Introduction to Cell Biology

“All human beings by nature stretch themselves out toward knowing”

Aristotle,
*METAPHYSICS* (translated by Sachs J), 2nd edition
(Green Lion Press, Santa Fe 2002)

What’s cell biology

- Etymology: βίος – life; λόγος – word, concept, speaking, opinion, reason

  ↓

  *speaking about cell life*

- Part of biology studying biological processes under the cell context (how the cell is structured, and how it acts)
- Biological process – a chain of biochemical reactions occurring in a well defined sequence
- Descriptive part (analytical cell biology) – morphological organization of the cell (cell organelles and other morphological elements) – microscopic approach (LM, EM)
- Functional part (integrative cell biology) – how cell morphological elements act (by themselves and by cross-talking in-between) to assure cell survival and their doing the best
Cell definition

The cell is the structural and functional elementary unit of all living organisms, conserving the features of the organism, having the ability of self-control, self-regulation, and self-reproduction, being the result of a long time of evolution.

A little bit of history

• The word cell comes from the Latin cellula, a small room, and was chosen by Robert Hooke, in 1665, when he compared the cork cells he saw to the small rooms monks lived in.
• The cell theory, first developed in 1839 by Matthias Jakob Schleiden and Theodor Schwann, completed by Rudolf Virchow, in 1858.

- all organisms are composed of one or more cells
- all cells come from preexisting cells (omnis cellula e cellula)
- vital functions of an organism occur within cells
- all cells contain the hereditary information necessary for regulating cell functions and for transmitting information to the next generation of cells.
What’s the reason to study the cell

- Cell definition – an answer?
- Live phenomenon – no live outside a cell
- Physiology vs. pathology
- Any medical act – accommodated by the body’s cells

The Corollary:
The cell must be known, understood and respected!

But, this is not easy at all 😞

Cell diversity

(cell classifications)
- According to their morphological complexity
  - Prokaryotic cells
  - Eukaryotic cells
Cell diversity

• prokaryotic
  No membrane bound organelle

• eukaryotic
  Several membrane bound organelle

Definition of organelle notion

### Prokaryotic / Eukaryotic

<table>
<thead>
<tr>
<th>Features</th>
<th>Prokaryotes</th>
<th>Eukaryotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical organisms</td>
<td>bacteria, archaea</td>
<td>protists, fungi, plants, animals</td>
</tr>
<tr>
<td>Typical size</td>
<td>~ 0.1-10 µm</td>
<td>~ 10-150 µm (sperm cells, apart from the tail, are smaller, egg cell/ovum is 150 µm in diameter)</td>
</tr>
<tr>
<td>Type of nucleus</td>
<td>nucleoid region; no real nucleus</td>
<td>real nucleus with nuclear envelope</td>
</tr>
<tr>
<td>DNA</td>
<td>circular (usually)</td>
<td>linear molecules (chromosomes) with histone proteins</td>
</tr>
<tr>
<td>RNA-/protein-synthesis</td>
<td>coupled in cytoplasm</td>
<td>RNA-synthesis inside the nucleus, protein synthesis in cytoplasm and some organelles</td>
</tr>
<tr>
<td>Ribosomes</td>
<td>50S+30S</td>
<td>60S+40S</td>
</tr>
<tr>
<td>Cytoplasmatic structure</td>
<td>very few structures (ribosome), no membrane bound organelles</td>
<td>highly structured in organelles by endomembranes (nucleus, nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, peroxisomes, mitochondria) and organelles without endomembranes (ribosome, cytoskeleton, proteasome, apoptosis)</td>
</tr>
<tr>
<td>Cell movement</td>
<td>flagella made of flagellin</td>
<td>flagella and cilia made of tubulin, cytoskeleton</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>none</td>
<td>one to several dozen (though some lack mitochondria)</td>
</tr>
<tr>
<td>Chloroplasts</td>
<td>none</td>
<td>in algae and plants</td>
</tr>
<tr>
<td>Organization</td>
<td>usually single cells</td>
<td>single cells, colonies, higher multicellular organisms with specialized cells</td>
</tr>
<tr>
<td>Cell division</td>
<td>Binary fission (simple division)</td>
<td>mitosis, meiosis (steps in germ cell differentiation)</td>
</tr>
</tbody>
</table>
Cell diversity

