Third Misconceptions Seminar Proceedings (1993)

Paper Title: **MISCONCEPTIONS ABOUT CELLS**
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Keywords: Concept Formation,Educational Methods,,Misconceptions,Cognitive Restructuring,Empowering Students,Cognitive Process,Concept Teaching,Concept Formation
General School Subject: Biological Sciences
Specific School Subject: Biology
Students: Junior High

Macintosh File Name: Zamora - Cells
Release Date: 5-19-1994 G, 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).

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MISCONCEPTIONS ABOUT CELLS

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INTRODUCTION

Cells are considered to be the units of life. Almost all living creatures are made up of cells. For this reason, the concept of cell is fundamental in learning biology. In Mexico, children learn about cells for the first time in fourth grade of grammar school. The concept is presented again the following two grades of grammar school, once again in junior highschool and once again in senior highschool. Every time,the information is reviewed and enlarged.

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We based our questions on the information obtained by Dr. Dreyfus & Dr. Jungwirth in 1988. Their work called "The Cell Concept of 10th graders. Curricular Expectations and Reality ", shows some of the difficulties in learning about cells. Essentially, students can visualize cells as bricks in a wall, that is inanimated units of construction. The idea of " units of life", with functions of their own, seems hard to accept.

How do students conceive a living organism made up of non living units ? This paper explores the alternative frameworks used by students to explain functions of cells that are caracteristic of all living creatures; such as reproduction, digestion, respiration, communication, etc. We are specially interested in human cells, in the relation between cells and the human body.

METHOD

The questionnaire was designed with the intention of inducing students to picture a cell and to relate this image with themselves. With this approach, we intended to find explanations that were not given by the teacher or the textbook, but were elaborated by the students out of their own experience. The first two questions were :

1) Draw a cell with all its details and explain it.
2) Have you ever been a cell ? Please explain.

The findings of Dr. Dreyfus show that the size of cells is confused in relation to the size of organs and molecules; yet it is clear that they are "smaller than a grain of sand ".

The following questions tried to explore how cells as microscopic beings relate to human beings. We list them below:

3) What happens to your cells when you grow ?
4) What does a cell need to live ?
5) How do your cells use whatever you eat and breath ?
6) If your stomach, your skin and your brain are made up of cells, why are they so different ?
7) How do cells make other cells ?
8) If you have so many different cells, how do they all work together as a unit ?

We presented this questionnaire to 150 students in 7th, 8th and 9th grades. We explained the purpose of it and entitled the work "Contribution to the Science Museum". They were asked to write down their age and their grade, not their name.

Evaluation of the questionnaires was carried out at three levels:

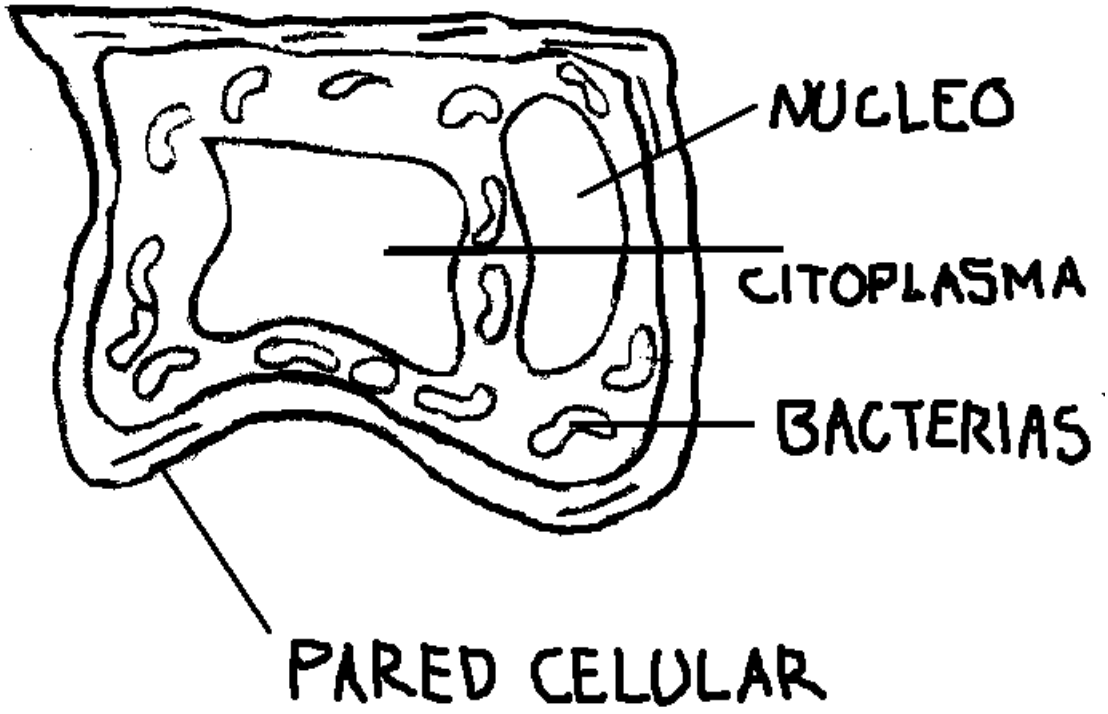
a)Each question by itself, using all the questionnaires.
b)Each questionnaire as a whole, relating answers among themselves in search of a framework.
c)All questionnaires as a whole, trying to separate general knowledge -which could be useful as a basic image of the cell- from individual misconceptions.

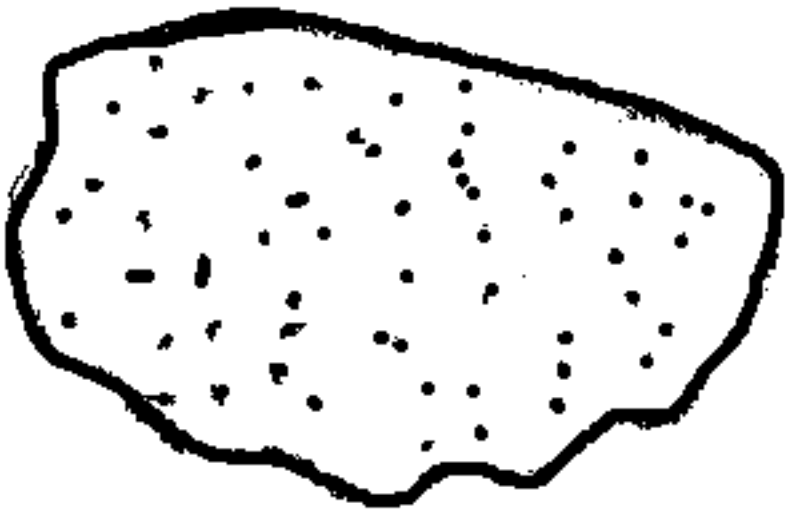
RESULTS

a) Evaluation of individual questions.

The answer to each question was compared among all questionnaires looking for similarities,ä in order to find the most frequent responses. We tried to determine the percentages of similar answers, but this was not possible due to the diversity of ideas and the way they were related among themselves. If we were to establish a standard, we would have perhaps added information that was not really there. We present the most frequent answer and some interesting misconceptions.

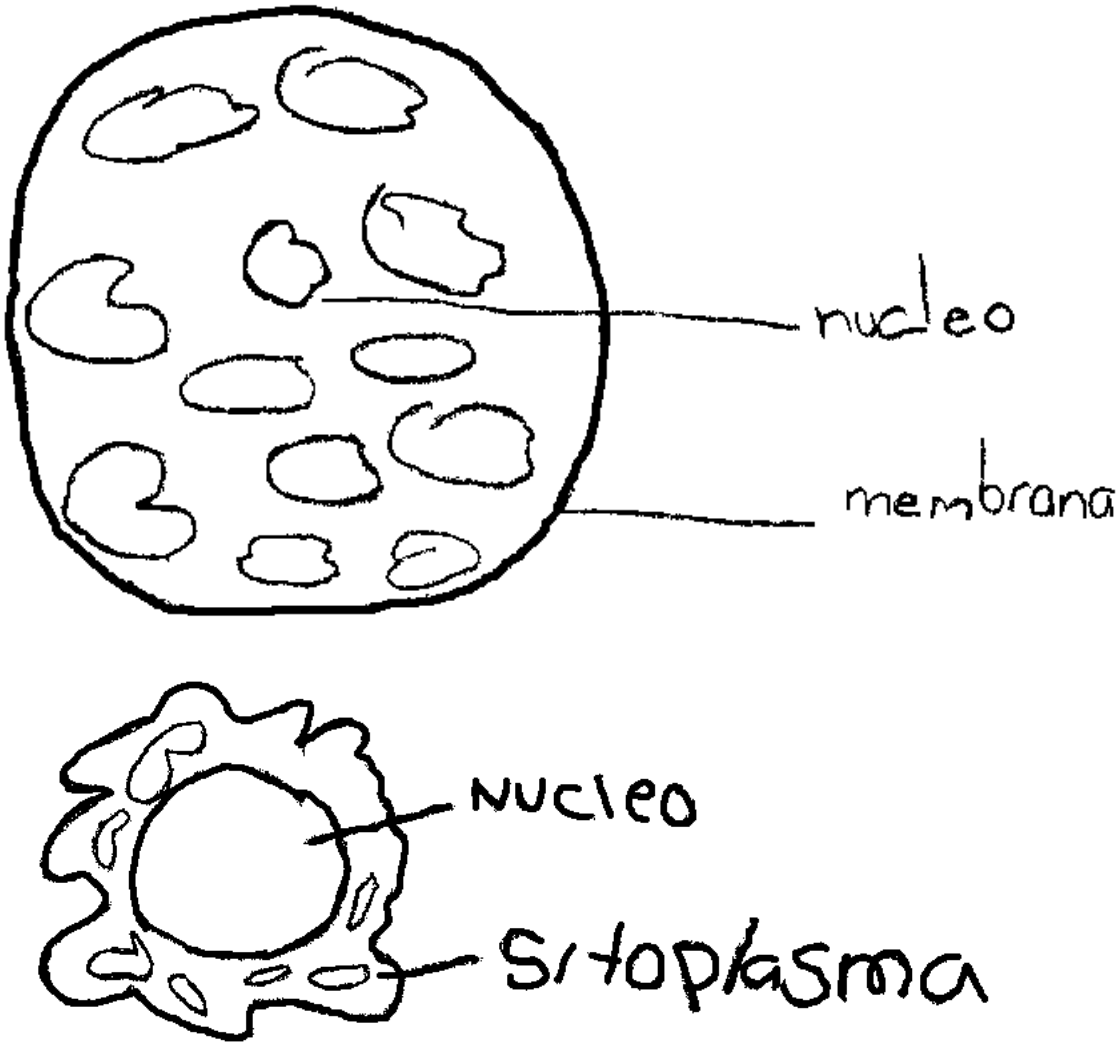
1. When asked to draw a cell,and explain its parts, the most common drawings were the following:

