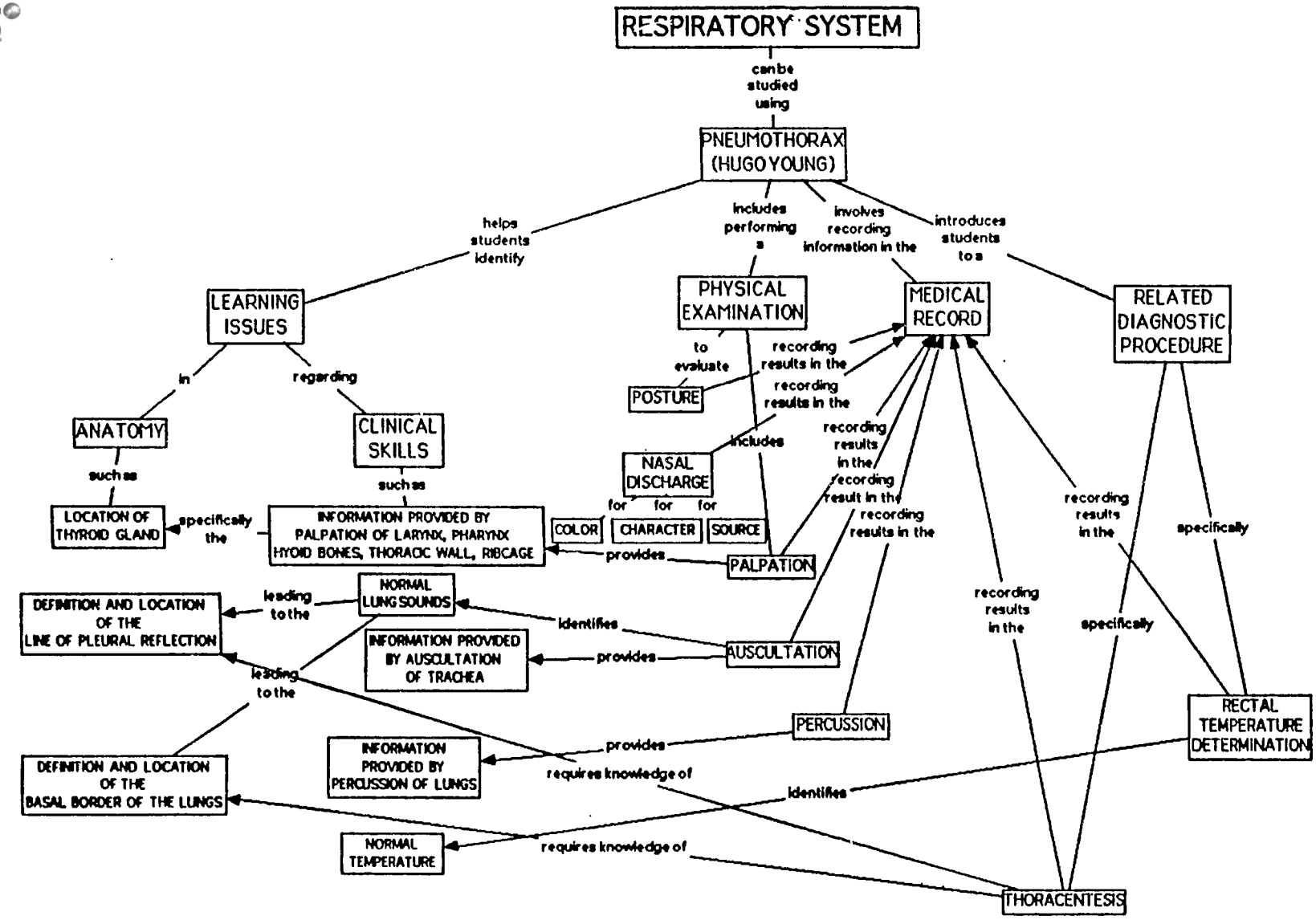

Figure 8: Concept map illustrating integration of case-related learning issues with clinical skills in "Animals, Veterinarians, and Society".

the same event in a deliberate attempt to help students, in their first week of veterinary school, to begin to integrate their learning, and emphasize to them the central role context plays in understanding.