(classifications for eukaryotic cells)

• According to the kingdom they belong
  – Plant (vegetal) cells
  – Animal cells

• According their differentiation
  – epithelial cells
  – muscle cells
  – nerve cells
  – mesenchymal cells

Organism’s cellularity

• Some organisms, such as bacteria, are unicellular (consist of a single cell)
• Other organisms, such as humans, are multicellular
• Humans have an estimated 100 trillion \(10^{14}\) cells
• Average cell size: 10 µm
• Average cell mass: 1 nanogram
• Cell volume: \(80\mu m^3 – 8000\mu m^3\)
• The largest known cell is an ostrich egg
• The largest cell in human beings is the egg cell (150µm in diameter)
Cell dimension

The structure of the course

• Introduction to cell biology (1 lecture)
• Molecular organization of the cell membrane (2 lectures)
• Cell membrane functioning as an integrative system (2 lectures)
  – Membrane transport (1 lecture)
  – Cell signaling (1 lecture)
• Ribosome and protein biosynthesis (1 lecture)
• Endoplasmic reticulum (1 lecture)
• The Golgi apparatus and cell secretion (1 lecture)
• The cytoskeleton (1 lecture)
• Cell junctions (1 lecture)
• Lysosome, peroxisome (1 lecture)
• Mitochondria (1 lecture)
• The nucleus (1 lecture)
• The cell cycle and cell division (1 lecture)
Lectures’ organization

- Definition of terms, concepts, notions (organelle, other morphological elements)
- Morphology of the organelle/element
  - Structural features (light microscopy look)*
  - Ultrastructural features (electron microscopy look)
- Functions of the organelle/elements and mechanisms of action toward the molecular level of understanding

* STED (Simulated Emission Depletion) microscopy
  — Stefan W. Hell – The Nobel Prize in Chemistry 2014: "for the development of super-resolved fluorescence microscopy"

Warning

Enhancement of knowledge in cell biology

An answer got ...

... Several questions arise!
Good luck in the cell study

• What’s the target?

To think in the same terms such as a cell “is thinking” (to think in the cell manner)
Molecular Organization of Cell Membrane

A walk from molecules to a functional biostructure

Cell Membrane

• Definition
  An ultrastructure separating connecting the cell to the environment
Coarse chemical composition

- Water: 20-30%
- Dry material: 70-80%
  - Minerals: ~1%
  - Organic compounds: ~99%
    - Lipids: 40-50%
    - Proteins: 50-60%
    - Sugar components: 1-10%

Why so low amount of water?

Mosaic Fluid Model for Molecular Assembly of Biomembranes


Cell Membrane Functions
1. Barrier
2. Metabolic
EDITORIAL

Cell secretion and membrane fusion: highly significant phenomena in the life of a cell

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Keywords: cell secretion, membrane fusion, porosomes, exosomes, electron microscopy, cancer, mathematical approach, secretory vesicles, science history

Introduction

Is there any cell that does not secrete something necessary for maintenance of the organism? Secretion involves membrane fusion, which is every cell’s existence, and they must be very well coordinated and controlled. Membrane trafficking, which involves vesicular budding of the source membrane, directed transport and eventually fusion with the target membrane is a very specific process. All of these processes depend, in particular, on basic principles of biological membrane structure and dynamics, a topic that was reviewed recently in this journal.
Physical, chemical and biological features of cell membranes

- Heterogeneity
- Asymmetry
- Two-dimensional fluidity

- Which components are responsible for these features?
- What’s the biological significance of these features?