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

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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

Artificial Selection and Natural Selection

Observations

Individuals in a population vary in their heritable characteristics.

Organisms produce more offspring than the environment can support.

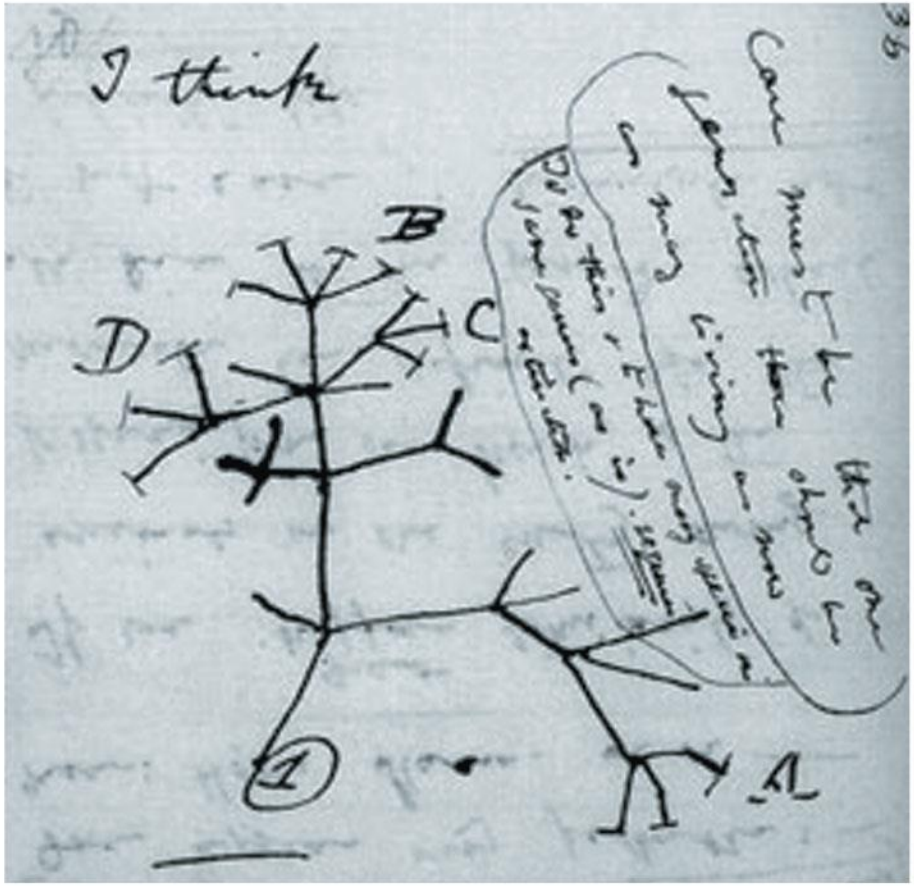
Inferences

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

and

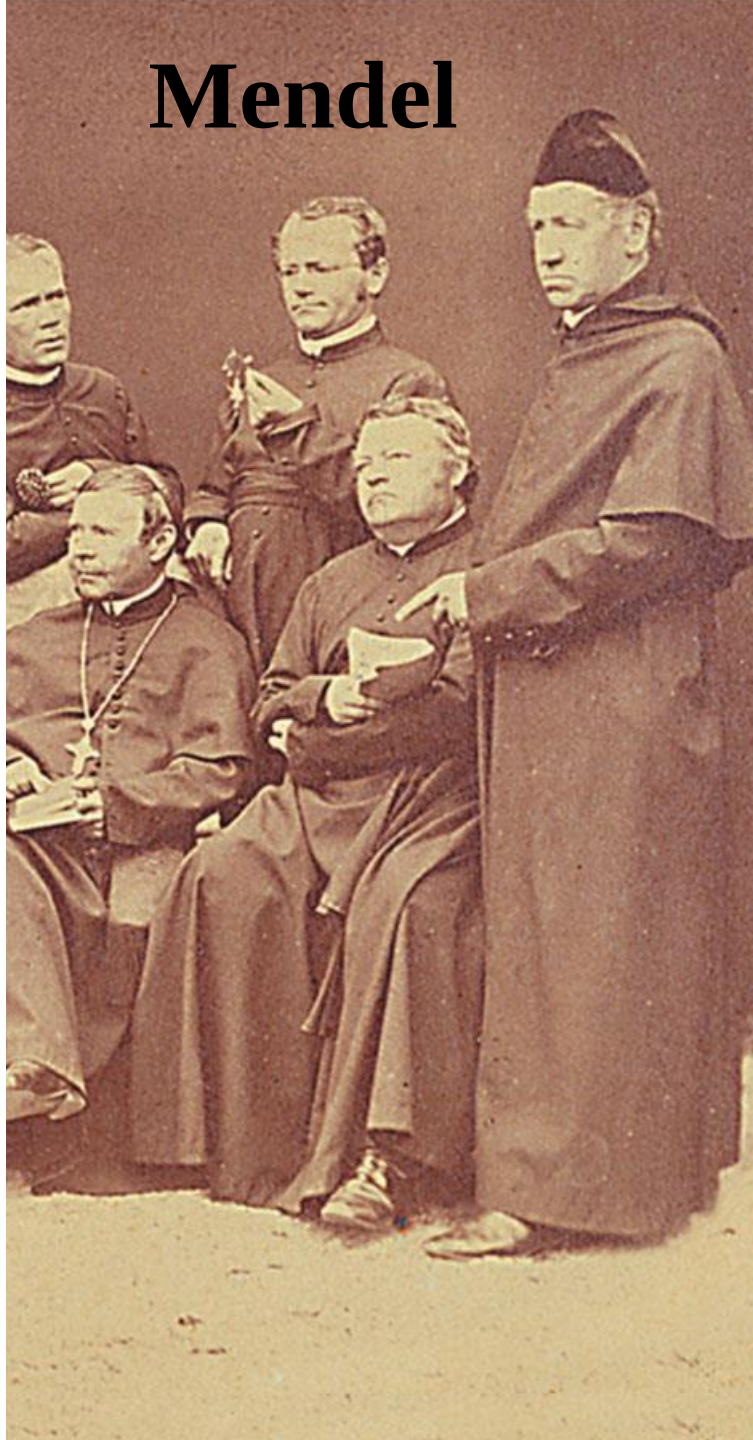
Over time, favorable traits accumulate in the population.

