

# GEORGE EMIL PALADE – A PIONEER OF CELL BIOLOGY

*T. Nicolici-Schultz and A. Neculae*

*West University of Timisoara, Romania, neculae@physics.uvt.ro*

## ABSTRACT

*George Emil Palade is probably the most world-wide recognised and awarded Romanian scientist. Due to his contributions on the cell structure and functionality, considered “mile-stones” in cell biology, he received the Nobel Prize in 1974. The paper focuses on three different aspects: the biography of the scientist, stressing his scientific and professional evolution, a short presentation of the domain he founded - the cell biology, and finally, a set of ideas, techniques and methods for making the biology lessons on the cell and molecule structure more attractive for the students in the primary school.*

**Keywords: George Emil Palade, cell biology, animal cell, vegetal cell, cell structure**

## Introduction

George Emil Palade (November 19, 1912 – October 7, 2008) was a Romanian cell biologist. In 1974, he shared the Nobel Prize in Physiology or Medicine with Albert Claude and Christian de Duve, for discovering the ribosomes [1, 2]. Our work is a tribute to this brilliant Romanian scientist, who due to his “*pioneering discoveries of a host of fundamental, highly organized structures in living cells...*” is considered to be one of the founders of cell biology. First, we present a synthetic biography, followed by a description of the basics of cell biology. An important part of this work is dedicated to the didactical aspects of teaching the fundamentals of cell biology in the primary school.



**Figure 1. George Emil Palade (1912-2008)**

## Short biography of George E. Palade

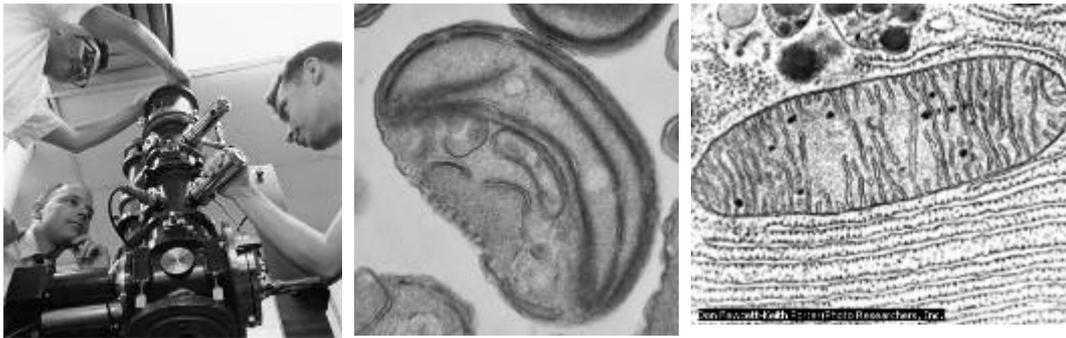
George Emil Palade was born on November 19, 1912 at Jassy (Iași), the old capital of Moldavia, the eastern province of Romania. His father, Emil Palade, was professor of philosophy at the University and his mother, Constanta Cantemir-Palade, was a high school teacher. Both parents strongly encouraged young George to further develop his native abilities through higher education. As he narrates in his autobiography, “*the family environment explains why I acquired early in life great respect for books, scholars and education*” [3]. He started his studies in Iași and then continued through a baccalaureate at the “Al Hasdeu” Lyceum in Buzau. Despite the expectations of his father, who had hoped he will go to study philosophy at the University, like himself, George “*preferred to deal with tangibles and specifics, and - influenced by relatives much*

*closer to my age than he was - I entered the School of Medicine of the University of Bucharest (Romania) in 1930” [3].*

Early in his student years, being fascinated by lessons of Francisc Rainer and André Boivin, professors of Anatomy and Biochemistry, respectively, he developed a strong interest in basic biomedical sciences and he started working in the Anatomy laboratory while still in medical school. After six years of hospital training, mostly in internal medicine, George E. Palade decided to do the work for his doctorate thesis in microscopic anatomy on a rather unusual topic for an Medicine Doctor (MD) degree: the nephron of the cetacean *Delphinus delphi*. It was an attempt to understand its structure in terms of the functional adaptation of a mammal to marine life. George E. Palade received his M.D. title in 1940 from the Carol Davila School of Medicine, in Bucharest, Romania. After a short period as an assistant in internal medicine, he went back to the field of Anatomy, considering that *“the discrepancy between knowledge possessed by, and expected from, the medical practitioners of that time made me rather uneasy”*. He was a member of the faculty of that famous school until 1945 when he went to the United States for postdoctoral studies.

George E. Palade started his scientific activity in the United States at the Rockefeller Institute for Medical Research, where he joined the team of Prof. Albert Claude. Palade used electron microscopy to study the internal organization of such cell structures as ribosomes, mitochondria, chloroplasts, the Golgi apparatus, and others. He focused on Weibel-Palade bodies (a storage organelle unique to the endothelium) which he described together with the Swiss anatomist Ewald R. Weibel. Here is how he described the research activity of the "Rockefeller group" in the field of biological electron microscopy with the general aim of developing preparation procedures applicable to organized tissue:

*“A period of intense activity and great excitement followed since the new layer of biological structure revealed by electron microscopy proved to be unexpectedly rich and surprisingly uniform for practically all eukaryotic cells. Singly, or in collaboration with others, I did my share in exploring the newly open territory and, in the process; I defined the fine structure of mitochondria, and described the small particulate component of the cytoplasm (later called ribosomes)” [3].*



**Figure 2. Electron microscope and cell images obtained by electronic microscopy.**

It was during this period that cell biology became a recognized field of research in biological sciences and that the Journal of Cell Biology and the American Society for Cell Biology were founded, and the "Rockefeller group" participated actively in each of these developments.

In 1952, George E. Palade became a naturalized citizen of the United States, and starting with 1958 he was a Professor at the Rockefeller Institute, where he activated until in 1973. In the

1960's, Palade and his research group I continued the work on the secretory process, performing a series of investigations which produced a good part of the ideas on the synthesis and intracellular processing of proteins for export. He was elected member of the National Academy of Sciences (U.S.A.) since 1961, and his scientific work in this period was recognized through an important number of awards and prizes, among them: the Lasker Award (1966), the Gairdner Special Award (1967), and the Hurwitz Prize - shared with Albert Claude and Keith Porter (1970).

In 1973, George E. Palade left the Rockefeller University to join the Yale University Medical School. The main reason for the move was his belief that the time had come for fruitful interactions between the new discipline of Cell Biology and the traditional fields of interest of medical schools, namely Pathology and Clinical Medicine. Palade was the first Chairman of the Department of Cell Biology at Yale University. Presently, the Chair of Cell Biology at Yale is named the "George Palade Professorship".

The supreme recognition of his brilliant scientific activity appears in 1974, when he shared the Nobel Prize in Physiology or Medicine with Albert Claude and Christian de Duve "*for discoveries concerning the functional organization of the cell that were seminal events in the development of modern cell biology*" related to his previous research carried out at the Rockefeller Institute for Medical Research. His Nobel lecture, delivered on December 12, 1974, was entitled: "*Intracellular Aspects of the Process of Protein Secretion*", published in 1992 by the Nobel Prize Foundation.

He was elected an Honorary Member of the Romanian Academy in 1975. In 1986 Palade also received the U.S. National Medal of Science in Biological Sciences for "*pioneering discoveries of a host of fundamental, highly organized structures in living cells...*" and in 1988 he was elected an Honorary Member of the American-Romanian Academy of Arts and Sciences (ARA).

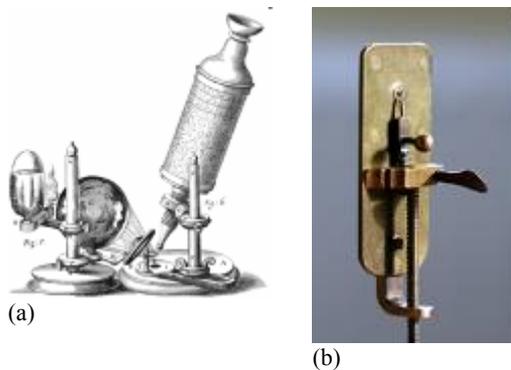
From 1990 to 2008, Palade was Professor of Medicine in Residence (Emeritus) at the University of California, San Diego, in the Department of Cellular & Molecular Medicine, as well as a Dean for Scientific Affairs (Emeritus), in the School of Medicine at La Jolla, California.

