# Third Misconceptions Seminar Proceedings (1993)

Paper Title: **The Value of Good "Wrong" Answers**

Author: Weck, Margaret A.

Abstract: Being able to identify the existing cognitive frameworks of students' knowledge of the human body is important for those of us who teach anatomy and physiology (or other specializations of biology). Students' prior understandings can serve as either anchors for (Cognition and Technology Group, 1992) or impediments against (Bloom, 1992; Duit, 1991; Lemke,1990; Stepans, 1985) meaningful learning of the material we present in our courses. The long-term effectiveness of any particular educational experience, or set of experiences, we might devise depends on our successfully using or challenging the prior understandings of our students. Unfortunately students' current knowledge and understanding of any subject is not immediately apparent, neither to the instructor nor, the students themselves, nor the general public (Lord and Rauscher, 1991).

Keywords: concept formation,testing,research methodology,scientific concepts,concept formation,thinking skills,pretests posttests,informal assessment,qualitative research
General School Subject: biological sciences
Specific School Subject: physiology
Students: college freshmen

Macintosh File Name: Weck - Good Wrong Answers
Release Date: 6-24-94, 11-10-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

# The Value of Good "Wrong" Answers

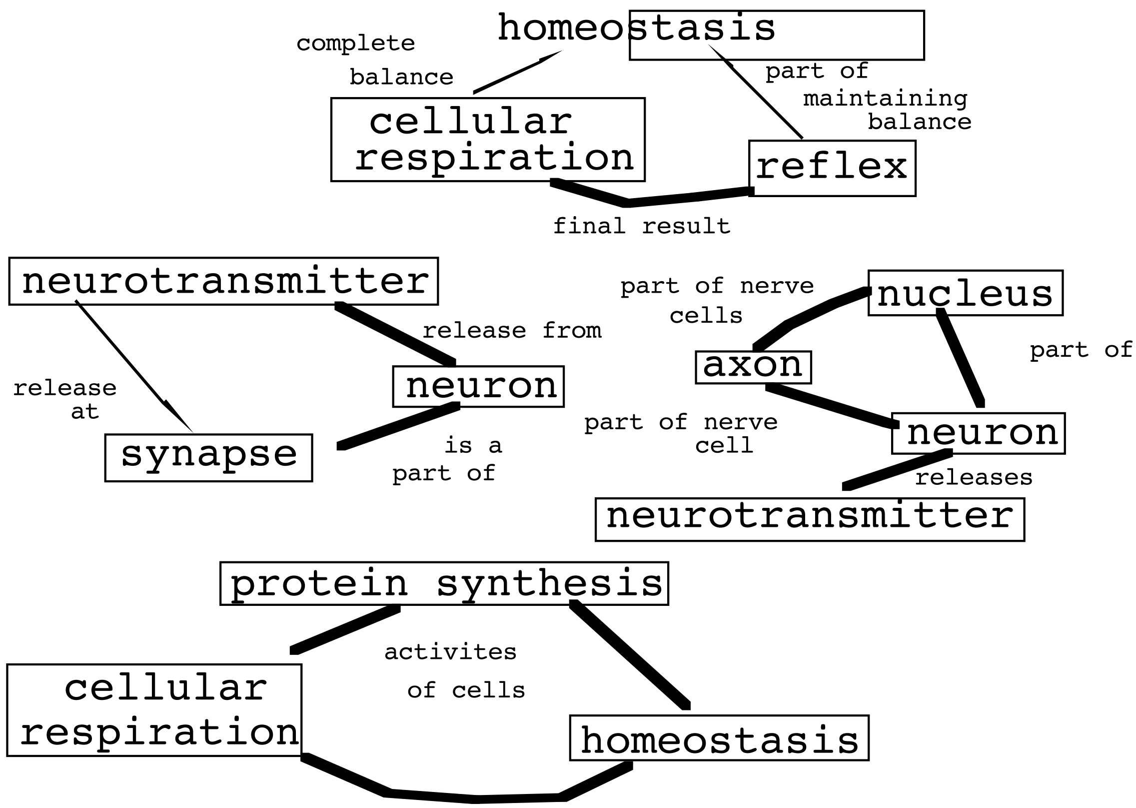
Margaret A. Weck
St. Louis College of Pharmacy, U.S.A.

## INTRODUCTION

Being able to identify the existing cognitive frameworks of students' knowledge of the human body is important for those of us who teach anatomy and physiology (or other specializations of biology). Students' prior understandings can serve as either anchors for (Cognition and Technology Group, 1992) or impediments against (Bloom, 1992; Duit, 1991; Lemke,1990; Stepans, 1985) meaningful learning of the material we present in our courses. The long-term effectiveness of any particular educational experience, or set of experiences, we might devise depends on our successfully using or challenging the prior understandings of our students. Unfortunately students' current knowledge and understanding of any subject is not immediately apparent, neither to the instructor nor, the students themselves, nor the general public (Lord and Rauscher, 1991).

One currently available source of data for illumination of students' cognitive frameworks and thought processes is the work students do on tests, quizzes, and other class assignments. Grades are an important motivator to degree-seeking students. Students take our tests and other assessments seriously. They give the best responses they can remember or synthesize at the time. Those of us who are teachers are all too willing to accept at face value student work which corresponds, more or less, with our preconceptions of what an appropriate answer should look like. Unfortunately "correct" answers may be simple restatements of the teacher/text without significant processing in the mind of the student (Stepans, 1985). Correct answers, therefore do not always provide reliable windows into the thought processes of our students. The individual "wrong" answers of students provide greater insight into the cognitive processes of students, however most regular assessment instruments generate student responses which may not call forth sufficient background or contextual support to determine with any precision a students' actual conceptions, and so are open to over interpretation. While the precise cognitive path each student pursues may be idiosyncratic, regularities in the progression of ideas or the order in which successive competing alternate conceptions are adopted are certainly possible (Mintzes, et al., 1991). Group tendencies in wrong answers provide helpful indications of potential directions and limitations for the interpretation of students' thought processes not possible to determine from analysis of individual answers alone.