While the activities and discussions in the longitudinal course will not always be derived directly from the case used in the corresponding Foundation course, the key concepts and principles from those cases will be considered with new information and in new contexts. As mentioned above, the meaning conveyed in a concept map is dependent upon both the position of concepts in the hierarchy and the labelled lines that create propositional statements. By changing the arrangement of the concepts and adding new examples, the map conveys new, but valid, propositional relationships. These maps illustrate the faculty's conceptions of veterinary medicine as multidimensional and highly integrated. By making these interrelationships explicit during their curriculum planning, the faculty have also explored new opportunities and alternative ways to highlight them in their teaching.

Approximately three months after working through the pneumothorax case, students will be involved in the second course ("Genetics and Development", Figure 3). The manx cat case is written to emphasize aspects of normal embryological development, genetics, and diagnostic techniques (illustrated by Figures 4 and 5). It will also serve as the impetus for discussion within the scope of "Animals, Veterinarians, and Society" for a number of issues related to genetics and ethics, such as transgenic animals, limits of selective breeding, and breeding to a defective standard. These dimensions of the case and other related issues are illustrated by the concept map shown in Figure 9.

Insert Figure 9 Here.

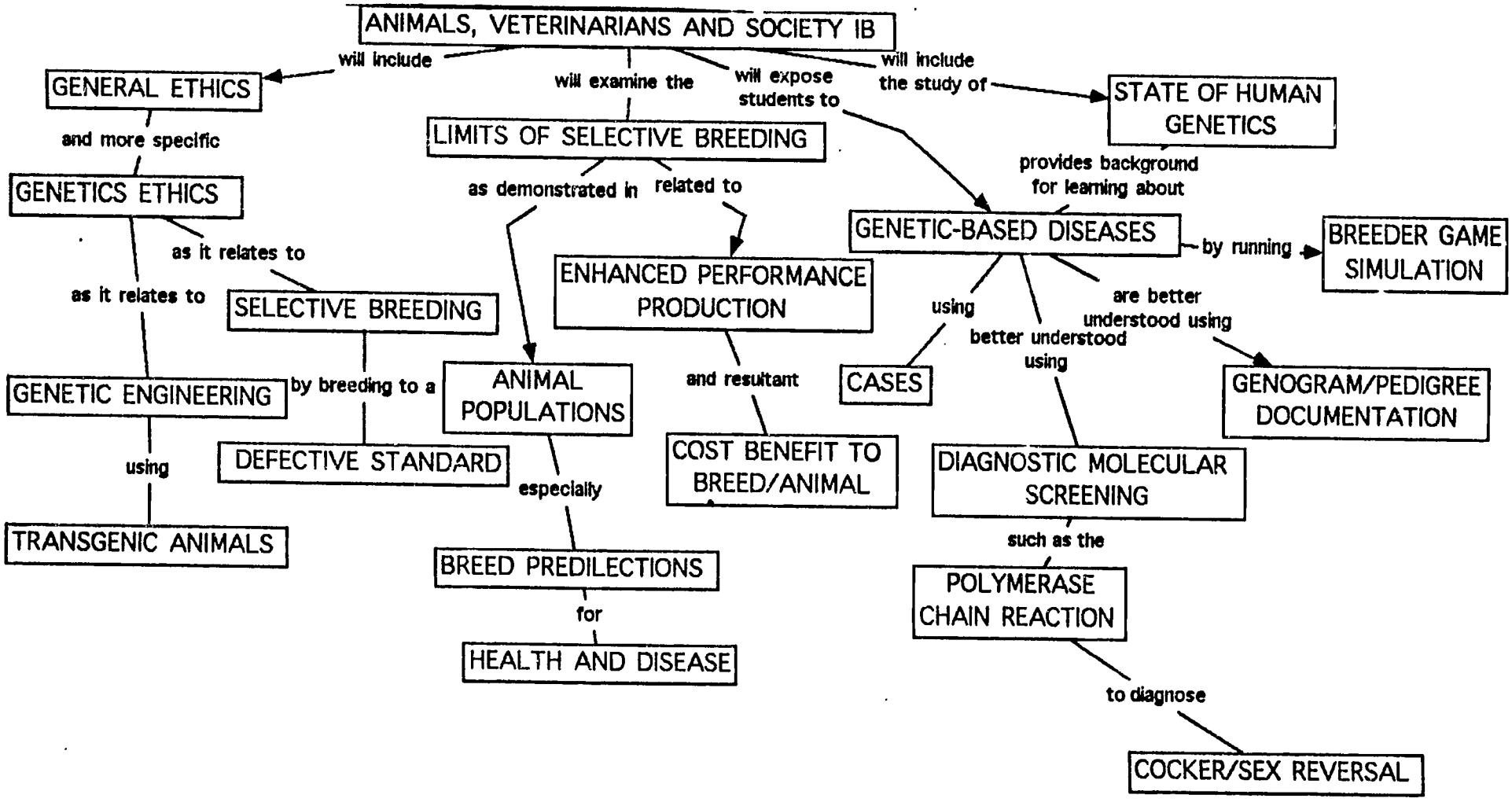

Figure 9: Concept map illustrating the integration of conceptual themes from "Genetics and Development" and "Animals, Veterinarians, and Society."