George E. Palade died on October 7, 2008, but his work, recognized all over the world, still represents the fundamentals of top research activity: one notes that the Nobel Prize in Chemistry was awarded in 2009 to Drs. Venkatraman Ramakrishnan, Thomas A. Steitz and Ada E. Yonath "*for studies of the structure and function of the ribosome*", discovered by Dr. George Emil Palade.

## **What is cell biology?**

Cell biology is the study of the structure of internal cellular components, their functions, and molecular mechanisms such as metabolism. The scientific progresses in this field were strongly correlated to the development of the microscopy, which is the most used investigative technique in cell biology.

From an historical point of view, Robert Hooke (1635–1703) is considered to be the first to observe cells under the microscope, but Anton von Leeuwenhoek (1632–1723) was first to observe one celled living things. Examples of these were bacteria and parameciums. For this reason, von Leeuwenhoek is named "the father of microbiology" [4].



**Figure 3. a) Hooke's microscope, from an engraving in Micrographia; b) Replica of microscope by Van Leeuwenhoek [4]**

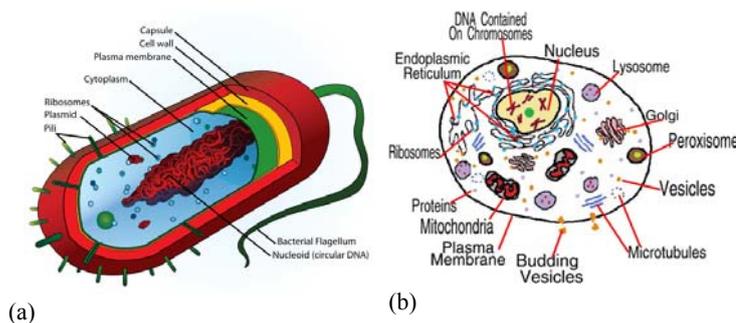
What is a cell?

“Cell” is the Latin word for “small room” and it can be defined as the "structural and functional unit of life". Living cells are divided into two types - procaryotic and eucaryotic (sometimes spelled prokaryotic and eukaryotic). This division is based on internal complexity.

Procaryotic (for example bacteria) consist, most of them, of only a single cell. These cells are simple in structure. They have an outer cell wall that gives them shape. Just under the rigid cell wall is the more fluid cell membrane. The cytoplasm enclosed within the cell membrane does not exhibit much structure when viewed by electron microscopy.

Eucaryotic (cells of protozoa, higher plants and animals) are highly structured. These cells tend to be larger than the cells of bacteria, and have developed specialized packaging and transport mechanisms that may be necessary to support their larger size. All higher life forms are made up of eucaryotic cells because they contain a distinct nucleus.

Cellular structure is the first step in understanding how a cell works. A cell is a small organized structure that is capable of metabolic activity necessary to keep an organism alive. It is a unique self contained environment. The nucleus is what enables the cell to reproduce and all eucaryotic cells reproduce by replication of DNA, while prokaryotic cells reproduce by binary fission (they divide in two). The fact that the origin of cells was the division of preexisting cells is expressed by Virchow's law (1858): “Omnis cellula e cellula” - every cell originates from another existing cell like it.



**Figure 4. a) Procaryotic cell; b) Eucaryotic cell**

Both plant and animals are eucaryotes. The structural and functional differences between plants and animals are manifested in the form of plant cell and animal cell differences. A comparative study of plant cell versus animal cell is done by first providing diagrams of a plant

(vegetal) cell and an animal cell (Figure 5a,b) followed by a table that lists the differences between the two (Table 1) [5].