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 White flowers

Genetic makeup: *PP* *pp*

Gametes: *P* *p*

F_1 Generation

Appearance: Purple flowers

Genetic makeup: *Pp*

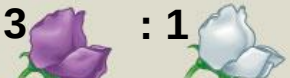
Gametes: $^1/_2$ *P* $^1/_2$ *p*

Sperm from F_1 (*Pp*) plant

F_2 Generation

Eggs from F_1 (*Pp*) plant

	P	*p*
P	*PP*	*Pp*
p	*Pp*	*pp*



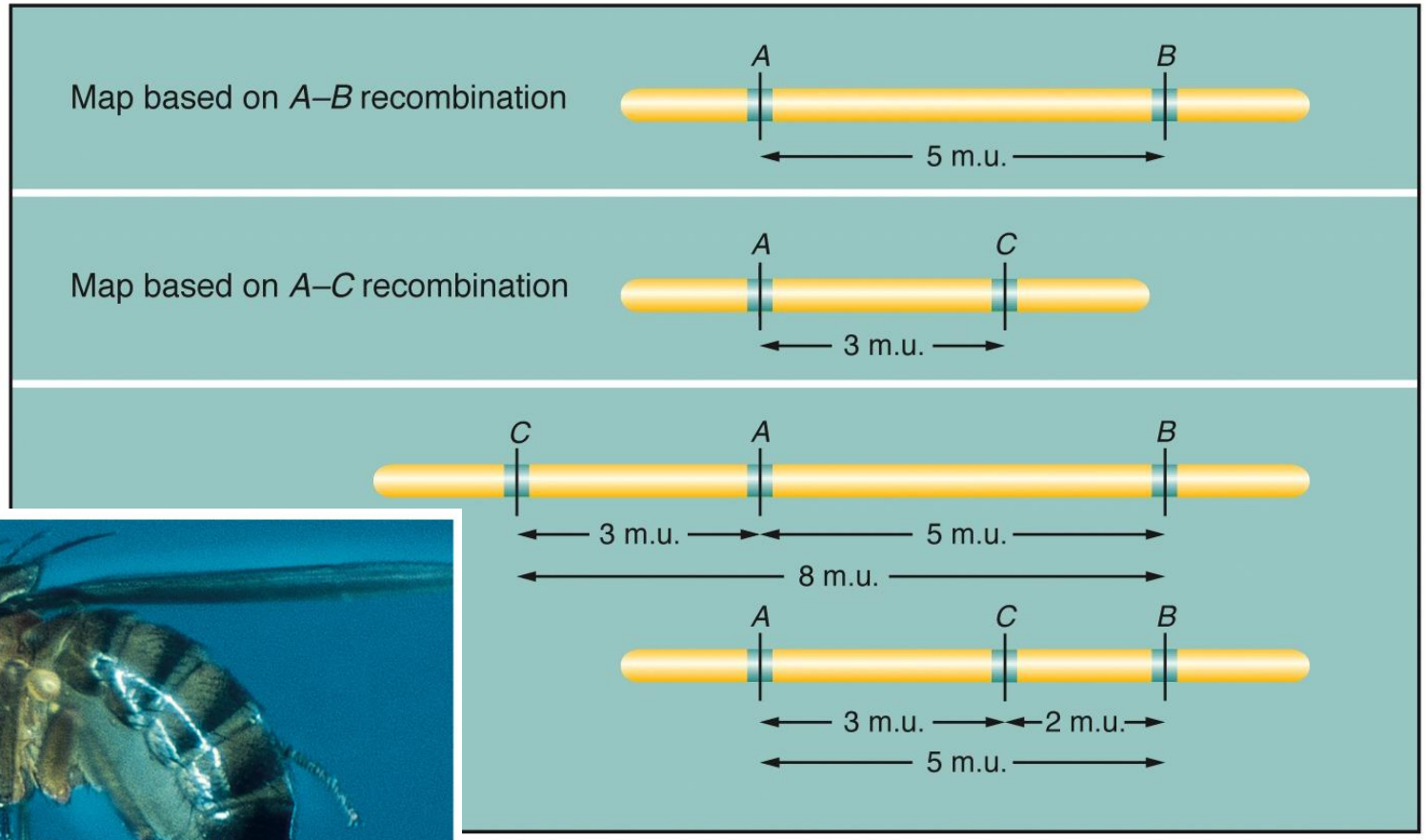
3 : 1

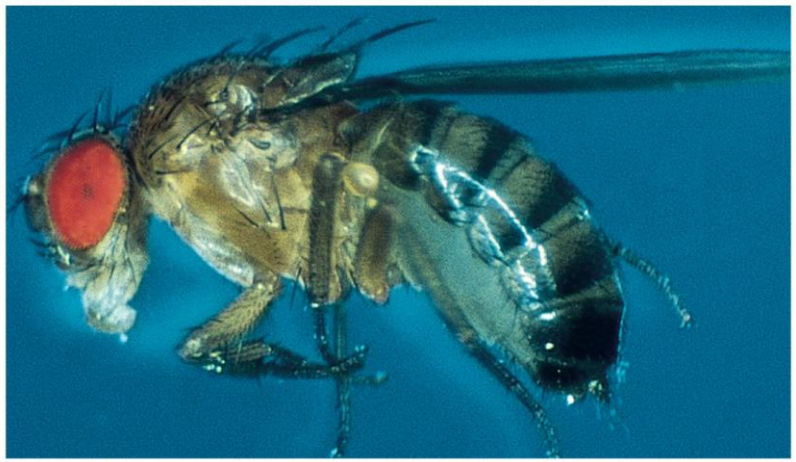
	Dominant	Recessive
Flower color	 Purple	 White
Flower position	 Axial	 Terminal
Seed color	 Yellow	 Green
Seed shape	 Round	 Wrinkled

	Dominant	Recessive
Pod shape	 Inflated	 Constricted
Pod color	 Green	 Yellow
Stem length	 Tall	 Dwarf

Mendel’s peas. What he studied were pairs of characteristics. Plants were either one or the other. No inbetweens. All act independently.

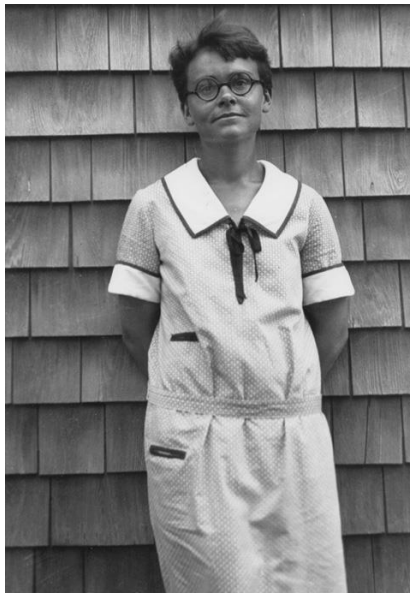
Fruit Fly. Model organism popularized by Hunt and Morgan for genetics





- 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

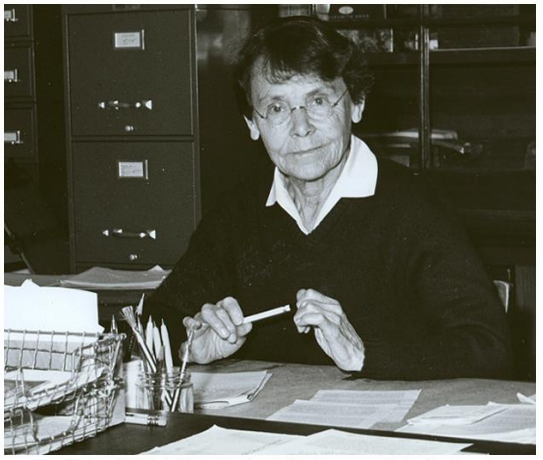
1941-67—Researcher in Genetics, Carnegie Institution of Washington Cold Spring Harbor, Long Island, New York

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



CHROMOSOME MORPHOLOGY IN *ZEA MAYS*

Barbara Mcclintock

Science 14 June 1929: 629.

A semi-diagrammatic representation of the haploid set is given in Fig. 1. One chromosome possesses

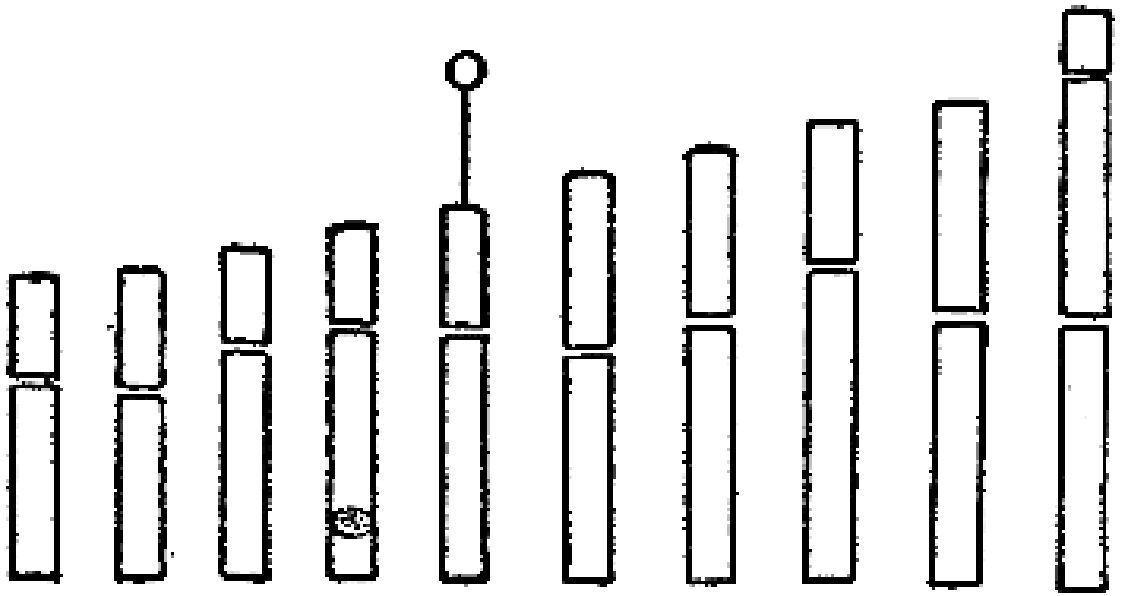


FIG. 1

- Schematic of maize/corn chromosomes. Chromosome 5 has a knob visible under a microscope.