The content of the map shown in Figure 9 is not as tightly correlated to a specific case of manx cat syndrome as with the example of the pneumothorax case, but the topics illustrated in this map serve as bridges between the two courses. In addition, details included in the manx case scenario raise many related issues relative to hereditary malformations, spaying and neutering, expression of phenotypes, and the human-animal bond. These features of the case provide additional links to the themes of the longitudinal course.

As illustrated by these examples, the concept maps help faculty to articulate the multiple dimensions of cases. Rather than write cases or plan courses in a less systematic manner and assume that integration of students' learning will automatically result, the use of concept maps conveys the intentions of the faculty, and a means to assess whether those goals have been achieved. (For the past two years, the author has taught each student in the entering class how to construct concept maps. Students have been asked to construct maps for aspects of some courses and as part of some exams.) As our library of completed cases grows, the concept maps also provide nice summaries of the breadth and depth of learning issues raised by each case, and possible areas for future modifications.

Curriculum Reform and Meaningful Learning

Coles (1990) has argued that problem-based learning has been successful because its elements fulfill the criteria for what he calls contextual learning. That is, it involves context, information, and the relating together of information. According to Coles, contextual learning generates the kind of elaborated knowledge needed for effective medical education. Coles has also criticized advocates of problem-based learning for lacking a clear strategy for implementation, and he has argued for a theoretically and empirically grounded model for medical education. Concept mapping and Coles's theories of contextual learning and of

elaborated learning (Coles, 1990a) are derived from common theoretical roots. The characteristics of contextual learning as Coles defines it correspond to Ausubel's definition of meaningful learning. Coles's notion of elaborated knowledge correspond to Edmondson and Novak's (1992) view of authentic understanding. What these compatible theories offer medical educators is a strong foundation on which to build meaningful curricular reform.

By choosing concept mapping to develop the new veterinary curriculum, the faculty at Cornell have found a way to maintain an emphasis on integration and accessibility of learning information while making logistical decisions. Our hope is that we will facilitate meaningful learning by making the content more accessible and facilitate integration through the juxtaposition of multiple aspects of a problem in the same place in time. Teaching does not cause learning, and curriculum reform does not guarantee improvement in student performance. To effect meaningful change in medical education, the design of a new curriculum cannot be reduced to reorganizing content and implementation of a new curriculum cannot be reduced to the adoption of new teaching methods. However, evidence from research in science and mathematics education (Jegede, Alaiyemola, and Okebukola, 1990; Heinze-Fry & Novak, 1990; Helm & Novak, 1983; Novak, 1987) makes us optimistic that our students' learning will qualitatively improve. This is because change has occurred simultaneously in the conceptual organization of the curriculum, teaching methods, and evaluation. This reform has been prompted by a desire on the part of the faculty for change, and it has been facilitated by a heuristic that helps faculty to reconceptualize their subject matter. The structure of veterinary medical knowledge has been made explicit, and this is an important element for meaningful learning. Subsequent qualitative changes in students' learning is an aspect of our program the author is eager to monitor, and it will be a focus of future research.

The Role of Concept Maps in Curricular Change

Curricular change was endorsed by the faculty at Cornell long before the use of concept maps was advocated as a means to achieve it. Use of concept mapping has been controversial to some, or dismissed by others as either too gimmicky, or too vague to be useful. For those faculty who view curricular change as redistributing content without restructuring their understanding of the subject matter, concept maps do not contain enough lists of specific facts for some faculty to feel comfortable that any topic has been "covered." Curricular reform, however, involves much more than redistributing content.