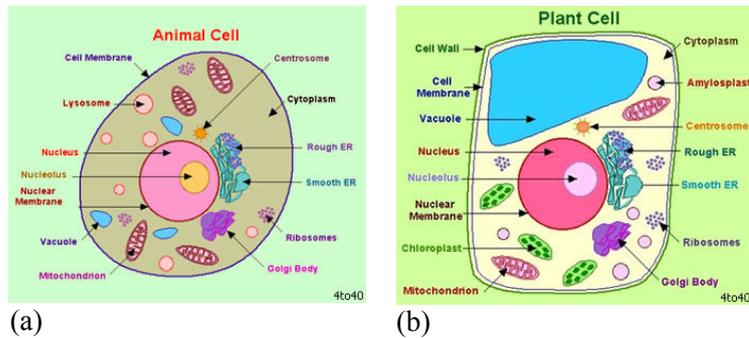


Figure 5. a) Animal cell; b) Plant cell [5]

Characteristics	Plant Cell	Animal Cell
Cell Size	Large	Smaller than plant cells
Cell Shape	Rectangular	Circular
Vacuoles	A single centrally located vacuole. It takes up almost 90% of the cell volume. The vacuole stores water and maintains turgidity of the cell.	If any, there are a number of small vacuoles spread throughout the cytoplasm that store water, ions and waste materials.
Cell Wall	A rigid cell wall (made of cellulose) is present around a plant cell that helps it maintain its shape.	Cell wall is absent. This allows animal cells to adopt different shapes.
Chloroplasts	Present. Chlorophyll is the pigment that traps sun's energy which is utilized by plants to make food through the process of photosynthesis. This pigment is present in the chloroplasts.	Absent. As animals lack this pigment, they cannot make their own food.
Cell Division	Cell division takes place by the formation of cell plate in the center of the dividing cell. This becomes the cell wall between the two daughter cells.	Animal cells divide with the formation of a cleavage furrow. This is formed as the chromosomes move to the ends of the microtubule spindle formed by the centrioles.
Centrioles	Present only in lower forms. Plants instead have microtubule organizing centers (MTOC) that produce the microtubules.	Present. Centrioles help in division of animal cells by creating microtubule spindles that pull the chromosomes to opposite ends for cell division to occur.
Centrosome	Absent. Instead two small clear areas called polar caps are present.	Present
Lysosomes	Absent	Present. Lysosomes are vesicles that contain enzymes that destroy dead cell organelles and other cells debris.
Golgi Bodies	In place of golgi bodies, its sub units known as dictyosomes are present.	Complex golgi bodies are present close to the nucleus.

Table 1: Differences between plant and animal cells [5].

### How to teach pupils the basics of cell biology?

In order to make the complex field of cell biology as familiar as possible to the young student, the teacher must choose the most suitable didactic tools and means. Because the direct observation of the cells (“hands-on” methods) is not always possible or suitable, the accent must be put on so-called “minds-on” methods, based on attractive short presentations with examples

and analogies, using attractive pictures [6, 7] and “comics” [8], which develop the intuition of the pupil. Together with the presentations, other complementary tools, like the computer (internet, softwares and simulations) and even art activities should be used in the teaching process. Next, we present some examples.

The first idea of a presentation in this subject is that “the cells are the starting point”. All living organisms on Earth are divided in pieces called cells. There are smaller pieces to cells that include proteins and organelles. There are also larger pieces called tissues and systems. Cells are small compartments that hold all of the biological equipment necessary to keep an organism alive and successful on Earth.

The pupil can understand the cell through the following analogy proposed in [5]: “Think of your school building. Each building is made up of a number of classrooms. Each classroom has four walls. Each wall is made up of bricks. Structurally, each brick is the smallest unit of your school building. So is the cell with respect to the body, that is, the structural unit. To understand the functional significance of a cell, let us consider the order of a class. Each class has a number of students. Out of these students some are monitors. These monitors report to the class teacher who looks after the overall functioning of his/her class. The smallest functional unit of a class is a student. So is the cell for the body. The bodies of both plants and animals are made of cells. However, they are not perfect copy of each other”.

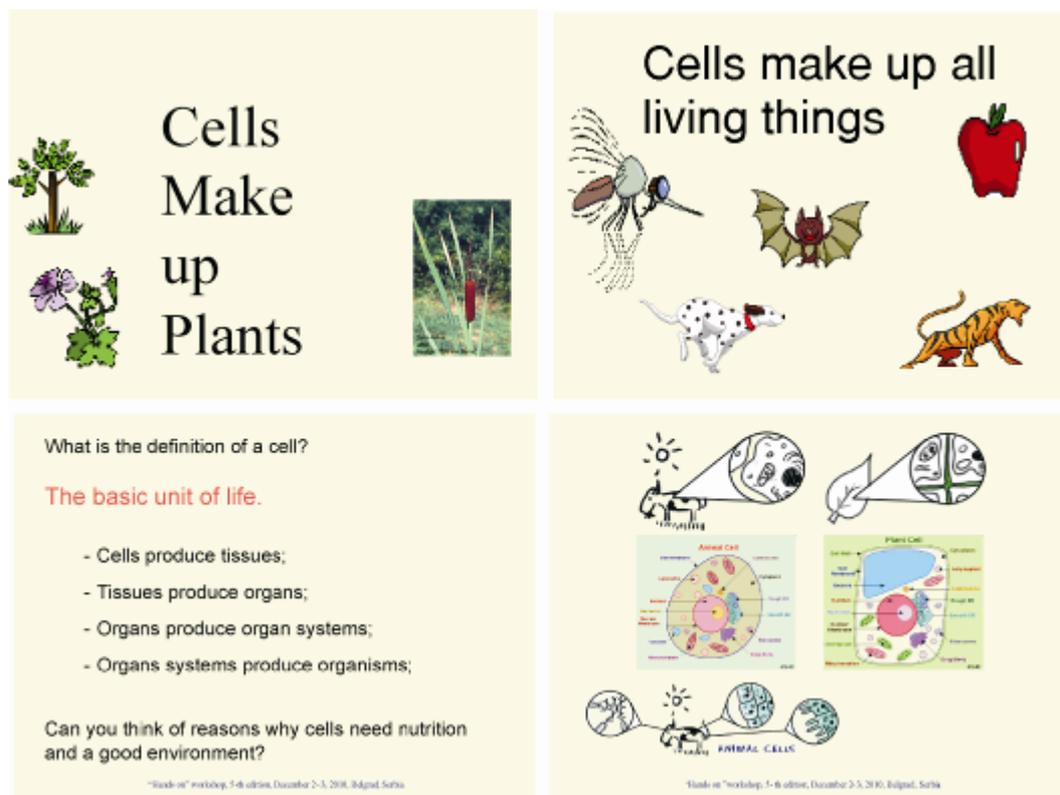


Figure 6. Examples of slides used in the presentation of the basics of cell biology [6]

Internet is another attractive tool in familiarizing children with cell biology. An useful example of using animation to compare the relative sizes of cells and organisms sitting on a pinhead is provided in [9]. Nearly invisible without magnification, dust mites dwarf pollen grains and human cells. In turn, bacteria and viruses are even smaller (Figure 7).



Figure 7. How big is a...? [9]

The same internet site can be used in order to present the differences between plants and animals using the interactive animation of plant and animal cells, together with their respective organelles, as shown in Figure 8, or by assembling jigsaw puzzles created with images of animal, cells, vegetal cells, red blood cells, etc, as shown in Figures 9 a,b.