A CYTOLOGICAL DEMONSTRATION OF THE LOCATION OF AN INTERCHANGE BETWEEN TWO NON-HOMOLOGOUS CHROMOSOMES OF ZEA MAYS

By Barbara McClintock

Department of Botany, New York State College of Agriculture

Communicated November 6, 1930

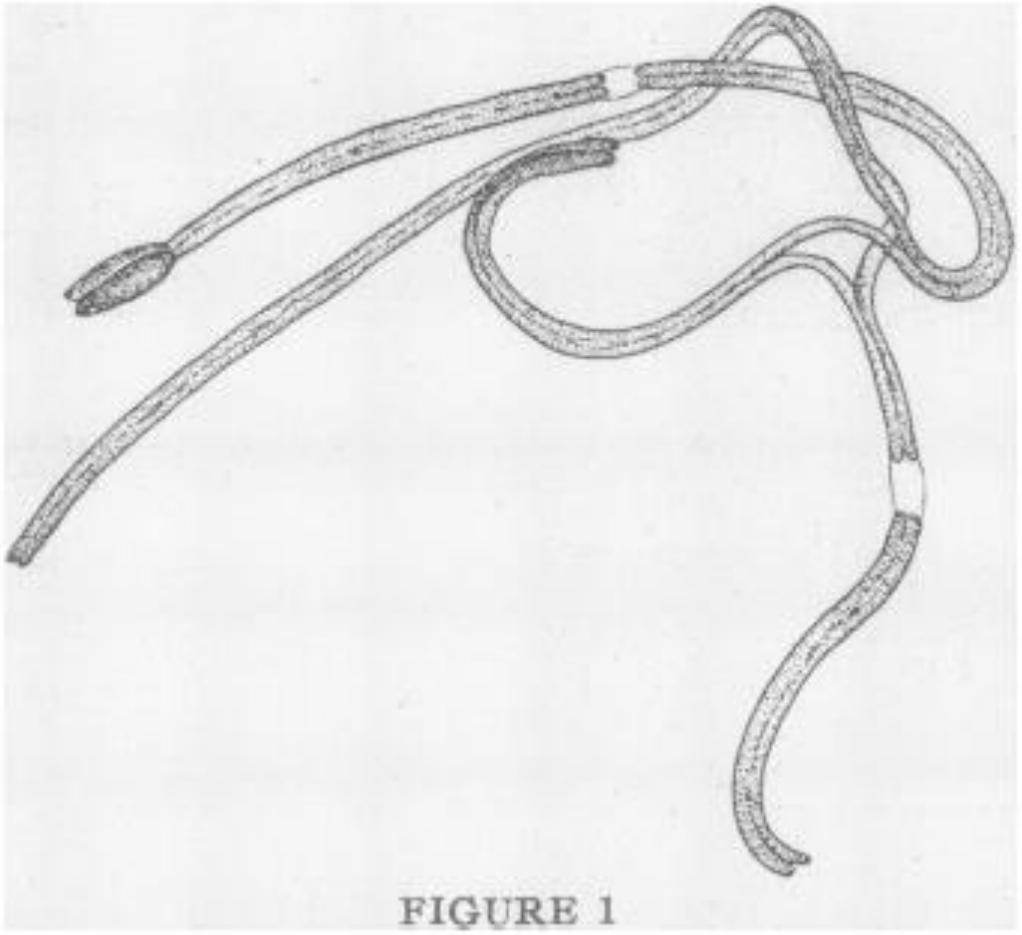


FIGURE 1

Interchange complex in mid-prophase, before

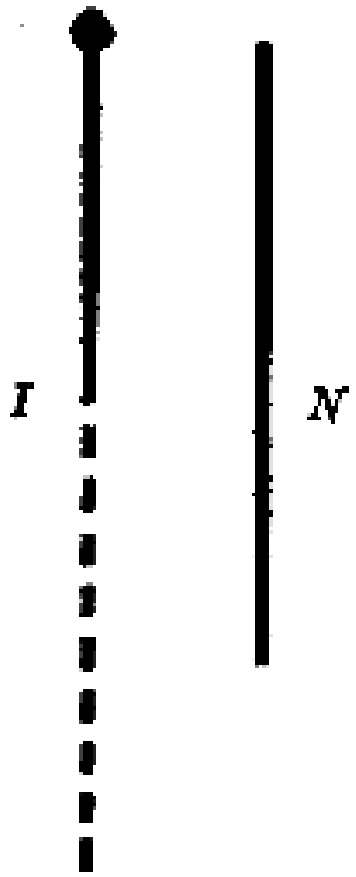
- Chromosomes that are not the same number should not interact during meiosis. However, this observation showed that sometimes they do.

A CORRELATION OF CYTOLOGICAL AND GENETICAL CROSSING-OVER IN ZEA MAYS

By Harriet B. Creighton and Barbara McClintock

Botany Department, Cornell University

Communicated July 7, 1931



- McClintock was the first to demonstrate that observed chromosome exchanges correlated with recombinations of genes.