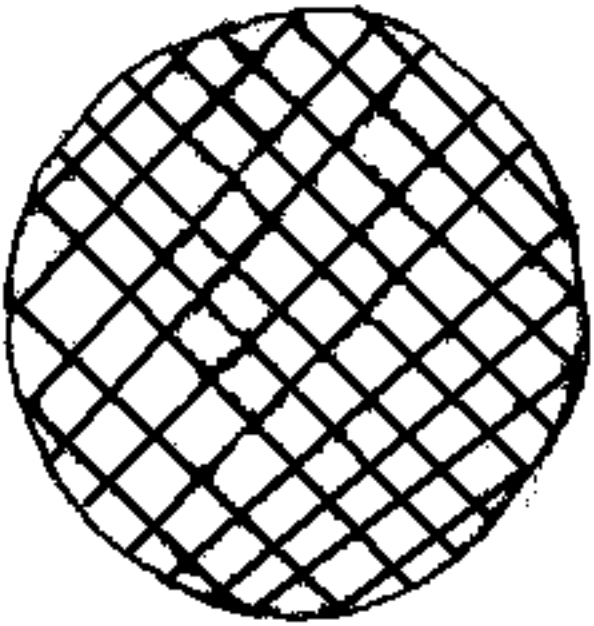


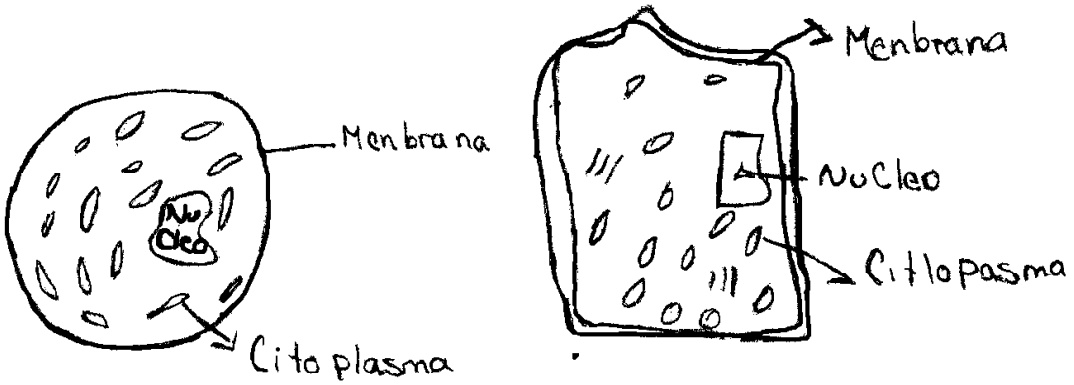


Celula

Nuclear


nucleo
membrana
NUCLEO
Sitoplasma





The only cell component that was frequently identified was the nucleus, after that came the cell membrane often confused with the cell wall. In a few cases the citoplasm was mentioned and only in two cases mitocondrions,cloroplasts and ribosomes were considered. No explanation was offered about anything.

2. When asked if they had ever been a cell, all the answers were "yes". The

mayority ventured an explanation. The most frequent ones were:"I was a cell from my mother"."I was a cell from my father". "I was a cell when I was born"." I am made of that". "I was a cell before I was born". Only very few agreed to the fact that "one cell from my mother and one cell from my father joined to form a single cell that was me".

3. When asked what happened to their cells when they grow, the most frecuent answer was: "They also grow". In spanish,the word grow refers only to size, not to number. It seems that the complexity derived from a large number of cells is overcomed by misconceptions hintedä by other answers like: "they gradually disappear"; "they split in half"; "more and more are formed"; "new cells are born from me"; "when cells start to grow they start to distribute themselves all over the body ". These last two answers implie that the human body is independent of cells, it produces cells instead of beeing made up of cells.

Several answers maintained that "cells go through stages: childhood, adolescence and adulthood". We can not tell if this implies that a human being is still an individual cell; or that cells mature in a similar way. It is quite possible that it's not clear to the respondants either.

4.When asked what does a cell need to live, the most frequent answers were: " It needs to be born ","it needs to eat "," it needs blood", "it needs food and excercise ","it needs that we eat well and that we are healthy". All the answers imply that cells need to be cared for by human beings. Some of them however, could mean that cells are similar to human beings, in the same way that answers to question 3 imply.

5.When asked how do cells use whatever you eat and breath, the most frequent answers were: "they use it to live","to have strenght","to multiply themselves ", "to help me grow". These answers seem to contradict the findings of Dr. Dreyfus about cells as briks; yet analyzing the questionnaire as a whole it is evident that many students confuse cells with organs. It is possible that they consider the life of cells as dependent on the body as the "life" of an organ. How long is an organ "alive" for a transplant ? The term "living" is quite confussing for most students as we show elswhere (Zamora

& Guerra 1993).

6.When asked why cells of different organs are different, the most common answer was "because they have a different function". Very few of them said "because they have different information". We can not tell if this is genetic information because the term genetic was never present in any questionnaire. The rest of the answers did not include a reason : "because they are different","because they have different cells".

7.When asked how cells make other cells the most frequent answers were: "they split in half", "Two cells of different sex need to get together " and "they are born, they grow, die and reproduce". The last answer seemed to be a mistake in the order of events, but it was too frecuent to be an individual error. After analyzing other questionnaires, we found another answer that explained this way of understanding cell reproduction:"when they die, a scar is formed and they live again". It could be the result of an explanation on how a wound is repaired by the reproduction of cells. Some of them die but others reproduce to take their place.

Other answer stated: "When they split they die, but two are formed and live forever", this could be a different interpretation of why they die first and reproduce afterwards.

8.When asked how all the cells in the body could function together, the most frequent answers were: "because if they didn't I would die" and "because of the brain and the heart". The later answer is consistent with the findings of other works, students consider the brain as the ultimate control of everything in the body, including heredity.

b) Evaluation of individual questionnaires.

As we analyzed all the answers in the questionnaire in search of a general idea of a cell, we found that the image of a cell is very obscure for most of the students. Many of the questionnaires were incomplete. They all had a drawing and two or three answers, but more than a half did not answer the last 3 questions. We interpret this omission as lack of information. Only a few ideas are clear enough to show how these students understand the

concept:
I once was a cell and now I have some cells that help me grow and heal wounds. Cells need that I stay in good health.
I once was a cell but now I produce cells because I need them to be healthy. They are all over my body to make it function.
I once was a cell but as I grew they disappeared by spliting in half. Each organ has a cell or is a cell.

These ideas can combine with one another to the extent of having contradictory ideas in the same questionnaire. As if they could only recall flashes of memorys that were not integrated into a model.Parts of a puzzle that do not seem to fit together.

It is quite significant that none of the questionnaires reflects the idea: "Once I was a cell and now I am a lot of cells". When they considered the instance of a large number of cells they always used the word "have" instead of "am".

c) Global evaluation of questionnaires.

Even though we could not find true alternative frameworks for the concept of cell, we tried to summaryse the ideas we found in order to fulfill our inicial purpose: a didactic aproach for the exhibit. The general idea of a cell that can be derived from all the questionnaires as a whole is:

"Cells are some little things that I need to heal my body, to be healthy. Once I was a cell but now I have cells only in some parts of my body. Cells have little things inside like organs or organisms. I have to eat well and do exercise so my cells can live. I make more cells when I need them because the brain orders this to happen".

DISCUSSION

The concept of cell is not related to every day life. Students do not have a referece where they can find out for themselves what cells are or where they are. The information they receive leaves a wide margin for imagination. The result is a variety of interpretations. The image they can see in a textbook does not have any reference to size or location in the body. This

causes confusion on whether the cell is an organ, an organism, a movile structure, or a whole human being at some stage of its development.

Since the reference is indirect,the interpretation students give to the image and the information the teacher gives them, is taken as a possibility. Which means they can accept contradictory information and play with it until it makes sense. It can not be integrated because some pieces of the puzzle are missing, mainly: Where is the cell?

Some information is easy to accept because it makes sense with everyday experience. Such is the case of "once I was a cell". Students have experienced the fact of growing, so it is reasonable to assume that once they were a microscopic being. The difficult part of the information is if they were a cell from their father or from their mother; or if they were an idependent cell inside their mother. Because it´s hard to imagine how two different cells from two different bodies, come together as one. Nothing similar takes place in their surroundings.

Another difficult part of the cell concept is: What happened to the cell when I started to grow ? Some movie images describe the first division of cells, but as division continues, individual cells cannot be distinguished. This can be interpreted as: "cells split in half and disappear ".

The difficulty in representing graphically the complexity of a large number of cells forming a human being, reflects in part the difficulties in accepting this reality, other problems are functional: How can they become different and organize themselves in such different parts as a body has ? How can all the different parts of the body function as one ? The alternative explanation students often give themselves is "I produce cells, I organize them through my brain and heart." The fact that "I" results an entity not made up of cells; or made up of them but independent to make desitions about cells, seems easier to accept than the difficulty of having cells -as independent beings - organize themselves into a human being.

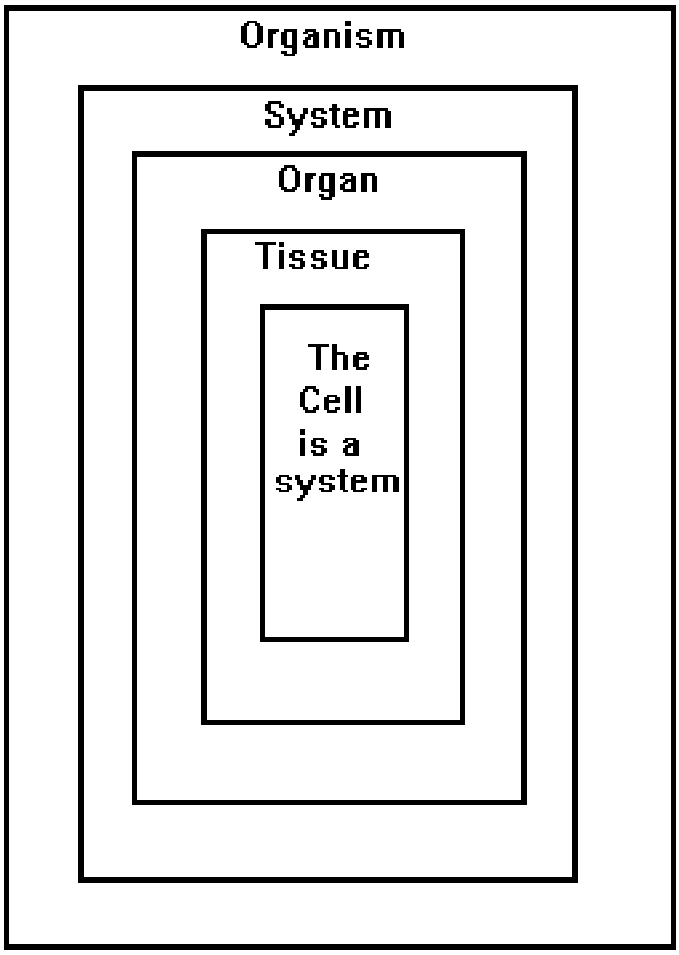
The conception of invisible entities that organize visible ones, is a stage in the scientific and philosophical development of knowledge: animism. Several authors (Gagliardi R,1988,...) claim the value of using the history of science in science teaching. This is undoubtedly true, yet it is not necessary to give the students all history, only the parts that are useful to them. In the present case,it would be enough to mention that other people, recorded by history, have supported animism, but that today the approach of cells as systems is prefered.

The theory of systems was developed in biology out of the need to consider the influence of many variables in a set of phenomena. Perhaps the best example would be an ecosystem. A lake could be considered an isolated entity, yet it is influenced by the climate, the mountains that surround it, the plants and animals that live in it, the contents of the rivers that flow to it, etc. The lake is therefore a complicated system.

If the students understand the concept of a system through examples that they can experience in their everyday life, it would be easier for them to accept systems that cannot be seen. They could analyze systems within other systems like: a city that contains a school, that contains a classroom, that contains children.

The human body could be presented as a system made of subsystems: circulatory system, digestive system, respiratory system, etc. Each system is composed of different organs and conducts which are themselves systems of tissues. Each tissue is a system of cells. Cells are very small systems, yet they are also systems of organells and molecules and so on.

The concept of system is a structural one (Gagliardi R.,1988), it helps to sustain a lot of knowledge in an orderly fashion. It is a basic idea (Moreira ,1991) on which other ideas can be built. Several subjects like math, science, language, geography,etc., could find this concept useful, so a certain integration can be achieved.



"Many recent studies indicate that educators need to empower learners by helping them organize and use carefully developed hierarchial knowledge structures" (Novak,J.D. 1993).It is quite possible that these hierarchies are organized like files in a computer. Files are in fact systems within other systems.

The exhibit called "Journey to the Center of the Cell" is a journey through various levels of organization. It is very important to help the visitor become aware of the size and the location in the human body of what he is observing. The title of the exhibit can be used in the classroom to stirr up the pupils imagination and to help them correct some of their misconceptions by providing a way of organizing isolated facts into hierarchies.

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