This author contends that paying more attention to identifying in greater detail what is currently not being successfully learned by our students is an important way to challenge our own assumptions of how novices build understandings of human anatomy and physiology (or any other subject) through time. Students' work on a variety of tasks from a year-long college freshman human anatomy and physiology course were collected. The examples of student work reproduced




a. January concept map (D,F student).

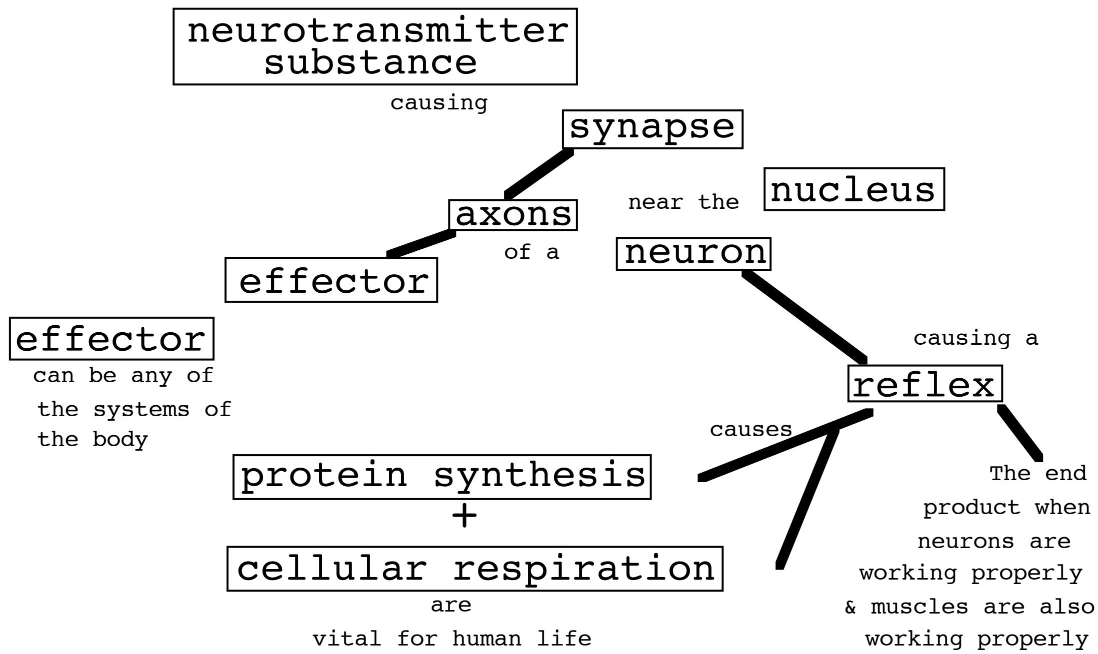



**Figure 1b.** April concept map by same student.

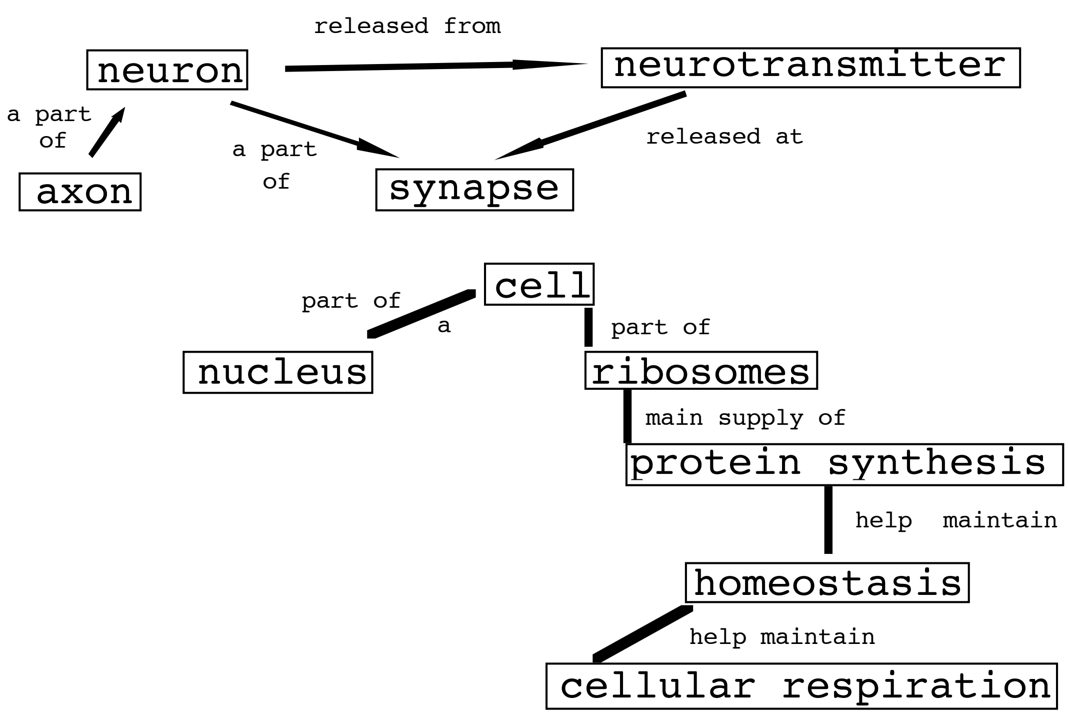


**Figure 2a.** January concept map (B,A student).

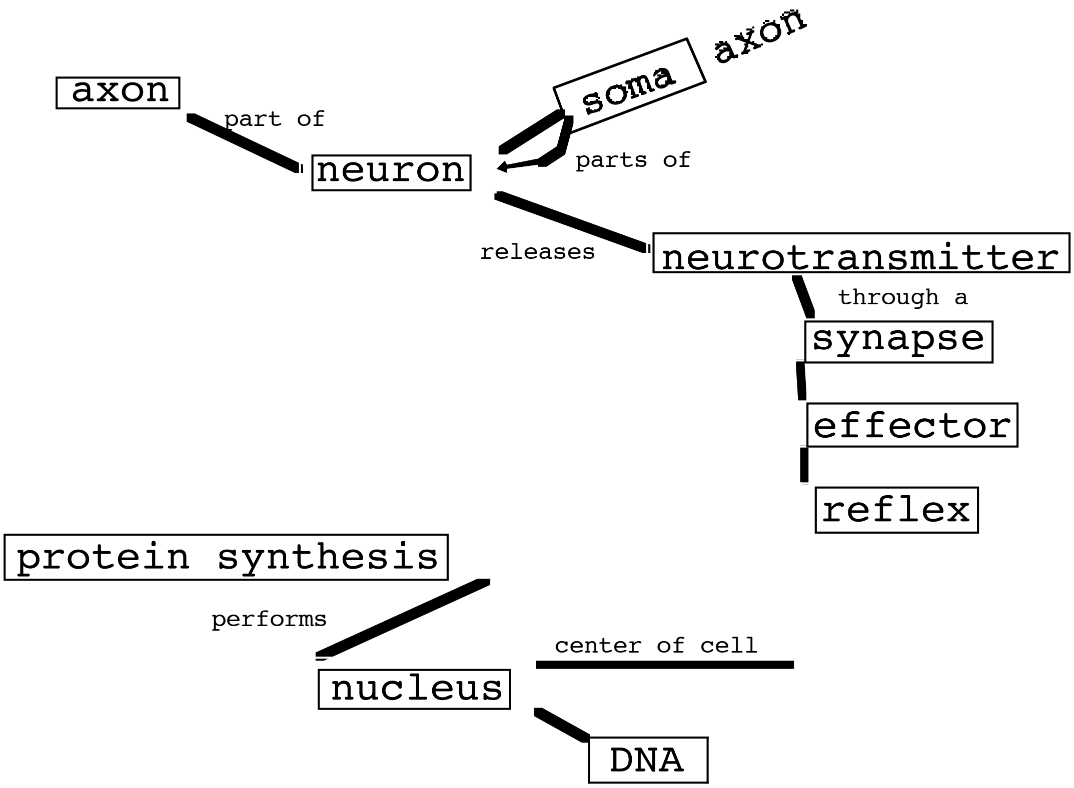



**Figure 2b.** April concept map by same student.

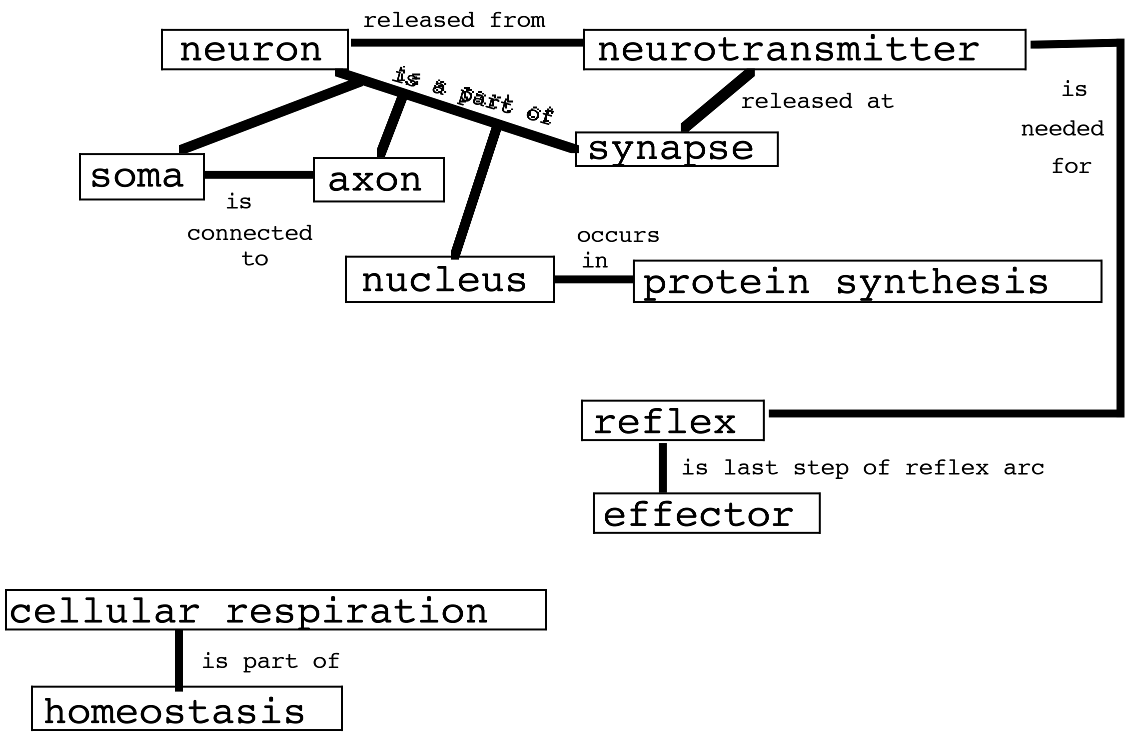



**Figure 3a.** January concept map (B,B student).

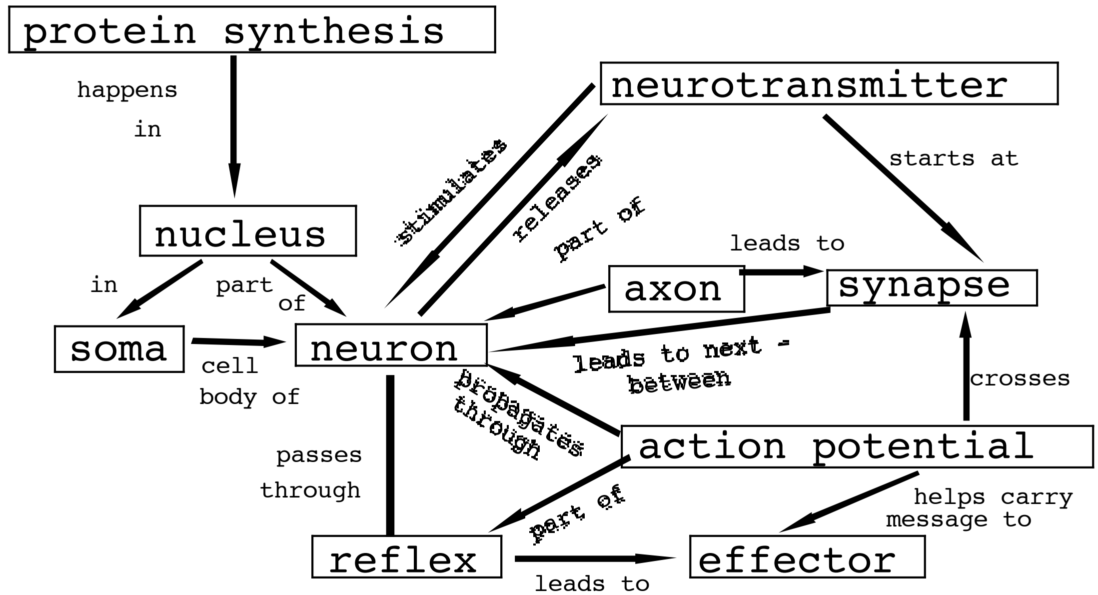



**Figure 3b.** April concept map by same student.

here come from three specific sources: 1. concept maps drawn (using terms introduced in the first semester) at the beginning and again at the end of the second semester, 2. written challenges to multiple choice questions on the first multiple-choice exam given in the first semester, and 3. written summaries of the central topic discussed in three consecutive lecture sessions in the middle of the second semester.

**Table 1**
Analysis of alternations to concept maps between January and April 1993.

| | fewer list words used (Δ -4 max.)[a] | same number of list words used (all, -1 or -2) | more list words used (Δ +5 max.)[b] |
|---|---|---|---|