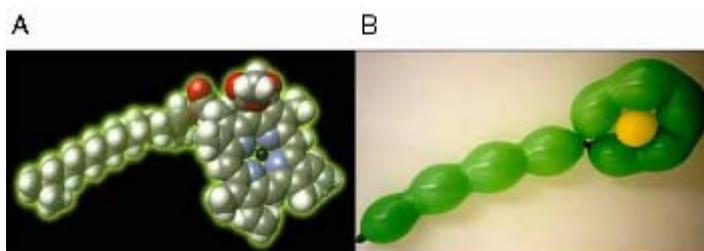
Figure 8. The structure of an animal cell [9]



Figure 9. a) Examples of puzzles with cell images; b) Red blood cell puzzle [9]

Another innovative and interesting approach of subjects as cells and molecules is “The STArT! teaching Science Through Art Program”, proposed by S. M. Halpine in [10]. The method, which proved to be very promising, consists of an initial short theoretical presentation of cells and molecules, introducing molecular visualization by handheld models and visualization softwares, followed by narrative discussions and art workshops. The program emphasizes low cost materials, and freeware programs such as WebLab Viewer Lite. At the end of the lesson, assessment tests indicate that, on average, 88% of third-grade students give a grade-appropriate description of the term “molecule” after a single one-hour presentation. Figures 10-12 present some of the results obtained in the frame of this program, together with the comments of S.M. Halpine:

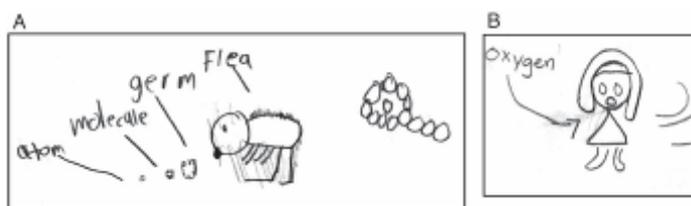
**Figure 10. Models of chlorophyll molecules:** (A) digital model of chlorophyll A, rendered using WebLab Viewer Lite software and (B) balloon model of chlorophyll molecule. The model is simplified to clearly define the ring with the central magnesium ion and tail structures.



**Figure 11. Many young students quickly integrate the concepts of atoms and molecules into their understanding of the world around them. This third-grade student drew a deer drinking from a river and indicated, “each drop of water has billions of molecules”**



Third-grade students were asked to include references to molecules in their paintings. This student painted molecular models of water and chlorophyll and indicated that they were found in the ocean and in leaves, respectively.



**Figure 12. Third-grade students used drawings to describe molecules for post-workshop assessment test:** (A) This whimsical drawing shows the relative sizes of an atom, a molecule, a germ, and a flea. A chlorophyll model is also included on the right. (B) Another student illustrated oxygen as a component of the air we breathe

## Conclusion

George E. Palade is one of the pioneers of cell biology, a fundamental domain of life sciences. The paper aims to present the personality and the scientific activity of this distinguish Romanian scientist, some basic aspects of cell biology and a set of tools and methods which could facilitate the primary school student the understanding of this field. If George E. Palade is now better known, and the reader found in this text some useful ideas for his didactical activity, the authors consider their goal successfully fulfilled.

## References

- [1] Editor (2007). "Tribute to Professor George E. Palade". *J. Cell. Mol. Med. (Romania)* **11** (1): 2–3
- [2] Tartakoff, Alan M (November 2002). "George Emil Palade: charismatic virtuoso of cell biology". *Nat. Rev. Mol. Cell Biol. (England)* **3** (11): 871–6
- [3] The Nobel Prize Lecture of George E. Palade (1974) The Nobel Foundation, ISBN 981-02-0791-3
- [4] <http://www.en.wikipedia.org>
- [5] [http://www.4to40.com/science/print.asp?p=Plant\\_Cell\\_Vs\\_Animal\\_Cell&c=Biology](http://www.4to40.com/science/print.asp?p=Plant_Cell_Vs_Animal_Cell&c=Biology)
- [6] <http://science.pppst.com/cells.html>
- [7] [http://www.biology4kids.com/files/cell\\_main.html](http://www.biology4kids.com/files/cell_main.html)
- [8] Tatalovic M. (2009) "Science comics as tools for science education and communication: a brief, exploratory study". *Journal of Science Communication*, **8** (4) 1
- [9] <http://www.cellsalive.com>
- [10] Halpine S.M. (2004) "Introducing Molecular Visualization to Primary Schools in California". *Journal of Chemical Education*, **81** (10) 1431-6