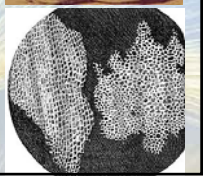
Mechanistic Ideas of Life: The Cell Theory

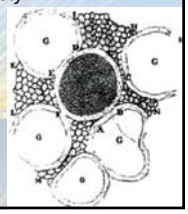
Robert Hooke-1665

- Examined thin slices of cork and discovered:
  "Yet it was not unlike a Honey-comb in these particulars...these pores, or cells, ... consisted of a great many little Boxes.... Nor is this kind of texture peculiar to Cork onely; for upon examination with my *Microscope*, I have found that the pith of an Elder, or almost any other Tree, the inner pulp or pith of ... several other Vegetables ... have much such a kind of *Schematisme*, as I have lately shown [in] that of Cork."
- Hooke called them “cellulae” (Latin word for “little rooms”).
- *Cells defined by their walls*



Antony van Leeuwenhoek

- Developed his own single-lens microscopes for use on fabrics (operated a drapery business in Delft)
- First to observe details of animal structure (muscle banding) as well as single-celled organisms (bacteria, sperm)
  - Sent results to the new Royal Society



Jan Swammerdam: (1637-1680)

Describes the appearance of blood under microscope:

> "If we begin the dissection in the upper part of the abdomen, and cautiously split the skin there, blood immediately escapes from that place. The blood, when received into a glass tube and examined with a very good microscope, is observed to consist of transparent globules (globulis), in no way differing from cow's milk, a fact that was discovered a few years ago in human blood also; for this is seen to consist of slightly reddish globules, floating in a clear fluid."

Marie François Xavier Bichat (1800): doing without microscopes

Rejected the value of observing with microscopes, but nonetheless made very astute observations:

- Two different sets of organs
  - Those under volitional control and serving locomotion
  - Those serving vital processes: digestion, assimilation, etc.
- Organs comprised of tissues, and Bichat identified different tissue types: nervous, vascular, connective, fibrous, cellular (connective)
  - Different tissues exhibit different pathologies
- All these observations made with naked eye

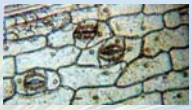
Limitations on early microscopes

- Spherical aberration: failure of light rays to fall all in one plane when focused through a lens
- Chromatic aberration: dispersive action of lenses in breaking white light into primary colors

- William Hyde Wollaston (1812): two plano-convex lenses, placed a prescribed distance apart—counters spherical aberration
- John Hershel (1821): aplanatic combination of lenses
- Joseph Jackson Lister (1824-1830): combined lenses of crown glass with others of flint glass, so adjusted that the refractive errors of each were corrected or compensated for by the other

Robert Brown

- In 1827, utilizing a very simple microscope, observed active molecules (Brownian motion)
- In 1831, observed an opaque spot in plant (Orchid) cells which he named the *nucleus* (Latin for kernel)

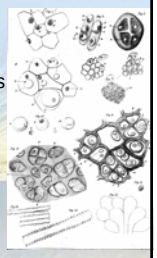


Matthias Schleiden: 1838

- Nucleus the most important structure in the cell—the unit from which the rest was formed
- Named the nucleus “cytoblast”
- Construed the nucleus as the defining mark of cells
  - What makes differently appearing entities all cells
- Investigations limited to plants

Theodor Schwann

- Problem: extreme variability in animal cells
- Focused on the similarities of some animal cells (ovum, epidermis) to plant cells
- Following Schleiden, came to emphasize the nucleus, which he found in embryonic tissues
- Strategy: show that despite the variability, animal cells all arose in the same manner and were all cells.



Cell Theory

- Cells the building blocks of all organisms
- “There is one universal principle of development for the elementary parts, of organisms, however different, and this principle is the formation of cells”
- “Each cell is, within certain limits, an Individual, an independent Whole. The vital phenomena of one are repeated, entirely or in part, in all the rest.”
- Key strategy: All cells develop in the same way and hence are fundamentally the same despite observed differences

Schwann’s Project

- Determine whether animal tissues develop in the same manner as plants
  - “I compared the cells of cartilage and of the chorda dorsalis with vegetable cells, and found the most complete accordance. The discovery, upon which my inquiry was based, immediately lay in the perception of the principle contained in the proposition, that two elementary particles, physiologically different, may l be developed in the same manner. For it follows, from the foregoing, that if we maintain the accordance of two kinds of cells in this sense, we are compelled to assume the same principle of development for all elementary particles, however dissimilar they may be . . .”

Schleiden’s (1838) Account of Growth in Plants

- “He found, that in the formation of vegetable cells, small, sharply-defined granules are first generated in a granulous substance, and around them the cell nuclei (cytoblasts) are formed, which appear like granulous coagulations around the granules. The cytoblasts grow for a certain time, and then a minute transparent vesicle rises upon them, the young cell, so that‟ in the first instance, it is placed upon the cytoblast, like a watch-glass upon a watch. It then becomes expanded by growth.”