| more new words added (Δ +4 max.)[c] | N=2 (B for crs.)<br>N=1 (D for crs.)[a] | N=2 (B for crs.)<br>N=1 (C for crs.)<br>N=1 (D for crs.) | N=2 (B for crs.)[c2]<br>N=1 (C for crs.)[b] |
| same number of new words added (0 or 1) | N=5 (B for crs.)<br>N=2 (C for crs.) | N=4 (C for crs.)<br>N=1 (F for crs.) | N=2 (D for crs.)[b1] |
| fewer new words added (Δ -2 max.)[d] | N=3 (B for crs.)[d1]<br>N=1 (C for crs.) | N=5 (B for crs.)<br>N=3 (C for crs.) | N=2 (A for crs.)<br>N=3 (B for crs.)[d1]<br>N=4 (C for crs.)[d1] |

Superscripts indicate individuals with specified maximal changes.

**TRACKING STUDENT PROGRESS**

This class drew a concept map of some terms related to neuron functioning and cell metabolism at the beginning of the second semester and drew a second map using the same terms at the end of the second semester. The tracking of student progress would seem to be straightforward, requiring only comparison of the Jan. maps with the maps drawn later (as in Table 1.). The April maps were expected to show some elaboration over the earlier maps, as the second semester of the course dealt with examples of specific autonomic reflexes in the context of their importance in regulation of organ system function. Further it was expected that there would beä a correlation between the overall complexity of the maps produced and the students' grades for the course.Students were given a list of ten words to use in constructing their maps (see Table 3 for lists). The number of words used from the list and the number of additional words (if any) were tallied for each map. Again the expectations were that good (A and B) students would be able to use all of the words from the list and would incorporate additional terms in order to make more solid connections among the terms given (see Table 2). These students were predicted to reliably produce maps like those in Figs. 3a & 3b, with increased elaboration and interconnections among the terms the second time the map was drawn (Briscoe and LaMaster, 1991; Cliburn, 1987).

**Table 2**

Words used in concept maps not on list given to class.

| January | class grade of student adding term to map | | | | | April | class grade of student adding term to map | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | F | | A | B | C | D | F |
| soma | 1 | 14 | 9 | | | receptor | | 3 | | | |
| action potential | | 2 | 1 | | | action potential | | 2 | | 1 | |
| axon hillock | | | 1 | | | axon hillock | | 1 | | 2 | |
| DNA | | 1 | | | | DNA | 1 | | | | |
| cell | 1 | | | | | cell | | 1 | | | |
| reflex arc | | 1 | | | | afferent neuron | | 1 | 2 | | |
| terminal end | | 1 | | | | interneuron | | 1 | 1 | | |
| ribosome | 1 | | | | | efferent neuron | | 1 | 1 | | |
| | | | | | | ATP | | 1 | | | |
| | | | | | | presynaptic membrane | | 1 | | | |
| | | | | | | postsynaptic membrane | | 1 | | | |
| | | | | | | affector | | 1 | | | |
| | | | | | | cell wall | | 1 | | | |
| | | | | | | organelles | | 1 | | | |
| | | | | | | skeletal muscle | | | 1 | | |
| | | | | | | anaerobic | | | 1 | | |
| | | | | | | movement | | | 1 | | |
| no additional words included in map | 0 | 7 | 5 | 4 | 1 | no additional words included in map | 1 | 12 | 13 | 2 | 1 |

Total of 45 students with both maps. Total students by grade: A=22, B=22, C=16, D=4 & F=1.
Max.# additional words per student = 3 in Jan., 5 in Feb.
Ave.# additional words for students with additions = 1.2 in Jan., 2.6 in Feb.

This is not what occurred. The lack of correlation between map complexity and student course grade was as marked as it was surprising. The map in Figure 1a. shows four separate and disconnected set of terms, even though terms are repeated in two or more of the groups and could have served as bridges between the groups. This map was drawn by a student who barely passed the semester when these topics were first covered. The map in Figure 1b. shows that not much progress was made in clearing up the relationships among these terms during the second semester, as there are still few connections among the terms. The big surprises however were the occurrences of similar gaps in the maps drawn by students who went on the get A's and B's inä the course. A representation of this phenomenon is given in Figures 2a. and 2b. Notice the simple chain of relationships among the terms and though additional terms are included, the complexityä of the map does not increase, nor does the student develop the capability of linking general cellular processes to neurons even by the end of the course.

The tendency of the class (34 of the 45 samples containing both maps) was to produce more simplified maps, rather than more elaborate maps in April, possibly the result of forgetting and possibly the result of asking for the map (a non-graded exercise) on a morning in which a major chemistry exam (counting toward the course grade) was scheduled for the next class period. Another potential influence on the "linearity" of these second maps was the presentation of ideasä in class. Students' only exposures to concept maps within this course were the two times thes were asked to draw them. Concepts maps were not used for instruction in the course. Most ofä the examples on the board were represented as straight chains of structures or temporal sequences of events comprising some bodily or cellular process. It is therefore not too surprising that they would consider linear chains to be adequate expressions of connections among terms. If it is true that modes of presentation in class can shape students modes of thinking about topics (Sutter, 1992), then we must take care that the metaphors we use today (Flick, 1991; Tobin 1990) do not become the misconceptions our colleagues have to deal with tomorrow.

**Table 3**

Words on list given to class omitted from student concept maps.

| | class grade of student adding term to map | | | | | | class grade of student adding term to map | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January terms list | A | B | C | D | F | April terms list | A | B | C | D | F |
| neuron | | | | | | neuron | | 1 | 1 | 1 | |
| neurotransmitter | | | | 1 | | neurotransmitter | | 1 | | | |
| synapse | | | | | | synapse | | | | | |
| axon | | 1 | 1 | | | axon | | 1 | | | |
| nucleus | | 1 | 1 | 1 | | nucleus | 1 | 4 | 1 | | |
| protein synthesis | | 3 | 4 | | | protein synthesis | | 3 | 1 | 1 | |
| cellular respiration | 1 | 6 | 7 | 2 | | cellular respiration | 1 | 4 | 3 | 1 | |
| effector | 1 | 3 | | 1 | 1 | effector | | 1 | | 1 | |
| reflex | 2 | 3 | | 2 | | reflex | | 4 | | 1 | |
| homeostasis | | 4 | 3 | 2 | | soma | | 1 | 2 | | 1 |
| no words missing from map | | 14 | 8 | 1 | | no words missing from map | | 10 | 10 | 3 | |

Total number of students with both maps. Total by grade: A=2, B=22, C=16, D=4 & F=1.

Max.# of words missing by one student = 5 in Jan., 5 in Feb.

Ave.# of words missed by all students missing terms = 2.2 in Jan., 1.6 in Feb.

Quantitative scoring of concept maps has produced no predictive descriptor(s) for this class. There is no apparent strong tendency in number of terms used (Table 3.), number of new terms added (Table 2.), or relative change in both between maps (Table 1.) and a student's eventual grade in the course. Student's maps did not remain static through time, but did exhibit a rather distressing amount of stability.

There was an overall convergence in students' ability to use allä of the terms in their later cognitive maps, but the students who did not see connections among all of the terms in the list were not necessarily the students receiving the lowest grades in the course. What was most interesting about the general trends in the maps was the nature of the terms which students were either totally unable to incorporate into their maps or only tenuously connect to other terms. Table 3. shows that be far the most common word omitted from maps in both January and April were the terms dealing with internal cellular structures and processes.

**LOOKING FOR STUDENTS' CONCEPTIONS**

What do students think and how close are their ideas about the structure and function of the human body to those promoted by anatomists and physiologists? The semi-quantitative analysis of the concept maps pointed future investigation in some interesting directions, but because the labeling of connections in the maps was so incomplete, the window into students' thought processes provided by these maps was limited. In order to obtain a more detailed window into the thoughts of my students larger thematic chunks of student generated text were needed. The maps hinted at some of the connections among ideas proposed by students, but follow-up probes or other tasks are required to elucidate more fully the nature of those connections.

**Table 4**

Student Challenge to Multiple-Choice Question #10.

| | |
|---|---|
| Exam Question | 10. Choose the most correct statement.<br>a. Each organ system of the body is interconnected to all of the other organ systems and the functioning of one system will affect the functioning of other systems.<br>b. Each organ system has a discrete, well-defined and entirely isolated set of functions to perform for the body.<br>c. Each organ of the body is a functional part of one and only one organ system.<br>d. None of the above statements are even vaguely correct. |
| Student Challege | **Written Challenge:** "I believe that the correct answer would be none of the above. I agree that the systems are interconnected, but if functioning of one system had a direct impact on another system, all the systems would react adversely to the trauma.<br>"For example, say you cut your epidermis layer of skin, this would affect the Integumentary system because your skin would no longer be as protective. However, the cut would not affect your skeletal system's ability to support the body, protect the organs, produce new blood cells or decrease movement. There are some trauma's such as a uniary infection that would not affect your nervous system. All things do not affect all systems." |

Students in this human anatomy and physiology course were allowed to challenge the answer key's answer to any multiple choice question. Once their exam was scored it was returned to them for their use in studying for the courses' comprehensive final. Students were encouragedä to look at the exam again and read the key's answers. If they felt after reading the key that the answer they gave was better than the key's answer they could write a paragraph explaining why their answer was better. Some examples of student challenges to multiple choice questions are given in Tables 4 and 5.Exam Question

Imbedded in these written challenges are some interesting ideas. Sometimes they highlight the instances of ambiguity in the way a particular question is worded. And sometimes they reveal underlying ideas which interfere with a student's ability to ignore one or more of the distractors. These are the sorts of ideas which fit Stike and

Posner's (1992) modified definition of misconceptions, although here once more additional probing would be required to verify the status of these ideas as true misconceptions.

