Lecture 7:
The Biological Revolution: What is Life?

Astronomy 141 – Winter 2012

This lecture explores the biological revolution that led to great changes in how we view life.

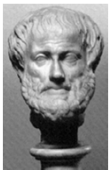
Long persistence of the ancient notion of spontaneous generation.

Invention of the microscope enabled new observations of living organisms.

Heredity is the study of how traits are transmitted from parents to offspring.

Genes and DNA discovered to be the agents that store and transmit hereditary information.

Spontaneous Generation is an ancient notion about the origin of life from non-living matter.



Classical expression of the idea comes down to us from Aristotle in his *History of Animals*.

Animals spontaneously generated from putrefying earth or vegetable matter.

The idea remained common in the Renaissance:

"Your serpent of Egypt is bred now of your mud by the operation of your Sun: so is your Crocodile."

(Shakespeare, *Anthony & Cleopatra*, 2, 7)

Francesco Redi argued against spontaneous generation (1668).

Meat in an open jar → maggots

Meat in a tightly sealed jar → no maggots

Meat in a gauze-covered jar → no maggots

Flies beget maggots, which develop into flies, which beget maggots, which…

Spontaneous Generation persisted and was taken seriously well into the 19th century.

Famous experiment by Felix Pouchet in favor of Spontaneous Generation

Boiled an infusion of hay to sterilize it.

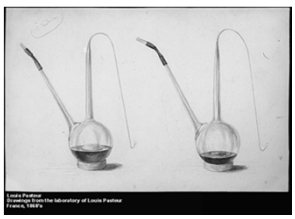
Exposed it to oxygen generated by electrolyzing water (no outside air admitted)

Microorganisms soon appeared in the hay.

Concluded spontaneous generation had occurred, but in reality he didn't know about heat-resistant spores.

Louis Pasteur did a famous experiment in 1859 that disproved Spontaneous Generation.

Two samples of broth, one boiled, one not, put into special flasks with a long neck to admit air but not airborne yeasts.



The unboiled broth quickly fermented.

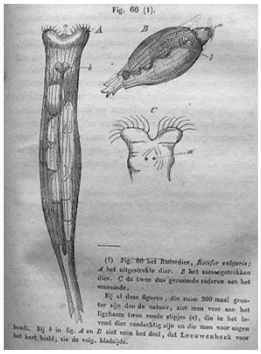
The boiled broth did not, until he put the end of the gooseneck into the broth.

The invention of the microscope was a key technological advance in the study of life.

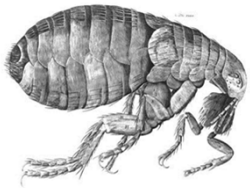
Anton van Leeuwenhoek (1632-1723)

Allowed the study of small details in tiny animals and plants:

- Discovery of cells
- Discovery of eggs for small insects
- Discovery of micro-organisms



Rotifers in water droplets



Hooke's Flea

Leeuwenhoek's microscope was to biology life what Galileo's telescope was to astronomy.

Heredity is the transmission of characteristics from parents to their offspring.

Numerous Ideas put forward for how traits are transmitted:

Blending Inheritance
- Traits of both parents mix together eventually get averaged out

Acquired Inheritance
- Individual traits enhanced by parents

Pangenesis
- Body cells shed "gemmules" that gather in the sex cells

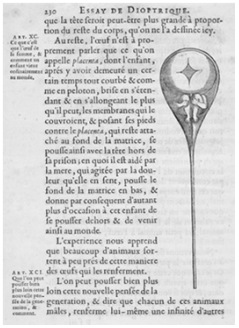
A very old idea was the Homunculus model for human sexual reproduction.

Sperm contained a tiny copy of a complete human within it.

Idea was abetted by fanciful microscopic observations.

Problems:

- Why did children also share their mother's traits?
- Problem of infinite regress.



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que la tête seroit peut-être plus grande à proportion du reste du corps, qu'on ne l'a dessinée icy.