We have found concept maps to be effective tools for mapping the content in a way that allows faculty from various disciplines to reach consensus on how to design interdisciplinary courses. This includes help prioritizing concepts: What should the cases cover?; What should be left to the students?; What should global lectures address? and help identifying basic principles that run across disciplines (e.g. the tension between stability and change, the relation between structure and function, regulation and control of various processes, etc.). As one faculty member said, after struggling to understand why they were sharing their concept maps of their disciplines with each other in the design of a new course: "Oh, I see. It's a whole new way of thinking about it." The faculty have come to understand how concept maps can be helpful in eliminating redundancy. Initially, some found the maps most helpful in literally mapping content, but as they gained experience, the faculty realized their true power in helping to reconceptualize their subject matter and communicate a great deal of information succinctly.

Concept mapping facilitates theory-driven curriculum development that is grounded in learning theory and proven in practice. Use of concept maps helps faculty to create integrated, interdisciplinary courses, communicate with each other, visually explain the conceptual

relationships that serve as the educational objectives for any course or unit, and facilitates faculty's efforts to reconceptualize their subject matter. This reconceptualization leads them to question their assumptions about the nature of knowledge, the relation between the knower and the known, the roles of teacher and student. These issues are fundamental to meaningful curricular change, but are often ignored during curricular reform. As a heuristic for revealing the structure of knowledge, concept mapping as a tool is not bound to any discipline; the development of this veterinary curriculum can serve as a model for other faculty or institutions facing similar challenges.

References

Ausubel, D., Novak, J. D. & Hanesian. H. (1968). Educational psychology: A cognitive view. New York , NY: Holt, Rinehart, and Winston.

Barrows, H. S. & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. New York, NY: Springer Publishing Company.

Blumberg, P., Michael, J. A., & Zeitz, H. (1990). Roles of student-generated learning issues in problem-based learning. Teaching and Learning in Medicine 2(3), 149-154.

Branda, L. A. (1990). Implementing problem based learning. Journal of Dental Education 54 (9), 548,9.

Coles, C. R. (1990). Evaluating the effects curricula have on student learning: Toward a more competent theory for medical education. In Z. M. Nooman, H. G. Schmidt, & E. S. Ezzat (Eds.) Innovation in medical education. New York, NY: Springer Publishing Company.

---- (1990a). Elaborated learning in undergraduate medical education. Medical Education 24, 14-22.

Edmondson, K. M., & Novak, J. D. (1992). Toward an authentic understanding of subject matter. Paper presented at the Second International Conference on History and Philosophy of Science in Science Teaching, Kingston, Ontario, May 11-15, 1992.

Gowin, D. B. (1981). Educating. Ithaca, NY: Cornell University Press.

Heinze-Fry, J. A. & Novak, J. D. (1990). Concept mapping brings long-term movement toward meaningful learning. Science Education 74(4), 461-472.

Helm, H. & Novak, J. D. (Eds.) (1983). Proceedings of the International Seminar on Misconceptions in Science and Mathematics Conference. Ithaca, NY: Cornell University.

Jegede, O. J., Alaiyemola, F. F., & Okebukola, P. A. O. (1990). The effect of concept mapping on students' anxiety and achievement in biology. Journal of Research in Science Teaching 27(10), 951-960.

Mahler, S., Hoz, R., Fischl, D. & Tov-Ly, E. (1990). Didactic use of concept mapping in higher education: Applications in medical education. Unpublished monograph, Dept. of Education, Ben-Gurion University of the Negev, Beer-Sheva, Israel.

Novak, J. D. (1991). Clarify with concept maps. The Science Teacher 58(7), 45-49.

----- (1990). Concept mapping: A useful tool for science education. Journal of Research in Science Teaching 27(10), 937-949.

----- (Ed.) (1987). Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics. Ithaca, NY: Cornell University.

Novak, J. D. & Gowin, D. B. (1984). Learning how to learn. Cambridge: Cambridge University Press.

Novak, J.D., Gowin, D. B., & Johansen, G. T. (1983). The use of concept mapping and knowledge vee mapping with junior high school science students. Science Education 67(5), 625-645.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. Journal of Research in Science Teaching 29(8), 791-820.

Schwab, J. J. (1978). Science, curriculum, and liberal education. Chicago: University of Chicago Press.

Starr, M. L. & Krajcik, J. S. (1990). Concept maps as a heuristic for science curriculum development: Toward improvement in process and product. Journal of Research in Science Teaching 27(10), 987-1000.

Willerman, M. & Mac Harg, R. A. (1991). The concept map as an advance organizer. Journal of Research in Science Teaching 28(8), 705-711.