Analogy with Crystals

- Already in the Preface Schwann announces:
  - "The principal result of this investigation is, that one common principle of development forms the basis for every separate elementary particle of all organised bodies, just as all crystals, notwithstanding the diversity of their figures, are formed according to similar laws"

Analogy with Crystals Developed

- "The only other difference in the formation of cells is, that the separate layers do not consist of the same chemical substance, while a common crystal is always composed of one material. In instituting a comparison, therefore, between the formation of cells and crystallization, the above-mentioned differences in form, structure, and mode of growth fall altogetner to the ground. If crystals were formed from the same substance as cells, they would probably, in *these* respects, be subject to the same conditions as the cells."

Schwann's Theory of Cell Formation

- Cells formed in the "cytoblastema": a structureless substance which sometimes is extracellular (in animals) and sometimes intracellular (in plants).
- Nucleolus appears first
- Granules coalesce around it, creating the nucleus, which then grows.
- Yet another layering of granules generates the cytoplasm
- This general principle was taken to show that all tissues of animals are comprised of cells
- Powerful analogy: crystal formation
  - Attraction: Renders the process mechanical

Schwann's "Cell-Theory"

- "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so that it may be asserted, *that there is one universal principle of development for the elementary parts of organisms, however different, and that this principle is the formation of cells.*
- "the fundamental phenomenon attending the exertion of productive power in organic nature is accordingly as: *a structureless substance is present in the first instance, which lies either around or in the interior of cells already existing; and cells are formed in it in accord with certain laws, which cells become developed in various ways into the elementary parts of organisms."*

Cells and Physiology

- Cells not just anatomic units, but structures that correspond to function:
  - "This variety in the elementary parts seemed to hold some relation to their more diversified physiological function in animals, so that it might be established as a principle, that every diversity in the physiological signification of an organ requires a difference in its elementary particles; and, on the contrary, the similarity of two elementary particles seemed to justify the conclusion that they were physiologically similar."

Schwann's "Theory of the Cells"

- Presents this as more speculative than the claim that all organisms are made of cells, characterized by how they are formed.
- Cell as the basic unit of life:
  - "The cells, therefore, not only attract materials from out of the cytoblastema, but they must have the faculty of producing chemical changes in its constituent particles. Besides which, all the parts of the cell itself may be chemically altered during the process of its vegetation. The unknown cause of all these phenomena, which we comprise under the term metabolic phenomena of the cells, we will denominate the *metabolic power*."

Teleological vs. Physical Views

- Purposeful behavior would be different from what is found in inorganic nature
  - "that which arranges and combines the molecules is a power acting with a definite purpose. A power of this kind would be essentially different from all the powers of inorganic nature"
- Physical alternative (Schwann's)
  - "The other view is, that the fundamental power of organised bodies agree essentially with those of inorganic nature, that they work altogether blindly according to laws of necessity and irrespective of any purpose, that they are powers which are as much established with the existence of matter as the physical powers are."

Power in the Whole vs. Causes in the Parts

- On one view "the cause of the growth of the elementary parts resides in the totality of the organism. The other mode of explanation is, that growth does not ensue from a power resident in the entire organism, but that each separate elementary part is possessed of an independent power, an independent life, so to speak; in other words, the molecules in each separate elementary part are so combined as to set free a power by which it is capable of attracting new molecules and so increasing, and the whole organism subsists only by means of the reciprocal action of the single elementary parts."

Cell Division

- While Schleiden and Schwann were presenting a view of cell formation on analogy with crystals, other investigators (e.g., Hugo von Mohl) observed what they described as cell division
- Rudoph Virchow (1855): "Omnis cellula e cellula"
  - Virchow was a pathologist
    - Focus not on the mechanism
    - But on the continuity of disease
    - Undermined theories of spontaneous generation that were still current

- Not until development of stains in the 1860-1870s was it possible to acquire evidence for a mechanism of cell division

Discovering Mechanisms of Cell Division (1870s-1880s)

- Robert Remak
  - Nucleus division prior to cell division
- Edouard van Beneden
  - Characterized structures in the nucleus as bâtonnets (little rods)
  - Reported that they moved apart in the process of division
- Hermann Fol
  - Described spindle and astral rays
  - Proposed analogy with lines of force in magnets
- Walther Flemming
  - Described mitosis
  - *Omnis nucleus e nucleo*
  - Named chromatin

From cells to their fluids

- Hugo von Mohl: plant cells contain “an opaque, viscous fluid, having granules intermingled in it”
  - Recalled earlier observations of the movement of cell contents
  - Nucleus lies within the fluid, not bound to the cell wall
  - Named the fluid: protoplasm
- Dujardin (1835): sarcode: "I propose to give this name to what other observers have called a living jelly - this glutinous, transparent substance, insoluble in water, contracting into globular masses, attaching itself to dissecting needles and allowing itself to be drawn out like mucus; lastly, occurring in all the lower animals interposed between the other elements of structure."

Shift of Focus from Cells to Protoplasm

- Cohn: “But all these properties are possessed also by protoplasm, that substance of the plant cell which must be regarded as the chief site of almost all vital activity, but especially of all manifestations of movement inside the cell.... Hence it follows with all the certainty that can generally be attached to an empirical inference in this province, that the protoplasm of the botanists and the contractile substance and sarcode of the zoologist, if not identical, must then indeed be in a high degree similar formations.”
- Max Schultz (1860): cell “a small mass of protoplasm endowed with the attributes of life.”