Au reste, l'oeuf n'est à proprement parler que ce qu'on appelle *placenta*, dont l'enfant, après y avoir demeuré un certain temps tout courbé & comme en peloton, brise en s'étendant & en s'allongeant le plus qu'il peut, les membranes qui le couvroient, & posant ses pieds contre le *placenta*, qui reste attaché au fond de la matrice, & pousse ainsi avec la tête hors de sa prison; en quoi il est aidé par la mere, qui agitée par la douleur qu'elle en sent, pousse le fond de la matrice en bas, & donne par conséquent d'autant plus d'occasion à cet enfant de se pousser dehors & de venir ainsi au monde.

L'experience nous apprend que beaucoup d'animaux sortent à peu près de cette maniere des œufs qui les renferment.

L'on peut pousser bien plus loin cette nouvelle pensée de la generation, & dire que chacun de ces animaux mâles, renferme lui-même une infinité d'autres

Hartsoeker's homunculus (1694)

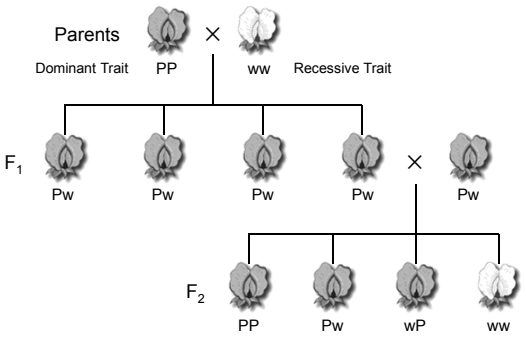
Gregor Mendel (1822-1884) performed a series of brilliant experiments in heredity.

Experiments with garden peas led to two important insights:

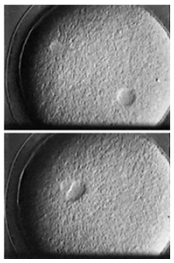
Hereditary factors come in pairs, one from each parent.

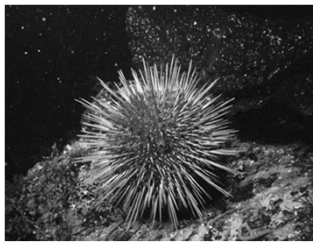
One factor must be dominant, the other recessive.

Example: Heritability of flower color in peas



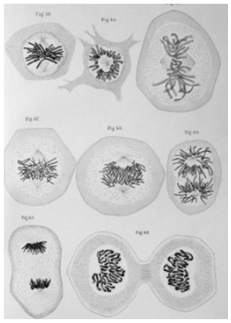
Microscope studies of sea urchin fertilization showed a cell nucleus is formed of material from both egg & sperm.





Hereditary factors reside in the cell nucleus.

Microscope studies of cell division: **chromosomes** in original cell nucleus are shared between two "daughter" nuclei.

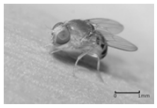


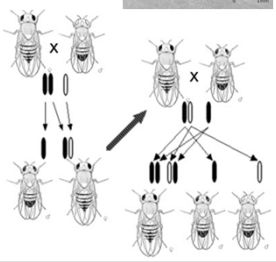
Walther Flemming (1882) looked at cell division in salamander cells.

He named the process of division "mitosis".

He didn't know at the time that hereditary factors reside in the chromosomes.

Experiments breeding fruit flies (*Drosophila*) revealed the transmission of sex-linked traits





Experiments by Thomas Hunt Morgan (1910) revealed that chromosomes were the site of hereditary factors, or "genes".

Watson and Crick showed how Deoxyribonucleic Acid (DNA) can store and *replicate* genetic information.

Chromosomes are long strands of DNA carrying molecular instructions for how to build proteins.

DNA Molecule

Life is a physical phenomenon governed by understandable laws that make testable predictions.

The implications of the biological revolution are still being played out today.

Great advances in the past few decades in the areas of molecular genetics and molecular biology.

Essential for understanding the nature and requirements for life if we are to start looking for it elsewhere.