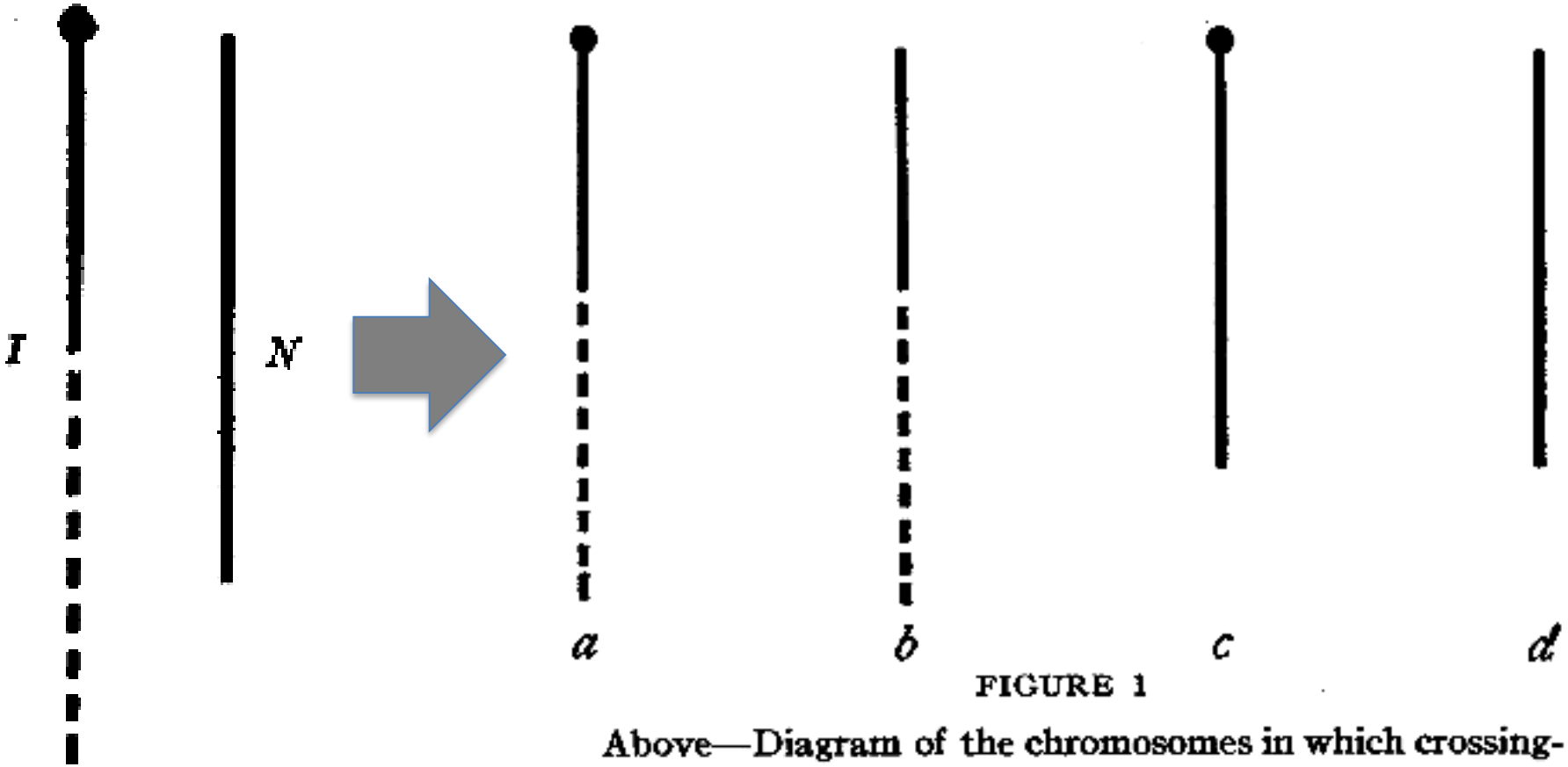


FIGURE 1

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

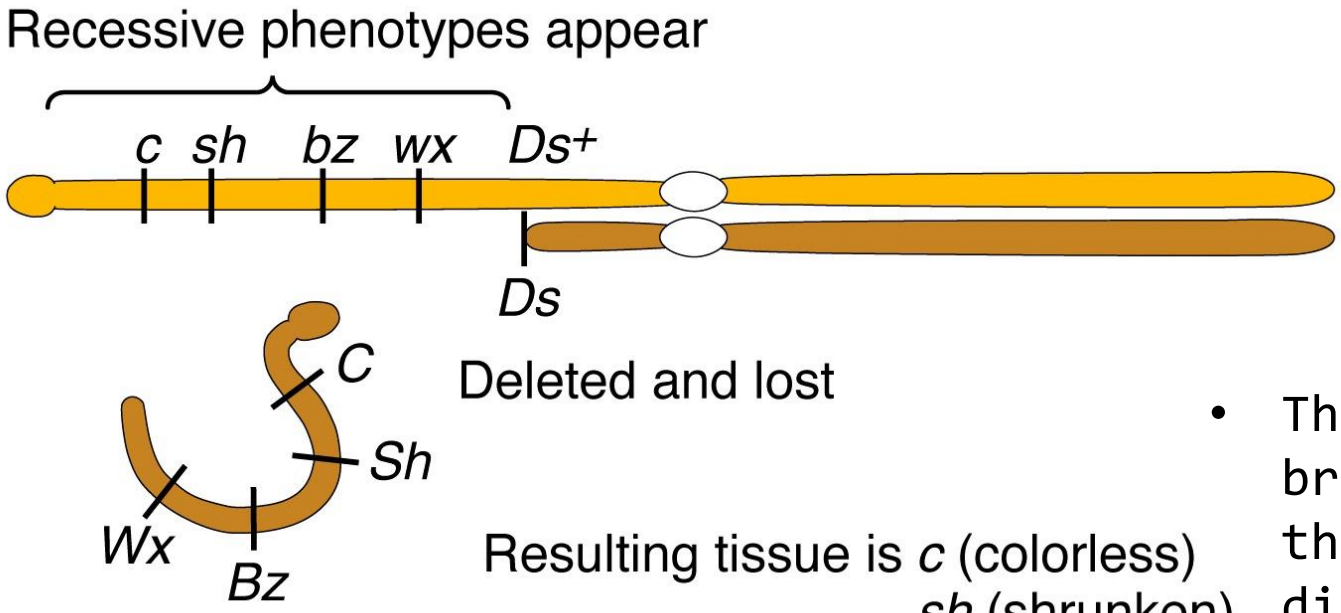
Communicated April 8, 1950

INDUCTION OF INSTABILITY AT SELECTED LOCI IN MAIZE

BARBARA McCLINTOCK

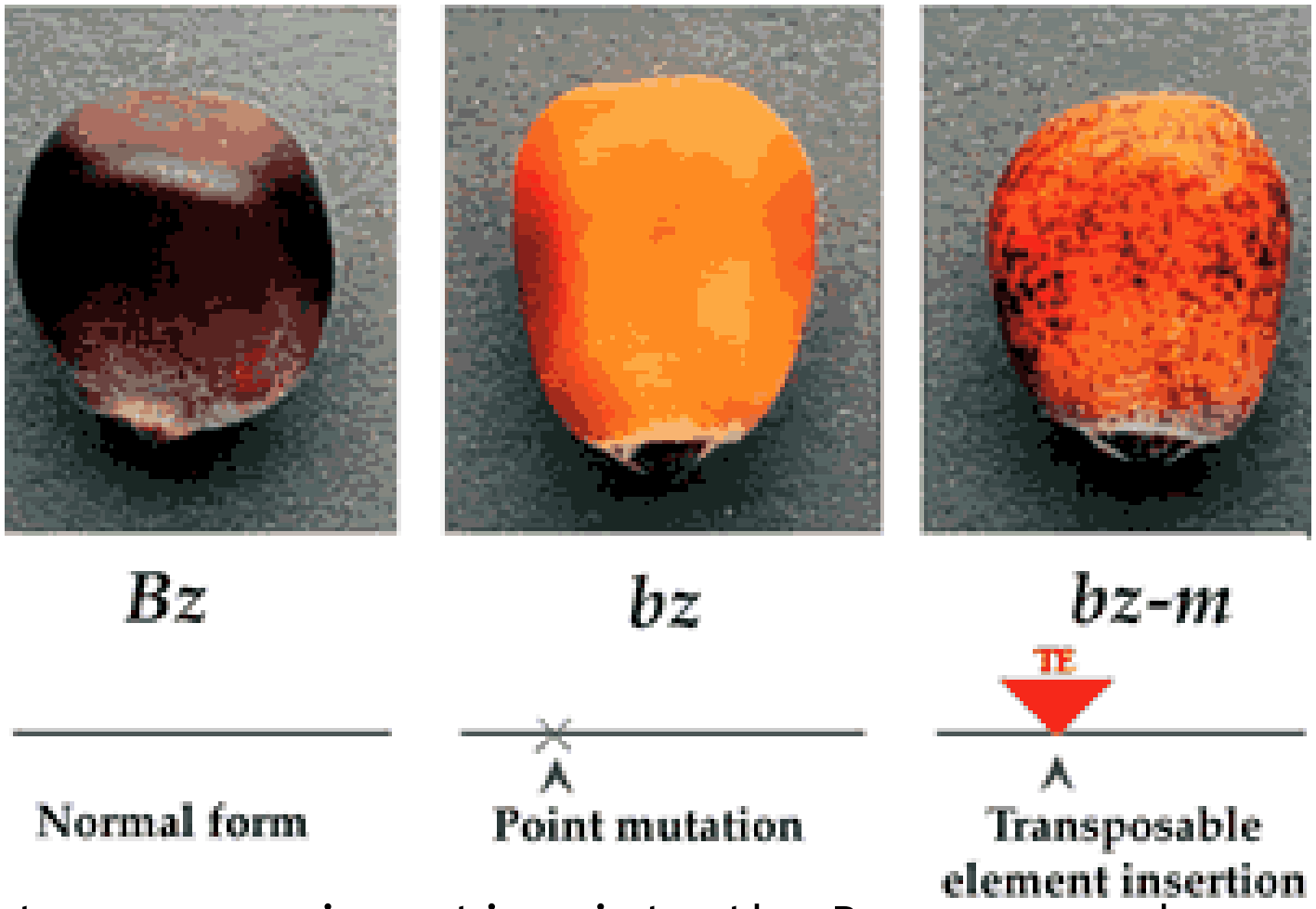
Department of Genetics, Carnegie Institution of Washington, Cold Spring Harbor, N. Y.

Received April 14, 1953



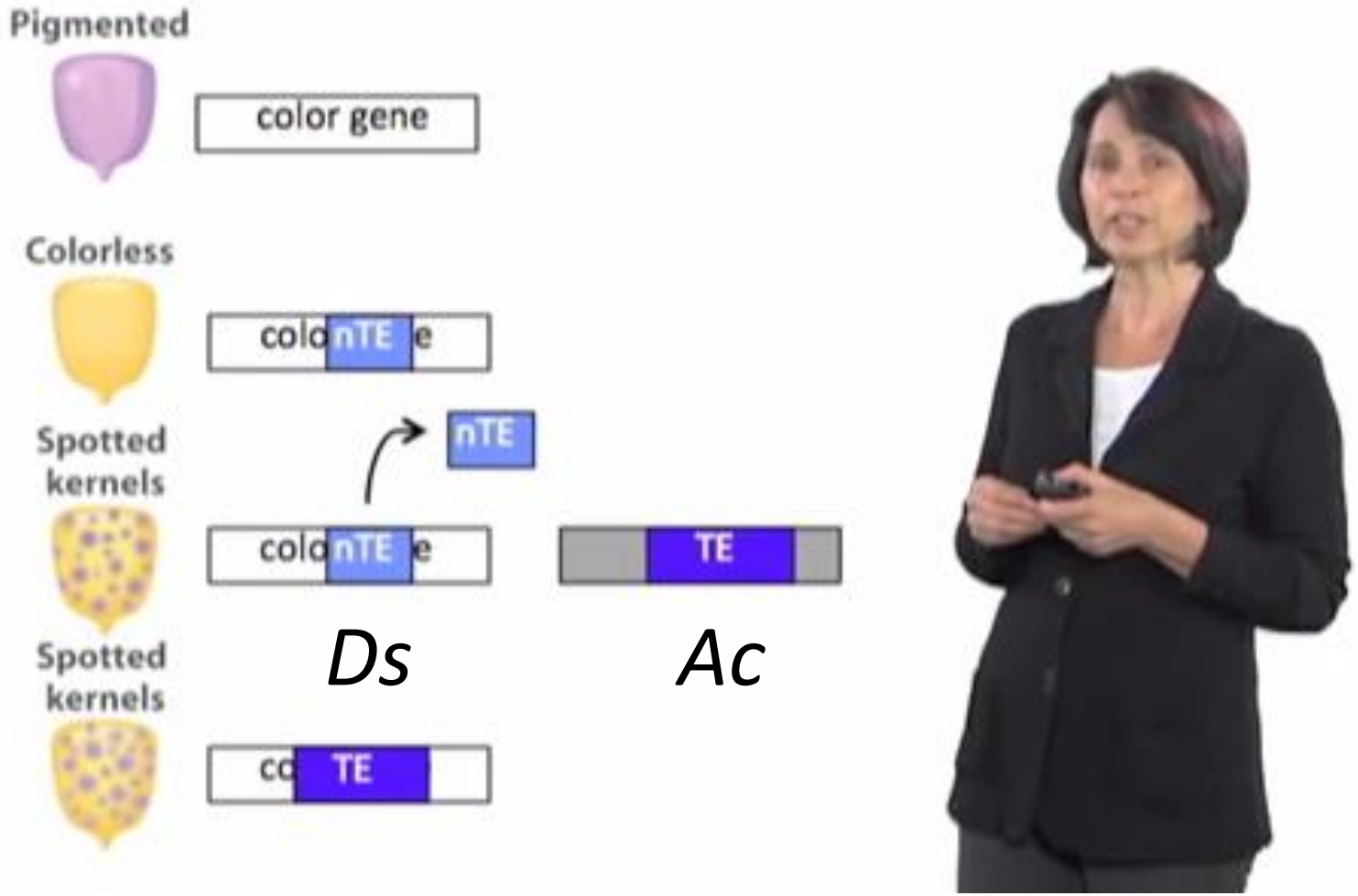
Resulting tissue is *c* (colorless)
sh (shrunken)
bz (bronze)
wx (waxy)

