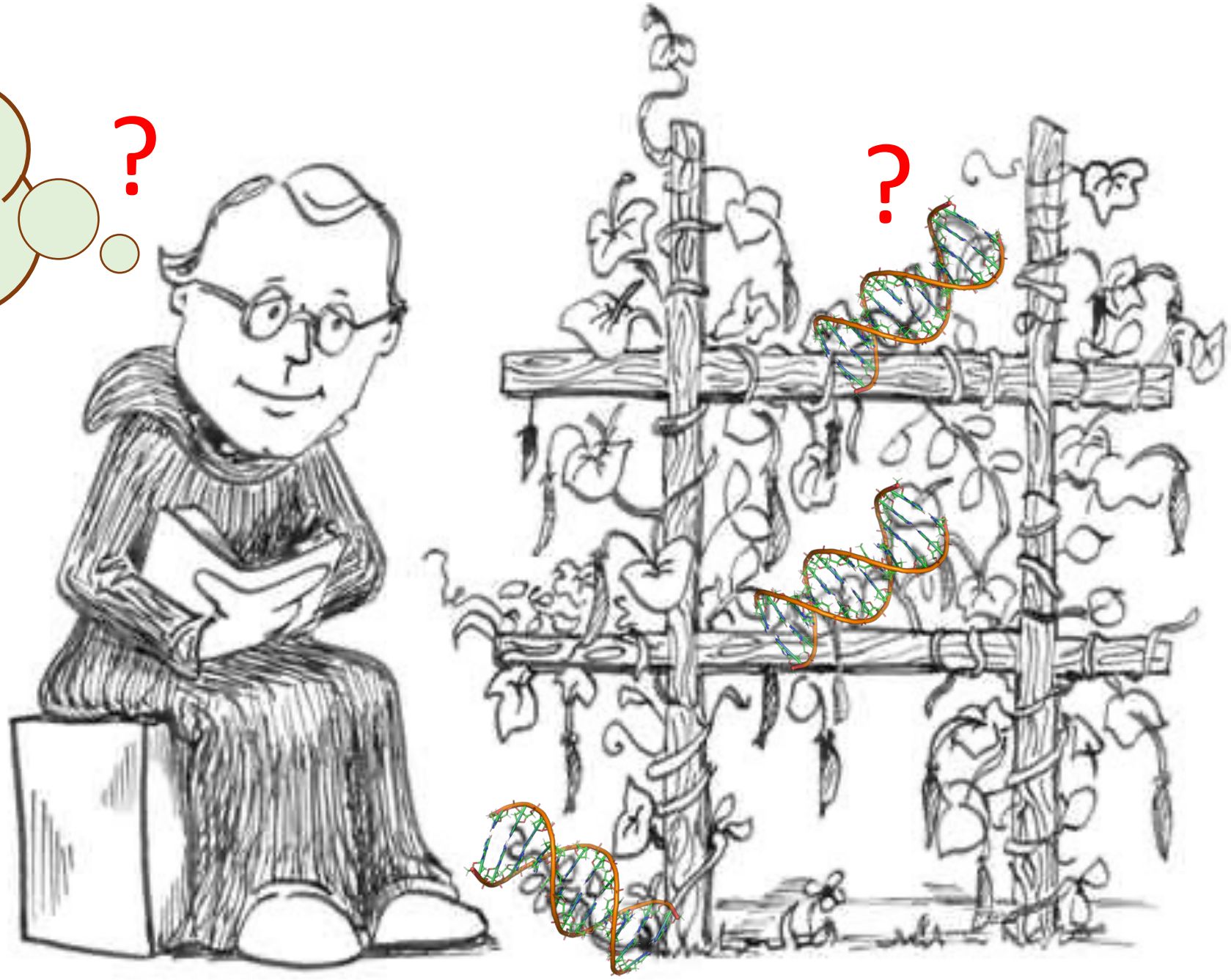
(Reverse)
Engineering
Biology



http://clipart-library.com/clipart/558290.htm

Today's topics

- Engineering Biology
  - iGEM and the idea behind iGEM
- Reverse Engineering Biology
- Heredity
  - Brief digression: β-thalassemia
- Applications in day-to-day life

Postage stamps 1999

1997 The cloning of a sheep to produce Dolly

DNA fragments are separated by electrophoresis

Paul Berg. Nobel Prize in Chemistry, 1980
Developed the first methods for cloning genes