The only student challenge to question #10 (see Table 4.) is presented here. The student assumes that interconnection of function means that any damage to an organ system (no matter how slight) must necessarily incapacitate any organs it is connected to. There is no referent for compensatory mechanisms or complex shades of functioning of organs and organ systems. The idea that damage to one system could either not interfere with its ability to perform its overall function for the body, or that <u>by definition</u> if the function of one organ system is compromised,ä we know this usually BECAUSE the function of some other group of cells or tissues has been effected.

So now we are left with the question of what exactly was interfering. Chemicals released form dead and dying cells do influence the composition of the blood, and therefore do affect other cells in their vicinity. This is the factual information the student appeared to be lacking, but was that all that was missing? Was there a common-usage definition (Laferrièr, 1987; Wandersee, 1988) of what it means to "affect the functioning" of an organ system getting in the way?, or was there a basic inability to believe that functions of some cells meaningfully influence the functionä of other cells at a distance? Specific follow-up would have to be designed to resolve this issue satisfactorily, if in fact these various influences can be meaningfully isolated from one another (Strike and Posner, 1992) .

The catalog of characteristics of living things is used by biologists to define what it means for something to be alive. These characteristics inform scientific explanation of how cells and organisms keep themselves alive and these explanations are central to the study of physiology and yet they are some of the most difficult to discuss or lecture about convincingly.

**Table 5**
Student Challenges to Exam Question #11.

| | |
|---|---|
| Exam Question | 11. Which of the following is NOT a characteristic of all living things?<br>a. having a definite form or organization<br>b. having the ability to move<br>c. having the ability to get larger or grow<br>d. having a metabolism<br>e. all of the above are true for all living things. |
| Student Challenges | **Written student challenge 1:** "I believe that having the ability to move is a characteristic of all living things. The text says: metabolism is the ability to take in food & energy and use it to perform vital functions such as growth, movement, and reproduction. A plant takes in nutrients and grows new leaves and stems, reproduces new cells and the roots move deeper into the soil in search of nutrients. I know this could also be considered growing, but for plants it is also movement because the roots & leaves do not stay in the same place." |
| | **Written student challenge 2:** "This is in regards to question number 11: 'Which of the following is NOT a characteristic of all living things?'<br>"I put answer E - All of the above are true for all living things because . . . pg 11 in text - 'metabolism is the ability to assimilate food and/or energy and to use them to perform vital functions such as growth MOVEMENT [emphasis added by student] and reproduction.'<br>"'Responsiveness. . . include MOVEMENT [emphasis added by student] away from danger or poor environmental conditions toward a more suitable environment. . . ' Also under the 'characteristics of life' is growth and development. A cell must physically move during cell division. pg. 94. We learned of mitosis and meiosis and the cell actually divides and completely separates. This is a perfect example of movement.<br>"The same is true with reproduction. A single cell becomes fertilized and rapid movement takes place within as it divides.<br>"Also, movement occurs in negative feedback because that is when a deviance in any body parameter is brought within normal range.<br>"So, the letter E is the correct answer." |
| | **Written student challenge 3;** "I feel that on #11, B is also true of a characteristic of all living things.<br>"Cells have to 'move' to grow, and develop. Cells have to move in such ways as: deviding [sic]. I understand that the other selections of the 5 characteristics of living things were specifically what we had learned, I just took it as a 'trick' question, therefore I choose [sic] the answer that I thought was right." |

The other multiple-choice question and set of written student challenges (in Table 5.) centered on the common properties of all living things. There was class discussion focussed onä the very issue of movement, and in class we defined the movement were talking about to be voluntary movement. We explicitly discussed why movement might not actually be a characteristic of all living things during the initial presentation of the topic. The number of students taking this exam was 97. The correct answer on the key was "b." Seventy-one (71) of the students selected the "correct" answer, the most common wrong answer was "e." (N=22, for which there were three written challenges, all given in Table 5.). These reactions are from a class of students 86 of whom had at least one semester of high school biology. Of the 71 who marked "b.", there is no way of knowing now whether they put that down because they truly believed it or because they knew it was the expected response.

Most of the students who answered incorrectly seemed (during the class discussion which followed the distribution of the scored tests) to see movement as a specific example of the general characteristic of responsiveness, and so were including it in the characteristics of living things. When pressed they will admit that not all living things move as part of their response to the environment. During the discussion, however, one student even went so far as to define movement so as to include the kinetic motion of molecules. Students have never seemed to appreciate test questions which required "deep" (ie. below the literal surface) analysis, or interpretation. Such questions which required reflection and analysis were universally castigated as being "tricky." Yet in order to defend selection of movement as a characteristic of living things, these same students were going to great interpretive lengths. That elementary students think living things exhibit movement is well established (Stepans, 1985; Mintzes, et al., 1992). This is the most likely underlying and unshakable conception, the rest of the verbiage is most likely *ad hoc* rationalization (Strike and Posner, 1992) in light of an answer key that went against them.

**Table 6**

Student Summaries of Baroreceptor Reflex in Control of Blood Pressure

| | | |
|---|---|---|
| brief, somewhat incomplete, but no errors and on the right track | | **Written student response 1:** "When the baroreceptors are are [sic] stretched they send a message thru the afferent neuron in cranial nerve IX. This message goes to the cardioinhibitory center which inhibits the heart rate by sending a message thru the efferent neuron to the SA node. this decreases blood pressure." |
| perfectly acceptable | | **Written student response 2:** "The baroreceptors in the aorta and cartoid sinus are stimulated when stretched by increased blood pressure. Nerve fibers travel from these areas via the vagus and glossopharyngeal nerves to the medulla oblongata. There they stimulate the cardioinhibitory area and inhibit the cardioacceleratory area, causing heart rate to decrease. They also inhibit the vasomotor area, causing the arteries to dilate, reducing peripheral resistance." |
| factual errors, cause and effect errors | | **Written student response 3:** "Baroreceptor Reflex - located in the aortic arch & carotid sinus.<br>- when activated there is a stretch in the cells which causes an increase in b.p.<br>- the reflex tries to decrease the b.p. this is done through stimulation of the vasomotor center, which goes to the smooth muscle of the blood vessels. stimulus here causes constriction of the blood vessels therefore decrease in b.p." |
| factual errors, simultaneous pos. and neg. messages not allowed | | **Written student response 4:** "Stimulation of baroreceptors causes parasympathetic message to travel through vagus nerve to central excitatory system which sends message back through vagus nerve to baroreceptor causing increase in blood pressure. When the BP is too high, a message is sent the same way to the central inhibitory center which then decreases BP." |
| incomplete, internal inconsistency and/or factual errors | | **Written student response 5:** " The baroreceptor reflex is a mechanical reflex. It has a direct influence on the heart rate by determining the amount of pressure that is put on the walls of the aorta. It also changes the peripheral resistance that is put on the vessels." |

The first written challenge to question #11 (see Table 5.) considered demonstration of movement of plant parts due to cell division to be sufficient backup to the idea that ALL living things move. Student challenge 2 demonstrated the presence of movement in some living things under a variety of circumstances and reasoned that therefore all living things MUST move. The problem of interpretation existed here, too. These could have been examples of reasoning from one specific example and student assumptions that was sufficient to imply the characteristic was true for all members of the class, or it could have been a stretch of logic and the rules of evidence in order to be able to keep movement as an acceptable characteristic for all living things. Again, there was no way to identify which interpretation was closer to the truth without further, targeted probes of the student which would not be appropriate in the context in which these challenges were being generated.

Written student challenge 3 (Table 5.) was every teachers' worst nightmare, providing the strongest example of the immutability of current conceptions. What could possibly be added to what the student herself gave as a justification for her answer?: "I understand that the other selections of the 5 characteristics of living things were specifically what we had learned, I just took it as a 'trick' question, therefore I choose [sic] the answer that I thought was right."

Another topic which seemed to provide students with an inordinant amount of difficulty was the neural reflex. Every organ system discussed had one or more neural reflex associated with the control and coordination of its function. Students were continually exposed to examples of reflexes and all of these reflexes had common features, yet many students seem to have to learn each particular reflex as if it were an entirely new phenomenon. During the course we spent three lecture sessions reviewing the baroreceptor reflex for the control of arterial blood pressure, because students indicated they did not grasp it from reading the text or the first lecture. After the third class period devoted to the baroreceptor reflex, students were asked to write a paragraph summarizing what they knew about the baroreceptor reflex at that point. Some selected examples of student responses to the task are given in Table 6. Of the 54 students in class that day, only nine (9) produced an acceptable summary of the reflex indicating good conceptual grasp of this reflex and its function, some of these were somewhat incomplete in detail. Eighteen (18) responses were so incomplete and/or so general that the description could have applied equally well to any number of reflexes. These students had some knowledge of reflexes in general. but were unableä to use this knowledge to help themselves understand the specific instance of the baroreceptor reflex for the control of blood pressure. This phenomena has been called the problem of inert knowledge (Cognition and Technology Group, 1992). The remaining 27 responses had major factual and cause/effect errors. Many of these last students seemed to start off fine and then get hopelessly mired in the details of this particular reflex. Causes and effects are routinely reversed and enough disconnected pieces of information are presented to establish that the students have no clear idea of what this or any other reflex does for the body.

## DISCUSSION --- DECIDING WHAT'S IMPORTANT

Many studies of science and biology literacy use multiple choice testing formats to sample the degree of literacy/familiarity over a range of topics within a specified population (Richmondä et al., 1991; Krupka and Vener, 1991; Lord and Rauscher, 1991). Not all right answers come from understanding and not all errors stem from alternate conceptions. Not paying attention to detail, forgetting and simply being mistaken do not necessarily imply a different conceptual infrastructure (Strike and Posner, 1992). The search for the actual formulations of students' "misconceptions" is hard work.

Even more difficult to counter than the misconceptions of grade school children (Mintzes, et al., 1992; Stepans, 1985) are the misconceptions conceptions of young adults, who now haveä had twenty years of life in which to solidify their interpretation of the world and natural phenomena. These ideas are as well cemented in place as they have power to explain the world. To meaningfully alter such conceptions, we must be able to recognize the context within which they currently exist and provide experiences either directly or by proxy (Strike and Posner, 1992) that force reorganization of the context so that the desired concepts fit better than the old concepts (Bloom, 1992).

While the data presented here are preliminary they do point to directions for further investigation which could help identify/clarify which concepts really <u>are</u> fundamental to building a sound understanding of the disciplines of anatomy and physiology.

Categorizations seem to be difficult for my students, especially when there are multiple possible schemes for a single body part/technical term/process. Students seem to have trouble with making and keeping knowledge classified in the hierarchical groupings, which is consistent withä the literature (Cliburn, 1987). Examination of the types of connections <u>not</u> made among the terms in the concepts maps, as well as the seeming inability of students to move between the general case of reflexes and the specific case of the baroreceptor reflex would support this view.

All instances of challenging students to think or rethink a topic do not necessarily increase the quality of student thought (Goodwin, etal., 1991), especially if the students have successful strategies for negotiating the course and getting the grade they desire without having to rethink the subject in any fundamental way. The concept maps of my A students are testimony to this. The cognitive challenges we put before our students need to be sufficiently demanding to foster conceptual change (Bloom, 1992), yet not so far beyond the cognitive capabilities of our students that they give up (Lemke, 1990; Sutton, 1992). If we can identify the essential concepts in our disciplines in sufficient detail, we can know how to remove the fat of excess terminology and trivia from our courses (Abrahams and Abrahams, 1993) without taking the meat from the bones as well.

Identification of the essential concepts in any discipline must precede, or at least coincide with, the development of the classroom experiences (and better assessment instruments) that areä to help students construct useful understandings consistent with that particular discipline. Analysis of students "wrong" answers, and the trends in such wrong answers over groups of students has given me a place to start the delineation of what really is important for students to remember and understand in the area of human anatomy and physiology.

**SUMMARY**

A good "wrong" answer is one that helps us uncover the nature of a student learning difficulty. Such answers are rare for many reasons, not the least of which is the usual structureä of the assessment tasks. Most individual student answers are too brief to give a realistic view ofä a student's complete thought processes. Therefore individual answers are subject to over interpretation unless there is further explication by the student. Patterns of response, however,ä are available for study in samples of normal classroom work without requiring the development of specialized assessment tools.

The data presented here from the analysis of patterns in wrong answers among a groupä of students in a human anatomy and physiology course have shown a current insufficiency in many students' conceptions of both biological topics and/or general cognitive structures. The strength and endurance of students' prior conceptions is eloquently expressed in students rebuttals to the notion that movement is not necessarily a characteristic of all living things. The students difficulty in linking cellular functions to whole organ or whole body function may be stemming from student's lack of biology knowledge or from their inability to apply general rules of hierarchical organization of ideas to the task. The difficulty students seem to have with understanding reflex arcs may be due to the wealth of structural detail involved, or it may be due to troubles in mastering temporal sequences of cause and effect and/or keeping track of multiple simultaneous processes.

While neither definitive nor exhaustive by themselves, these patterns point to areas of concern and indicate concepts which are being missed or misinterpreted by groups of students large enough to make addressing them explicitly in the classroom worthwhile. In order to begin finer resolution of the nature of students' cognitive difficulties that interfere with their understanding of human anatomy and physiology, the next step is to return to the classroom. With a more focussed attention on these identified problem areas, more systematic efforts will be made to explicitly address these cognitive issues within the course of instruction.

## REFERENCES


Abraham, D. & Abraham, K. (1993) Help stamp out gobbledygook, window dressing & trivia in the classroom! *The American Biology Teacher,* *55*(3), 159-160.

Bloom, J. W. (1992). Contexts of meaning and conceptual integration: How children understand and learn. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 177-194). Albany, NY: State University of New York Press.

Briscoe, C. & LaMaster, S. U. (1991). Meaningful learning in college biology through concept mapping. *The American Biology Teacher*, *53*(4), 214-219.

Cliburn, J. W. Jr. (1987). Helping students understand physiology interactions: A concept mapping activity. *The American Biology Teacher*, *49*,(7), 426-427.

The Cognition and Technology Group at Vanderbilt University (1992). Anchored instruction in science and mathmatics: Theoretical basis, developmental projects and initial reserch findings. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 244-271). Albany, NY: State University of New York Press.

Duit, R. (1991). Students' conceptual frameworks: Consequences for learning science. In S. M. Glynn, R.H. Yeany & B. K. Britton (Eds.), *The psychology of learning science* (pp. 65-85). Hillsdale, NJ: Lawrence Earlbaum Associates.

Flick, L. (1991). Analogy and metaphor: Tools for understanding inquiry science methods. *Journal of Science Teacher Education* *2*(3), 61-66.

Goodwin, L., Miller, J. E. & Cheetham, R.D. (1991). Teaching freshmen to think - does active learning work? *BioScience*, *41*(10), 719-722.

Krupka, L. R. & Vener, A. M. (1991). College students' knowledge of cardiovascular disease: Implications for the Biology teacher. *The American Biology Teacher*, *53*(7), 394-398.

Laferrière, J. E. (1987). Folk definitions influence the acceptance of technical vocabulary. *The American Biology Teacher*, *49*(3), 149-152.

Lemke, J. L. (1990). *Talking science*. Norwood, NJ: Ablex Publishing Corp.

Lord, T. R. & Rauscher, C. (1991). A sampling of basic life science literacy in a college population. *The American Biology Teacher*, *53*(7), 419-424.

Mintzes, J. J., Trowbridge, J. E., Arnaudin, M. W., and Wandersee, J. H. (1991) Children's biology: Studies on conceptual development in the life sciences. In S. M. Glynn, R.H. Yeany & B. K. Britton (Eds.), *The psychology of learning science* (pp. 179-201). Hillsdale, NJ: Lawrence Earlbaum Associates.

Richmond, G., Vener, A. M., & Krupka, L. R. (1991). Assessment of health knowledge in college women. *The American Biology Teacher*, *53*(5), 265-271.

Stepans, J. (1985). Biology in elementary schools: children's conceptions of "Life." *The American Biology Teacher*, *47*(4), 222-225.

Strike, K. A. & Posner, G. J. (1992) A revisionist theory of conceptual change. In, R. A. Duschl & R. J. Hamilton (Eds.). *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). Albany, NY; State University of New York Press.

Sutton, C. R. (1992). *Words, science and learning*. Buckingham, Great Briton: Open University Press.

Tobin, K. (1990). Metaphors and images in teaching. What Research Says to the Science and Mathematics Teacher, Number 5,(pp. 1-7). Perth, Western Australia; Key Centre for School Science and Mathematics.

Wandersee, J. H. (1988). The terminology problem in Biology education: A reconnaissance. The American Biology Teacher, 50(2), 97-100.