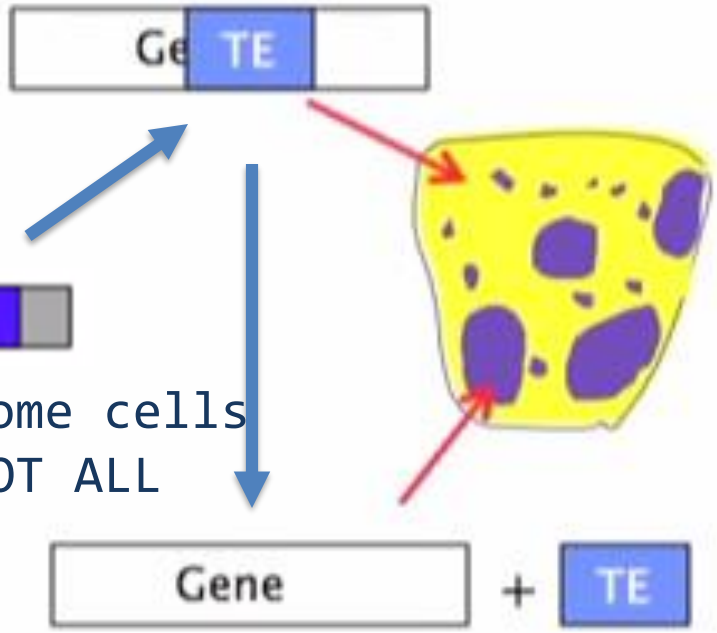
- This chromosome breaks and changes the genetics in different cells in a kernel. Normally, the brown chromosome (capital letter) alleles are the phenotype. But when the arm is lost due to Ds, then the yellow alleles make the color. The breaking element was called Ds



- 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




Ge
TE
TE
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

CellPress

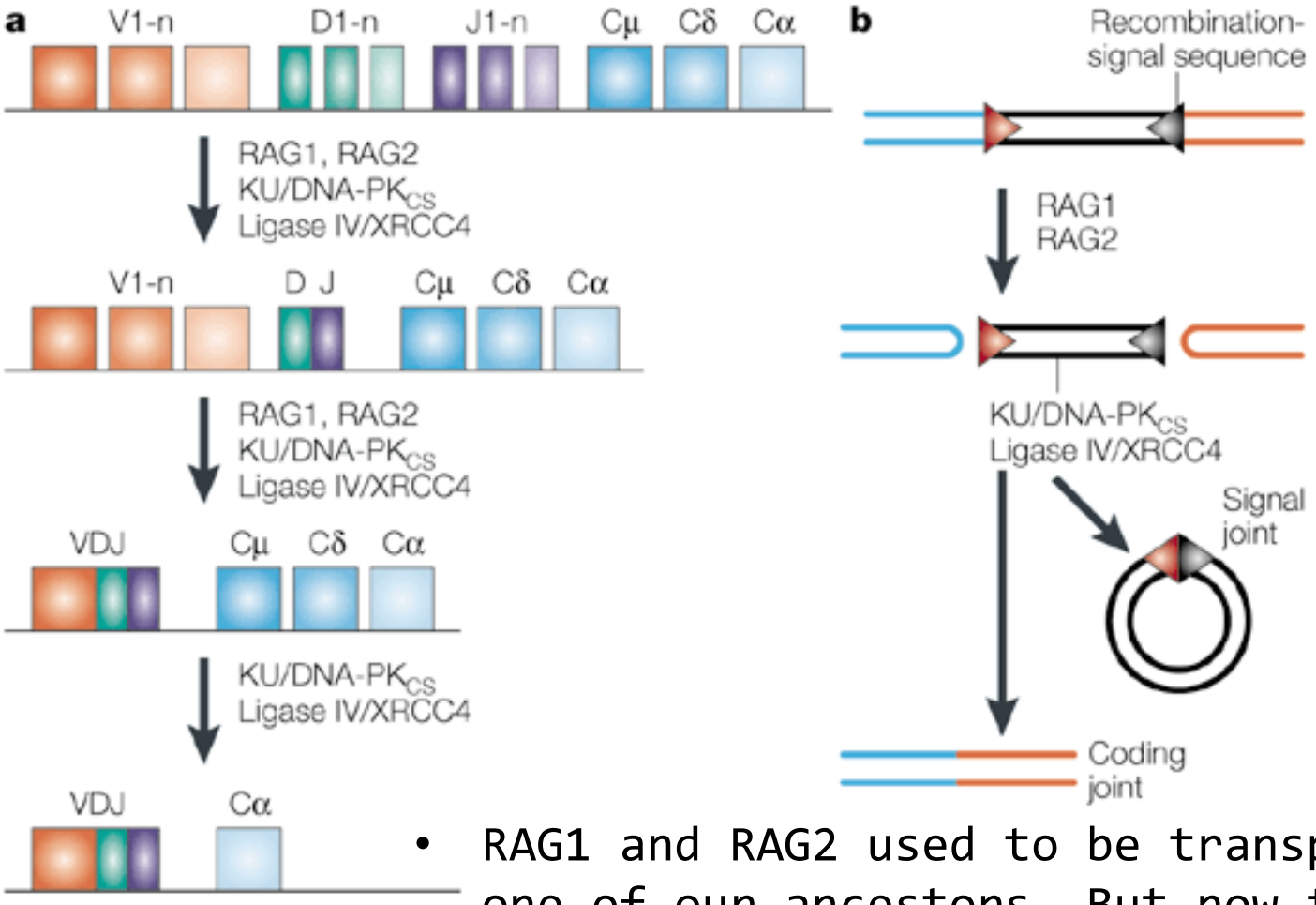
Review

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.

Nature Reviews | Genetics

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

-U.S. National Medal of Science in 1999.

-Darwin-Wallace Medal of the Linnean Society of London in 2008

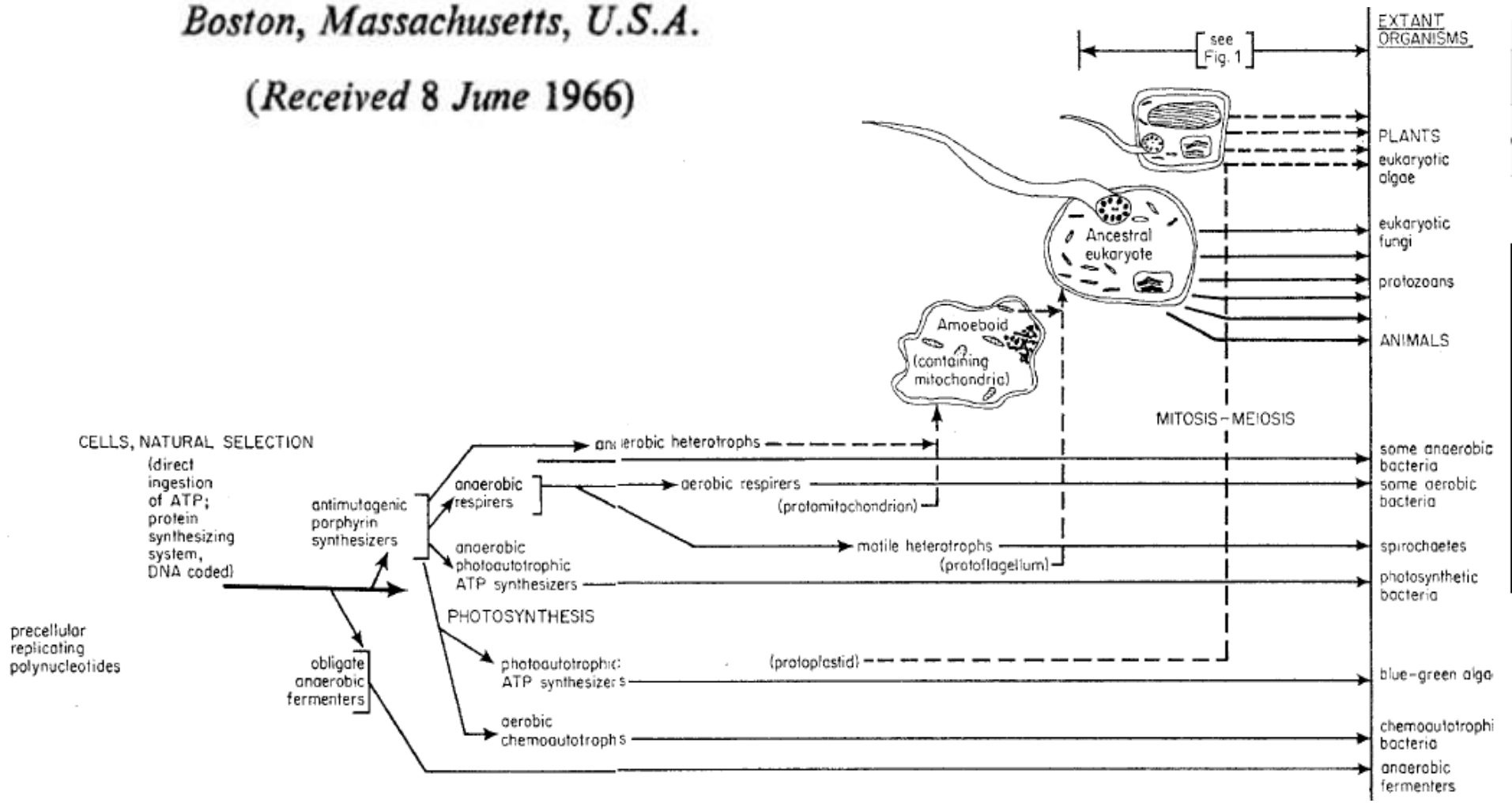
J. Theoret. Biol. (1967) **14**, 225–274

On the Origin of Mitosing Cells

LYNN SAGAN

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

(*Received* 8 *June* 1966)



J. Theoret. Biol. (1967) **14**, 225–274

On the Origin of Mitosing Cells

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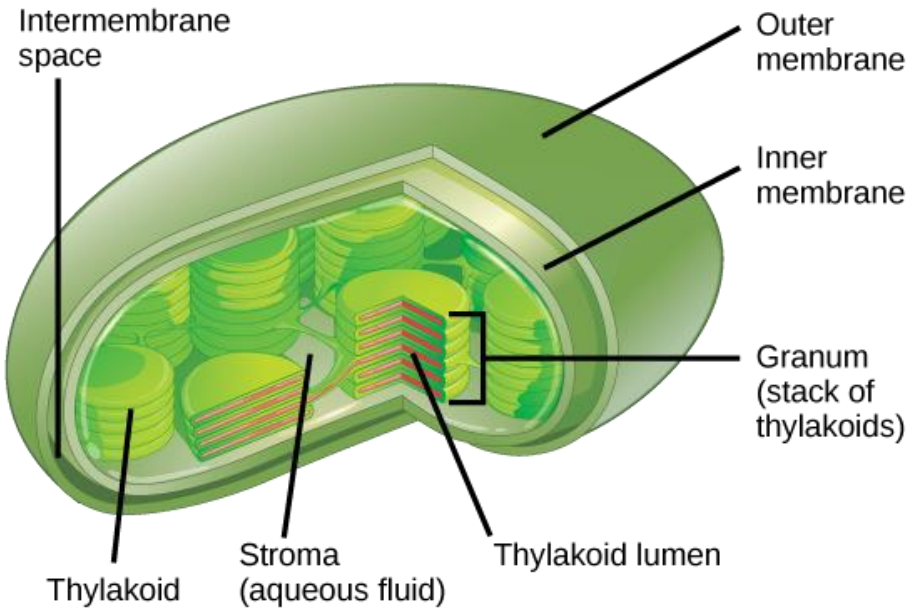
TABLE 2

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

Criterion	Techniques by which measured
Total homology of DNA base pairs	Direct DNA nucleotide sequence data Agar-gel technique for DNA homologies Ability to genetically recombine (i.e. classical genetic techniques) DNA base ratios on CsCl density gradient DNA denaturation (melting point) determinations
Homologous metabolic pathways	Classical biochemistry
Homologous cistrons, same "genetic code letters"	Homologous messenger RNA's (DNA-RNA homologies). Identity of individual transfer RNA's for specific amino acids
Ultrastructural morphology	Electron microscopy
Morphology and life cycle	Light microscopy, classical cytology
Single biochemical pigments, enzymes, etc., in common	Spectroscopy, classical biochemistry
Molecular structure of single pigment, or enzyme	Classical chemistry
Common phenotypic traits	Ability to grow on same carbohydrate, production of same end product, motility, etc.