Michael Smith. Nobel prize in Chemistry, 1993
Polymerase chain reaction

The human genome project

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068906/

https://www.livescience.com/40623-craig-venter-envisions-future-of-biology.html

LIVESCIENCE

News | Space & Physics | Health | Planet Earth | Strange News | Animals

Home > News

Genomics Pioneer Craig Venter Envisions Future of Synthetic Life

By Tanya Lewis published October 23, 2013

https://www.livescience.com/40623-craig-venter-envisions-future-of-biology.html

See also, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068906/

Synthetic biology

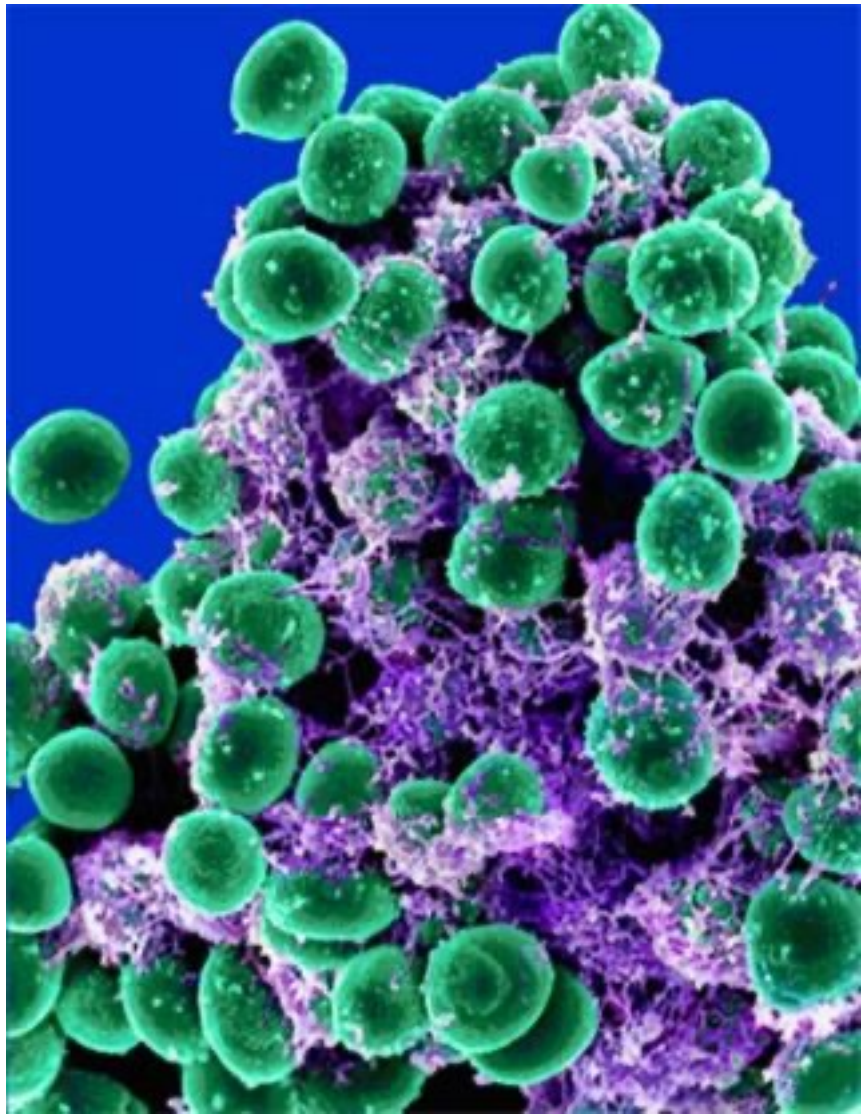
Pioneered by J. Craig Venter

- ***Making software that could build its own hardware***
- Created a synthetic bacteriophage, a virus that infects bacteria, and injected that into *E. coli*
  - The cells incorporated the synthetic DNA into their genomes, and they started assembling bacteriophages

https://www.livescience.com/40623-craig-venter-envisions-future-of-biology.html

https://www.livescience.com/1659-engineered-virus-attacks-bacteria.html

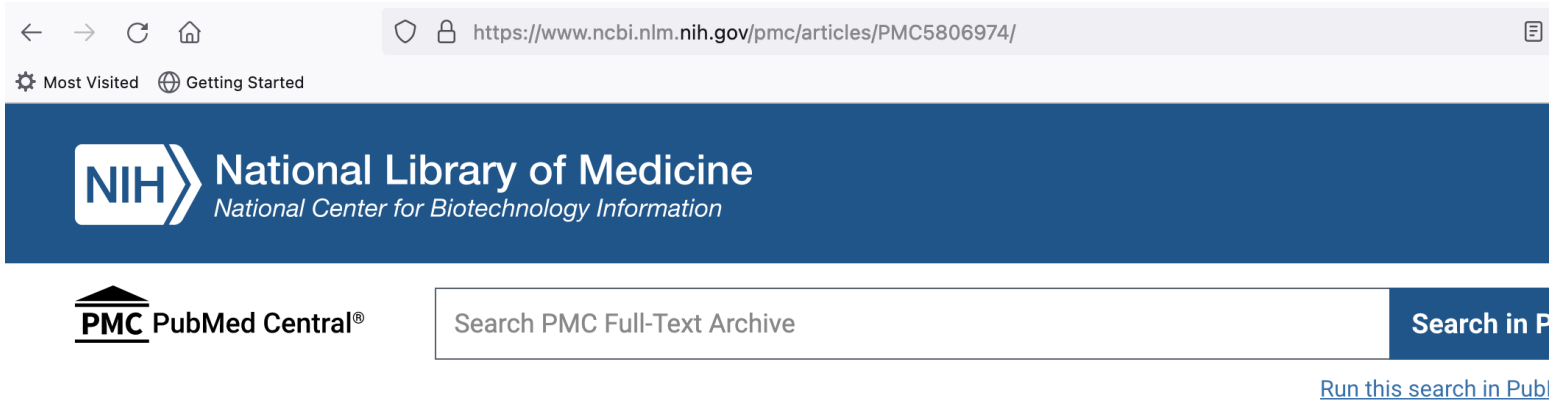
Engineered Virus Attacks Bacteria



Scientists have engineered viruses to attack and destroy mega-colonies of potentially harmful bacteria called biofilms.

https://www.livescience.com/1659-engineered-virus-attacks-bacteria.html

An example of biofilm: dental caries



dentistry journal
MDPI

Dent J (Basel). 2017 Jun; 5(2): 21.
Published online 2017 Jun 19. doi: 10.3390/dj5020021
PMCID: PMC5806974
PMID: 29563427

Dental Biofilm and Laboratory Microbial Culture Models for Cariology Research

Ollie Yiru Yu, Irene Shuping Zhao, May Lei Mei, Edward Chin-Man Lo, and Chun-Hung Chu*

Author information · Article notes · Copyright and License information Disclaimer

Abstract

Go to:

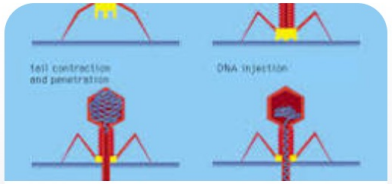
Dental caries form through a complex interaction over time among dental p https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5806974/

Phage therapy

Félix d'Hérelle

French microbiologist

Overview | Videos



Encyclopedia Britannica

Félix d' Hérelle | Canadian microbiologist | Britannica

Félix d' Hérelle, (born April 25, 1873, Montreal, Que., Can.—died Feb. 22, 1949, Paris, Fr.), French-Canadian microbiologist generally known ...

4 weeks ago

National Institutes of Health (.gov)

Phage as an antimicrobial agent: d'Herelle's heretical theories ...

The Franco-Canadian microbiologist Félix d'Herelle (1873 to 1949) is credited with the discovery of bacteriophage, a bacterial ...

Education

Lycée Condorcet

Awards

Leeuwenhoek Medal

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4946093/

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National Center for Biotechnology Information

PMC PubMed Central®

Search PMC Full-Text Archive

Run this search in PubM

Journal List > J Biol Res (Thessalon) > v.23; 2016 Dec > PMC4946093

Journal of Biological Research-Thessaloniki BMC

J Biol Res (Thessalon). 2016 Dec; 23: 16.
Published online 2016 Jul 15. doi: 10.1186/s40709-016-0055-6

PMCID: PMC4946093
PMID: 27429942

Ganges: special at its origin

Krishna Khairnar

Author information | Article notes | Copyright and License information | Disclaimer

River Ganges in India, for centuries, has been revered for its "self-cleansing and special healing properties". More than 450 million people depend on the waters of Ganges for many aspects of their life. In 1896, one of the first published works on Ganges water by Ernst Hankin, a British bacteriologist demonstrated antibacterial property of Ganges water against *Vibrio cholera* [1]. Further work by French

J Biol Res (Thessalon)

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4946093/

Synthetic biology

Pioneered by J. Craig Venter

- Modified a chromosome from a bacterium (*Mycoplasma mycoides*) and inserted it into the cell of another bacterium (*Mycoplasma capricolum*)
- Once inserted into the host, inserted DNA started making instructions for enzymes that chewed up the host bacterium's genome
- Essentially, it was a proof of concept study that showed that one species can be converted into another

https://www.livescience.com/40623-craig-venter-envisions-future-of-biology.html

Biological “robots” that self-replicate

- Life is a self-sustaining chemical system capable of Darwinian evolution
  - A definition that NASA uses...

URL for the video clip inserted in the next slide: https://www.inverse.com/innovation/robots-generate-offspring

https://www.inverse.com/innovation/robots-generate-offspring

Biology: discovery or invention or both?

- Can we engineer biological systems
  - to manipulate information,
  - construct materials,
  - process chemicals,
  - produce energy,
  - provide food, and
  - help maintain or enhance human health and our environment

Vaccines for Covid 19

Nature (2005) 438:449

Engineering “living machines”: bottlenecks

In a 2005 article...

- Unfortunately, our ability to quickly and reliably engineer biological systems that behave as expected remains quite limited.
- Foundational technologies are needed...
  - engineering of biology should become a routine work...

Nature (2005) 438:449

The Spruce

9 Tips for Buying and Putting Together IKEA Furniture

Visit

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Google search hit

https://igem.org

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What is iGEM?

The iGEM Foundation is an independent, non-profit organization dedicated to the advancement of synthetic biology, education and competition, and the development of an open, collaborative, and cooperative community.

The Premiere International Synthetic Biology

Competition

19	46	350	3 600	70 000
YEARS	COUNTRIES	TEAMS/YEAR	TEAMS	PARTICIPANTS

Multidisciplinary student teams from all over the world compete for medals and awards by designing, building, and testing projects using

Local people solving local problems

Projects

3 600	12
PROJECTS	TRACKS

Teams create projects from

Registry of Standard Biological Parts

From Wikipedia, the free encyclopedia

The **Registry of Standard Biological Parts** is a collection of genetic parts that are used in the assembly of systems and devices in synthetic biology. The registry was founded in 2003 at the Massachusetts Institute of Technology. The registry, as of 2018, contains over 20,000 parts. Recipients of the genetic parts include academic labs, established scientists, and student teams participating in the iGEM Foundation's annual synthetic biology competition.[1]

The Registry of Standard Biological Parts conforms to the BioBrick standard, a standard for interchangeable genetic parts. BioBrick was developed by a nonprofit composed of researchers from MIT, Harvard, and UCSF. The registry offers genetic parts with the expectation that recipients will contribute data and new parts to improve the resource. The registry records and indexes biological parts and offers services including the synthesis and assembly of biological parts, systems, and devices.

The registry offers many types of biological parts, including DNA, plasmids, plasmid backbones, primers, promoters, protein coding sequences, protein domains, ribosomal binding sites, terminators, translational units, riboregulators, and composite parts.[2] It also includes devices such as protein generators, reporters, inverters, receptors, senders, and measurement devices. A key idea that motivated the development of the Registry was to develop an abstraction hierarchy implemented through the parts categorization system.[3]

The registry has previously received external funding through grants from the National Science Foundation, the Defense Advanced Research Projects Agency, and the National Institutes of Health.

Registry of standard biological parts

- A registry of “standard biological parts”
  - These parts are made by “organisms”
- Free access to basic biological functions (=parts, components)
- These may be used to program synthetic biological systems
- Anybody may contribute, draw upon, or improve the parts

https://igem.org/

witter.com/iGEMRuiaMumbai/status/1061965660664799232

← **Tweet**

CMO Maharashtra @CMOMaharashtra · Nov 12, 2018

CM @Dev_Fadnavis meets and congratulates the team of students from Ruia College, Matunga, who bagged the Gold Medal and prizes at the International Genetically Engineered Machines (iGEM) 2018 competition held in Boston, USA last week. @iGEM @iGEMRuiaMumbai

7 67 238

CMO Maharashtra @CMOMaharashtra · Nov 12, 2018

The project by these students focuses on easy and eco-friendly way of removing paan stains, which is not only a health hazard, but also destroys the beauty of monuments and public areas.
This project takes its inspiration from PM @narendramodi 's @swachhbharat Mission!

5 45 114

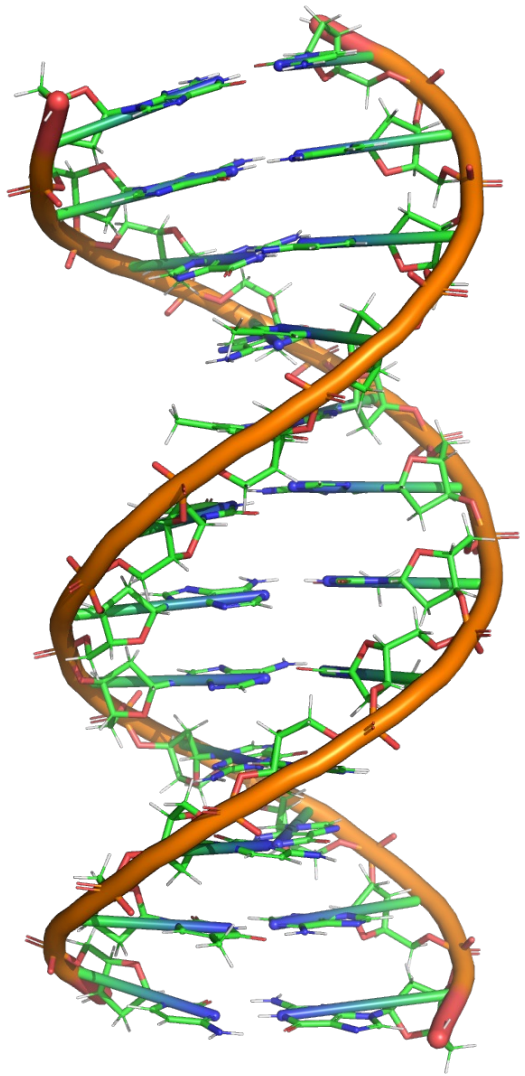
CMO Maharashtra @CMOMaharashtra · Nov 12, 2018

https://twitter.com/iGEMRuiaMumbai/status/1061965660664799232

Today's topics

- Engineering Biology
  - iGEM and the idea behind iGEM
- Reverse Engineering Biology
- Heredity
  - Brief digression: β-thalassemia
- Applications in day-to-day life

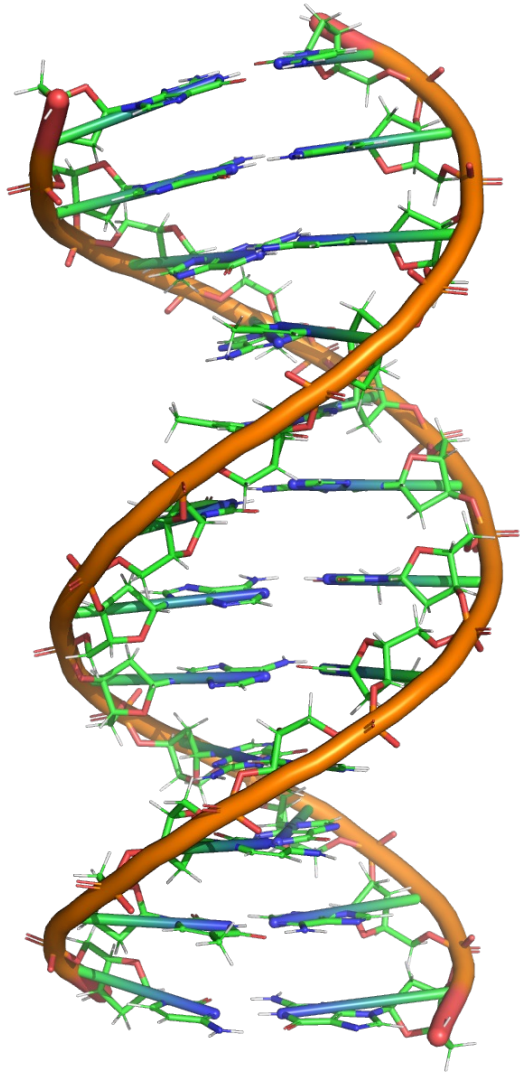
Reverse engineering a "living machine"
One of the approaches



Protein databank id: 2EZE.pdb

- Discovering the existence of an instruction manual
- Proving that DNA is the instruction manual
- Decoding the instruction manual

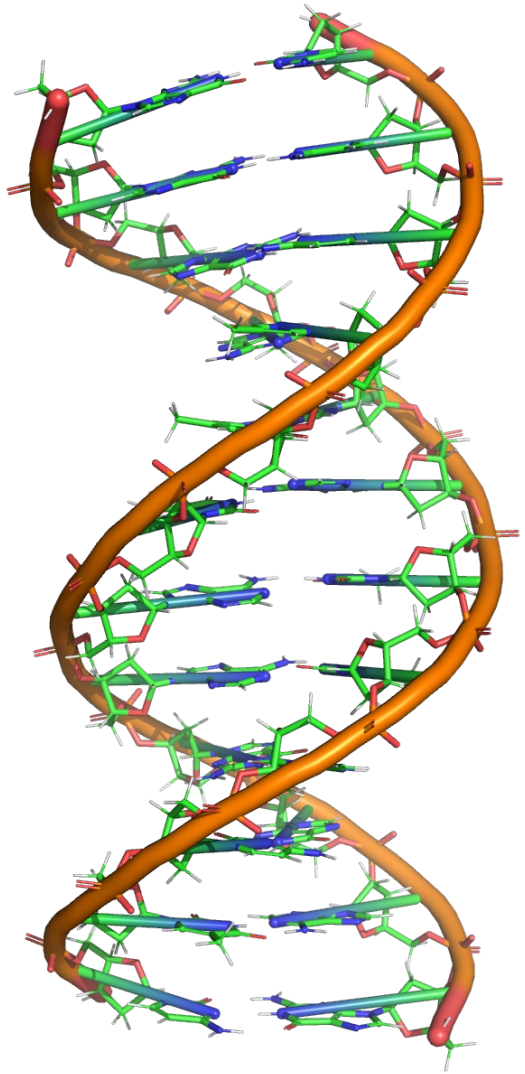
Reverse engineering a "living machine"
One of the approaches



Protein databank id: 2EZE.pdb

- Discovering the existence of an instruction manual
  - Gregor Mendel (pea plant; heredity)
  - Walther Flemming (cytogenetics)
- Proving that DNA is the instruction manual
- Decoding the instruction manual

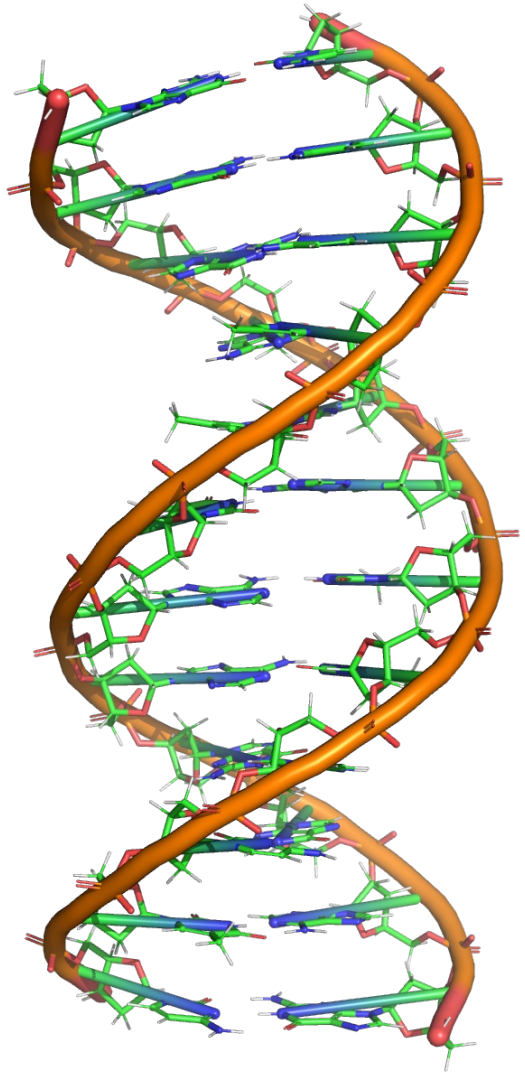
Reverse engineering a "living machine"
One of the approaches



Protein databank id: 2EZE.pdb

- Discovering the existence of an instruction manual
- Proving that DNA is the instruction manual
  - Frederick Griffith
  - Oswald Avery, Colin MacLeod, Maclyn McCarty
  - Alfred Hershey and Martha Chase
  - James Watson and Francis Crick
  - Matthew Meselson and Franklin Stahl
- Decoding the instruction manual

Reverse engineering a "living machine"
One of the approaches



Protein databank id: 2EZE.pdb

- Discovering the existence of an instruction manual
- Proving that DNA is the instruction manual
- Decoding the instruction manual
  - