Darwin Day 2020 Lecture
Heroes of Evolution—Margulis and McClintock: The Women Who Broke (Neo)Darwinian Theory

Stephen L. Gasior Ph.D.
Stephen Xootfly

February 12th, 2020
Science Circle
Darwin

- In 1859 Charles Darwin published *On the Origin of Species By Means of Natural Selection, Or the Preservation of Favoured Races in the Struggle for Life*
- Darwin perceived *adaptation* to the environment and the origin of new species as closely related processes
- Darwinian *Evolution* (a term he did not use in the book) is two processes:
  - current species are descendants of ancestral species via *descent with modification*
  - *natural selection* is a process in which individuals with favorable inherited traits are more likely to survive and reproduce
Observations

Individuals in a population vary in their heritable characteristics.

Organisms produce more offspring than the environment can support.

Inferences

Individuals that are well suited to their environment tend to leave more offspring than other individuals.

and

Over time, favorable traits accumulate in the population.
The history of life is like a tree with branches representing life’s diversity

Origin of New Species (each branch) Macroevolution
Mendel

**P Generation**

Appearance: Purple flowers
Genetic makeup: PP
Gametes: P, P

**F₁ Generation**

Appearance: Purple flowers
Genetic makeup: Pp
Gametes: 1/2 P, 1/2 p

**F₂ Generation**

Eggs from F₁ (Pp) plant

3:1 ratio of purple to white flowers
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Dominant</th>
<th>Recessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower color</td>
<td>Purple</td>
<td>White</td>
</tr>
<tr>
<td>Flower position</td>
<td>Axial</td>
<td>Terminal</td>
</tr>
<tr>
<td>Seed color</td>
<td>Yellow</td>
<td>Green</td>
</tr>
<tr>
<td>Seed shape</td>
<td>Round</td>
<td>Wrinkled</td>
</tr>
<tr>
<td>Pod shape</td>
<td>Inflated</td>
<td>Constricted</td>
</tr>
<tr>
<td>Pod color</td>
<td>Green</td>
<td>Yellow</td>
</tr>
<tr>
<td>Stem length</td>
<td>Tall</td>
<td>Dwarf</td>
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</table>

Mendel’s peas. What he studied were pairs of characteristics. Plants were either one or the other. No inbetweens. All act independently.
Study of “Linked” genes. Mendel’s Principles describe the behavior of Chromosomes. However, when genes are on the same chromosome they are passed down together in direct proportion to how close they are to each other. With enough traits, one can construct “linkage maps”
Chiasma. Homologous chromosomes exchange parts during meiosis. However, the # of genes and structure are not typically changed.
Barbara McClintock Timeline

1902—Born Eleanor McClintock in Hartford, Connecticut
fall of 1921—takes Genetics with C. B. Hutchison and cytology with Lester W. Sharp
1927—Receives PhD (botany), Cornell University
1927-40—Instructor and researcher and fellow in maize genetics, Cornell University, University of Missouri at Columbia, and California Institute of Technology, Kaiser Wilhelm Institute, Berlin, and Botanical Institute, Freiburg
1944—Elected to the National Academy of Sciences
1971—Receives National Medal of Science
1981—Recipient, Albert and Mary Lasker Award
1983—Receives Nobel Prize in Physiology or Medicine
A semi-diagrammatic representation of the haploid set is given in Fig. 1. One chromosome possesses

- Schematic of maize/corn chromosomes. Chromosome 5 has a knob visible under a microscope.
Chromosomes that are not the same number should not interact during meiosis. However, this observation showed that sometimes they do.
McClintock was the first to demonstrate that observed chromosome exchanges correlated with recombinations of genes.
Above—Diagram of the chromosomes in which crossing-over was studied. (Labeled as in figure 1, preceding paper.)
THE ORIGIN AND BEHAVIOR OF MUTABLE LOCI IN MAIZE

BY BARBARA McCLINTOCK

DEPARTMENT OF GENETICS, CARNEGIE INSTITUTION, COLD SPRING HARBOR, NEW YORK

Communicated April 8, 1950

INDUCTION OF INSTABILITY AT SELECTED LOCI IN MAIZE

BARBARA McCLINTOCK

Department of Genetics, Carnegie Institution of Washington, Cold Spring Harbor, N. Y.

Received April 14, 1953
Recessive phenotypes appear

- This chromosome breaks and changes the genetics in different cells in a kernel. Normally, the brown chromosome (capital letter) alleles are the phenotype. But when the arm is lost due to Ds, then the yellow alleles make the color. The breaking element was called Ds.

- Resulting tissue is c (colorless), sh (shrunken), bz (bronze), wx (waxy).
• A transposon insertion into the Bz gene can happen in the gene and turn it off, but sometimes it comes back out and the darker brown color comes back. One would not expect this rate of reversion from point mutations.

• THIS IS HAPPENING AT A HIGH RATE IN DEVELOPING TISSUE
Genetics of autonomous vs. nonautonomous elements

Pigmented
- Color gene

Colorless
- ColorTE

Spotted kernels
- ColorTE

Ds Ac
some cells
NOT ALL

Gene + TE
Transposons in Genomes

In summary, --genomes were thought to be static
--Variation came from point mutations and reshuffling of genes
--our genomes only contained the organisms genes

McClintock’s legacy is that
--genetic elements are also in genomes and they are mobile
--they can contribute to genetic variation
--the vertebrate immune system is one example of such elements becoming useful (not a general rule). But we could not live without an immune system
Science Impact

Review | Open Access | Published: 06 May 2016

Roles for retrotransposon insertions in human disease

Dustin C. Hancks & Haig H. Kazazian Jr.

Mobile DNA 7, Article number: 9 (2016) | Cite this article

Describes 124 specific gene variants with role in disease from retrotransposon insertions

Tools for genome engineering

Trends in Genetics

Volume 33, Issue 11, November 2017, Pages 852-870

Review
Special Issue: Transposable Elements

Gene Therapy with the Sleeping Beauty Transposon System

Partow Kebriaei 1, Zsuzsanna Izsvák 2, Suneel A. Narayanavari 2, Harjeet Singh 3, Zoltán Ivics 4
a specialized case of transposons as "controlling elements": VDJ recombination

- RAG1 and RAG2 used to be transposons in one of our ancestors. But now their remnants help us move gene segments to make antibodies.
Lynn Margulis

- born March 5, 1938, Chicago,
- University of Chicago in 1957
- master’s degree in zoology and genetics from the University of Wisconsin at Madison in 1960
- Ph.D. in genetics from the University of California, Berkeley, in 1965.

- 1966 to 1988 faculty in biology department of Boston University
- 1988-1997 distinguished university professor in the department of botany (then geosciences) at the University of Massachusetts at Amherst
- National Academy of Sciences in 1983
- William Procter Prize of Sigma Xi, an international research society
- Darwin-Wallace Medal of the Linnean Society of London in 2008
On the Origin of Mitosing Cells

LYNN SAGAN

Department of Biology, Boston University
Boston, Massachusetts, U.S.A.

(Received 8 June 1966)
On the Origin of Mitosing Cells

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**Table 2**

Taxonomic criteria in the formation of a natural phylogeny for microbes
(listed roughly in order of relative importance)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Techniques by which measured</th>
</tr>
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<tbody>
<tr>
<td>Total homology of DNA base pairs</td>
<td>Direct DNA nucleotide sequence data</td>
</tr>
<tr>
<td></td>
<td>Agar-gel technique for DNA homologies</td>
</tr>
<tr>
<td></td>
<td>Ability to genetically recombine (i.e. classical genetic techniques)</td>
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<tr>
<td></td>
<td>DNA base ratios on CsCl density gradient</td>
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<tr>
<td></td>
<td>DNA denaturation (melting point) determinations</td>
</tr>
<tr>
<td>Homologous metabolic pathways</td>
<td>Classical biochemistry</td>
</tr>
<tr>
<td>Homologous cistrons, same “genetic code letters”</td>
<td>Homologous messenger RNA’s (DNA-RNA homologies). Identity of individual transfer RNA’s for specific amino acids</td>
</tr>
<tr>
<td>Ultrastructural morphology</td>
<td>Electron microscopy</td>
</tr>
<tr>
<td>Morphology and life cycle</td>
<td>Light microscopy, classical cytology</td>
</tr>
<tr>
<td>Single biochemical pigments, enzymes, etc., in common</td>
<td>Spectroscopy, classical biochemistry</td>
</tr>
<tr>
<td>Molecular structure of single pigment, or enzyme</td>
<td>Classical chemistry</td>
</tr>
<tr>
<td>Common phenotypic traits</td>
<td>Ability to grow on same carbohydrate, production of same end product, motility, etc.</td>
</tr>
</tbody>
</table>
Photosynthesis takes place in chloroplasts, which have an outer membrane and an inner membrane. Stacks of thylakoids called grana form a third membrane layer.

In eukaryotes, oxidative phosphorylation takes place in mitochondria. In prokaryotes, this process takes place in the plasma membrane.
Complex structure of general plant cell

Chloroplast and mitochondrial genomes
Chloroplast genome mutations and uneven development can lead to variable phenotypes in different parts of the plant.

(a) Variegated plant

- All-white branch
- All-green branch
- Main shoot is variegated
The history of life is like a tree with branches representing life’s diversity but with merges
Larger thinking in evolution

“random mutation and natural selection are just cogs in the gears of evolution; the big leaps forward result from mergers between different kinds of organisms, what she calls symbiogenesis. Viewing life as one giant network of social connections has set Margulis against the mainstream in other high-profile ways as well.”
Presaged Microbiome

Human Microbiome

- Archaea
- Oral microbiome
- Skin microbiome
- Bacteria
- Viruses
- Urigenital microbiome
- Fungi
- Parasites
- Digestive tract microbiome
Challenges as Pioneers in Science

In 1951 and 1956 at the Annual Cold Spring Harbor Seminars her lectures were met with “stony silence”

This led to retreat from the larger social circles of the science community though still very admired and active at CSHL and colleagues who understood her work.

A Feeling for the Organism Chapter 9
By Evelyn Fox Keller
Challenges as Pioneers in Science

Lynn Margulis faced a lot of criticism from evolutionary peers for her ideas.

First, for organelle theory--symbiosis

Second, for the proposal of symbiogenesis being the driving force of speciation in evolution

And third, she was pretty ornery


[https://www.edge.org/conversation/lynn_margulis-chapter-7-gaia-is-a-tough-bitch](https://www.edge.org/conversation/lynn_margulis-chapter-7-gaia-is-a-tough-bitch)
Heroes of Evolution 2020