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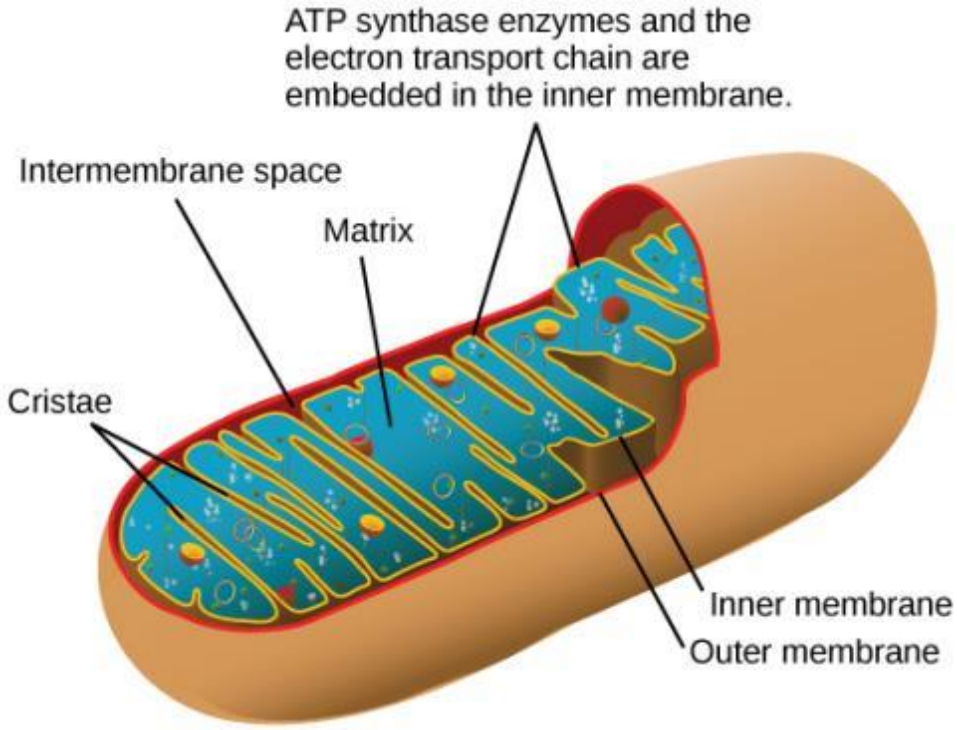
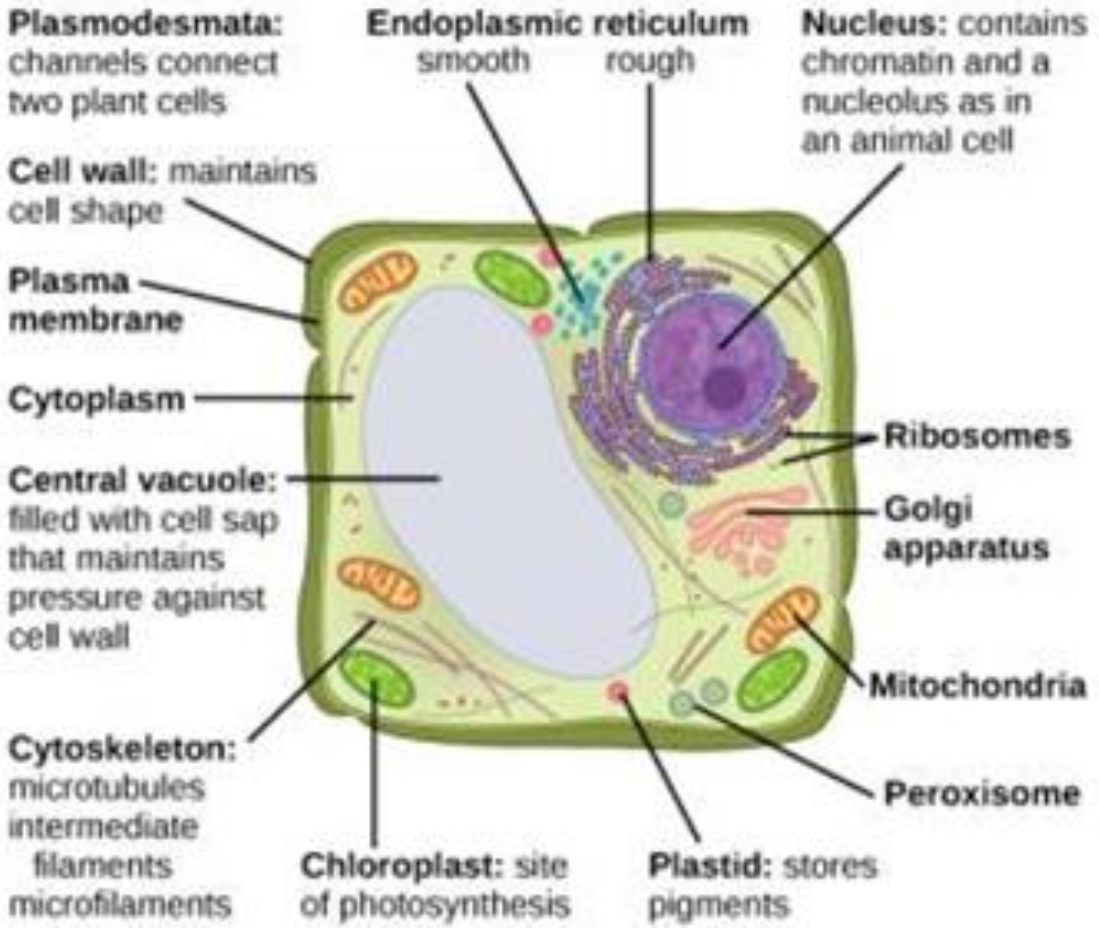
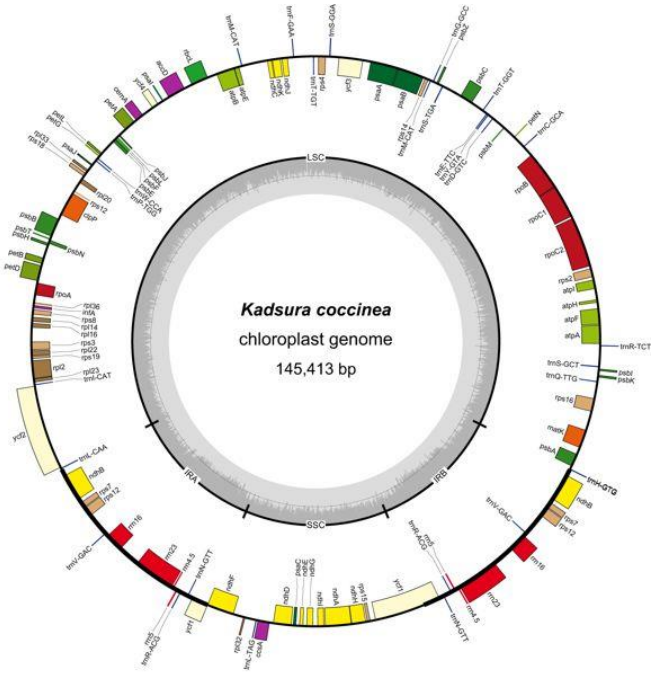
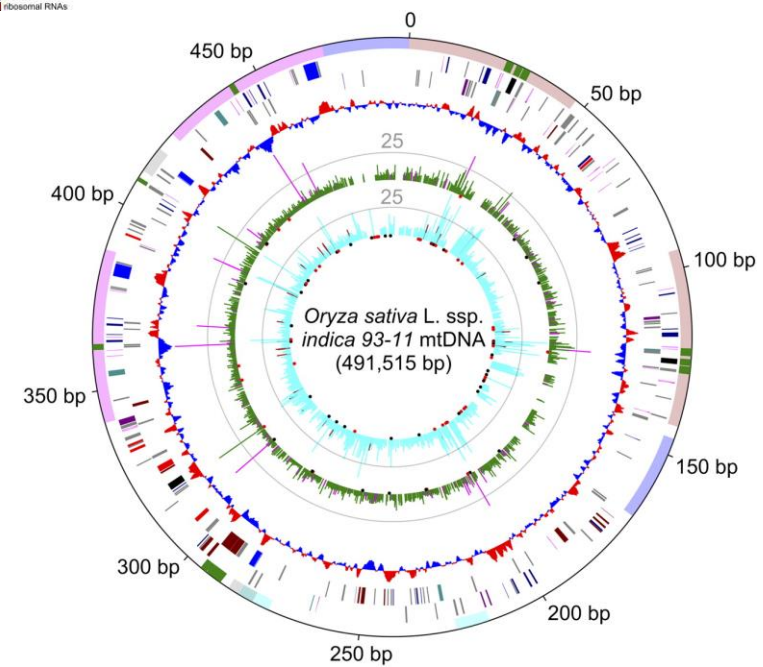
Photosynthesis takes place in chloroplasts, which have an outer membrane and an inner membrane. Stacks of thylakoids called grana form a third membrane layer.

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

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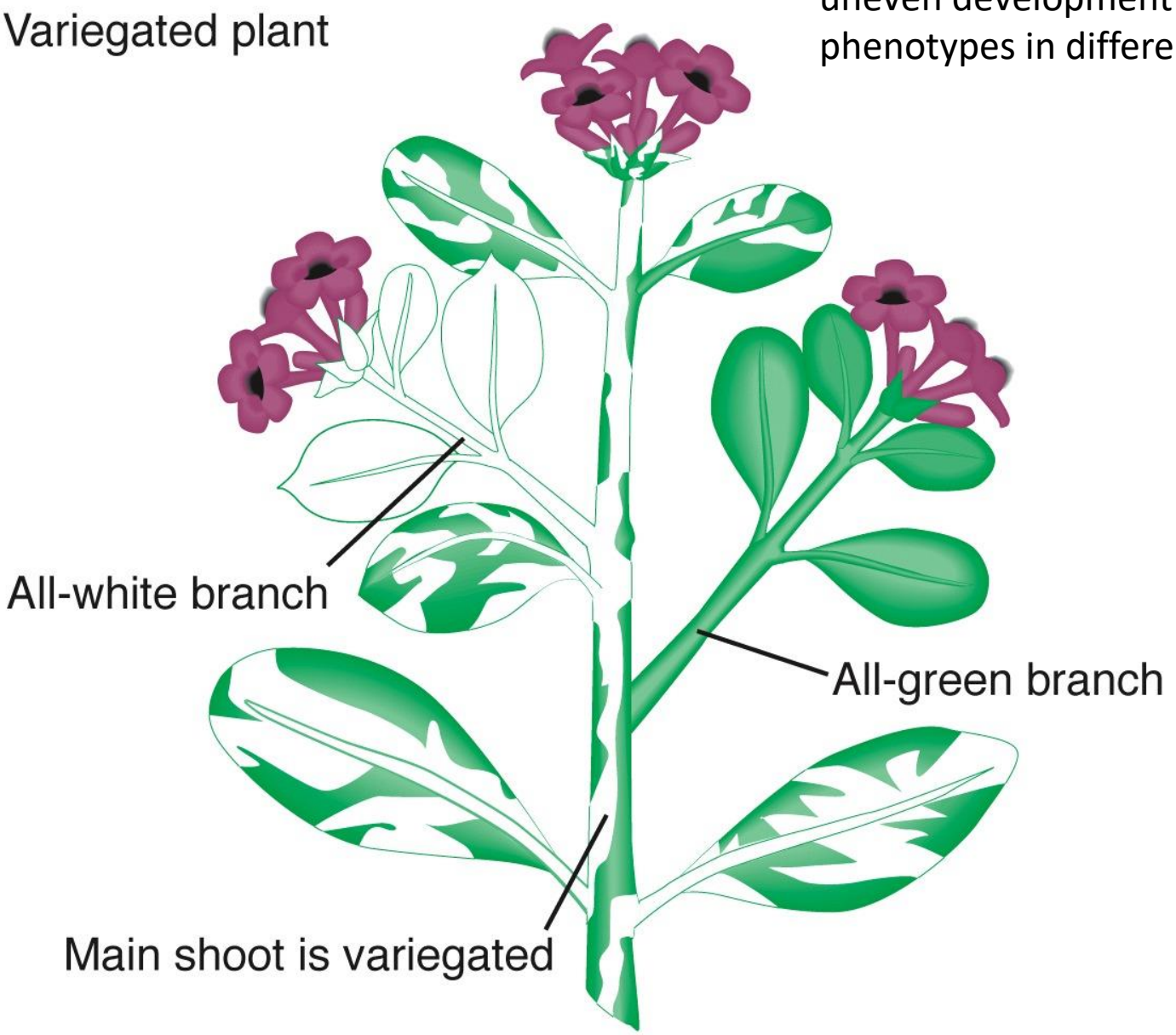
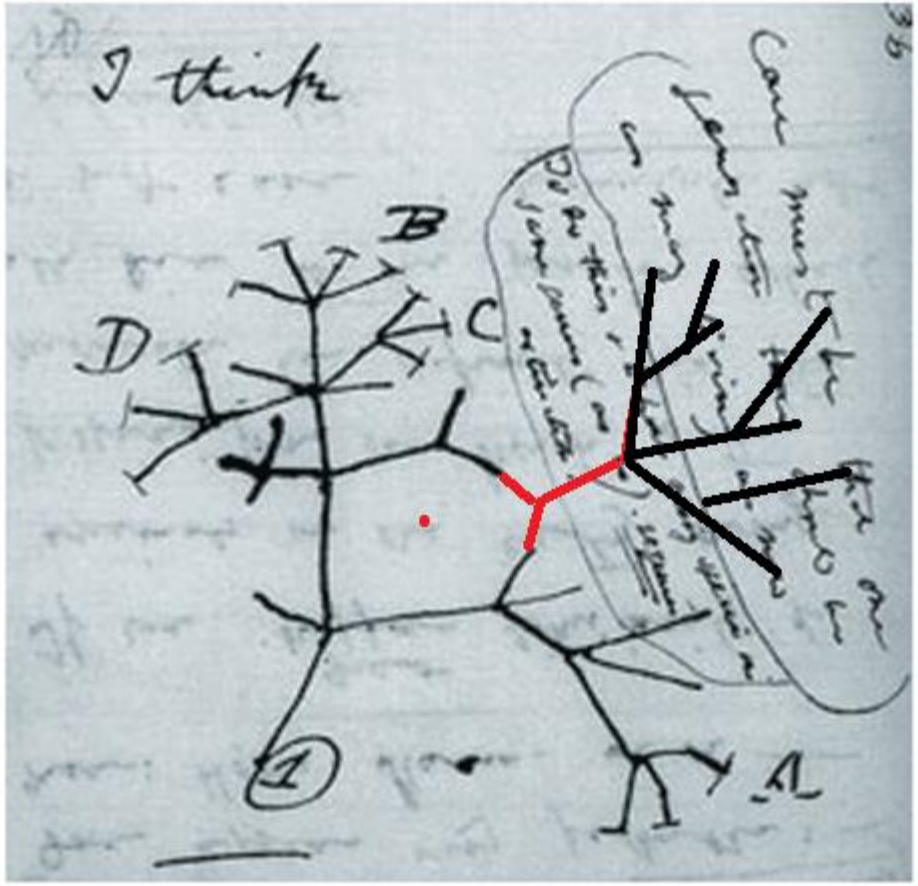
Chloroplast genome mutations and uneven development can lead to variable phenotypes in different parts of the plant



The history of life is like a tree with branches representing life's diversity but with merges



Larger thinking in evolution

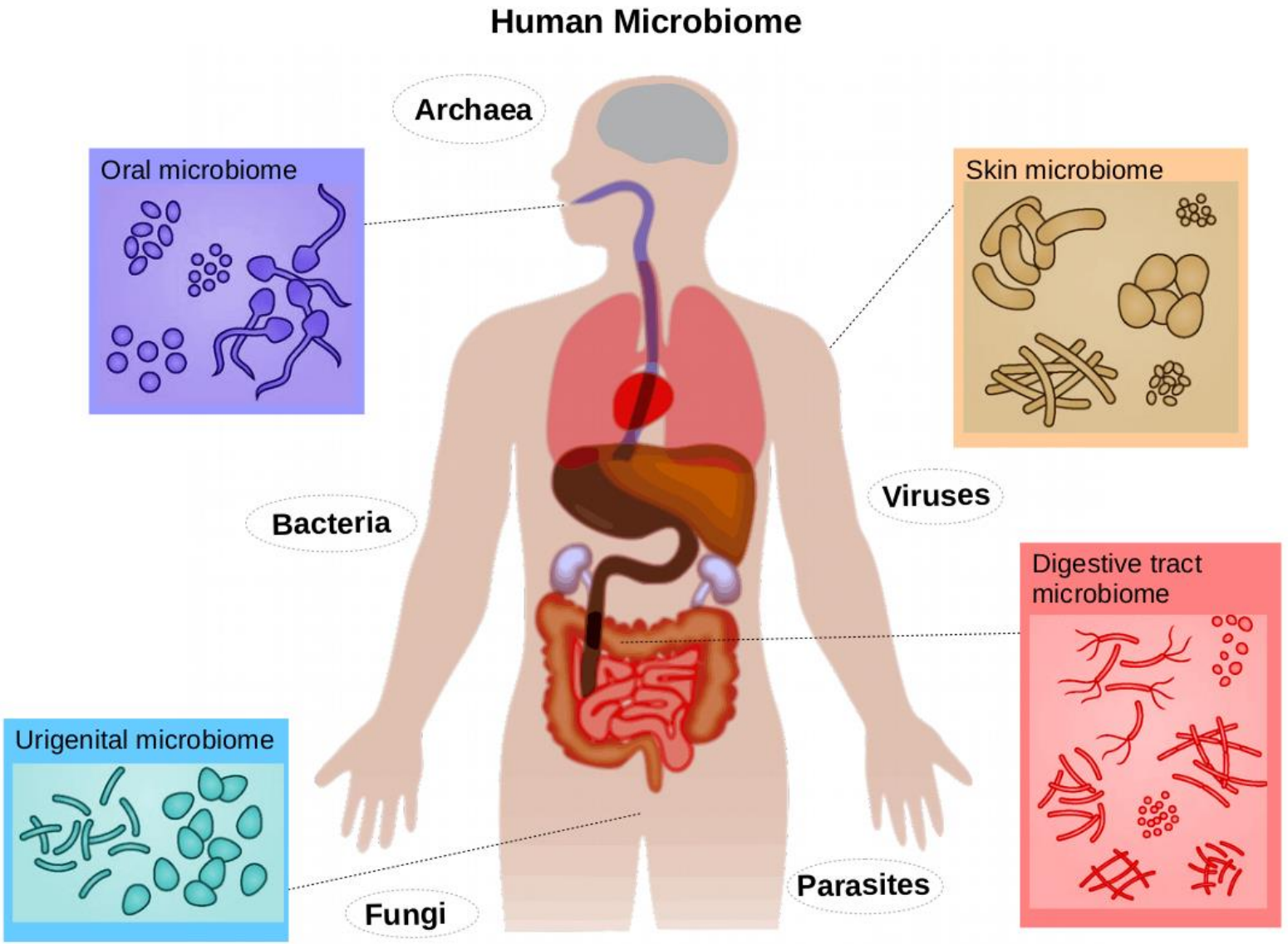
"random mutation and natural selection are just cogs in the gears of evolution; the big leaps forward result from mergers between different kinds of organisms, what she calls symbiogenesis. Viewing life as one giant network of social connections has set Margulis against the mainstream in other high-profile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

Proc Natl Acad Sci U S A. 2008 Nov 18; 105(46): 17867–17871
Published online 2008 Nov 11. doi: 10.1073/pnas.0804968105
From the Cover
Evolution
PMCID: PMC2584685
PMID: 19004808

Horizontal gene transfer of the algal nuclear gene *psbO* to the photosynthetic sea slug *Elysia chlorotica*

Mary E. Rumpho,[a,1] Jared M. Worful,[a] Jungho Lee,[b] Krishna Kannan,[a] Mary S. Tyler,[c] Debashish Bhattacharya,[d] Ahmed Moustafa,[d] and James R. Manhart[e]

Presaged 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*

"Gaia Is A Tough Bitch“ in *The Third Culture: Beyond the Scientific Revolution (1995)* by John Brockman in which he invited others to talk about Margulis.

https://www.edge.org/conversation/lynn_margulis-chapter-7-gaia-is-a-tough-bitch

Heroes of Evolution 2020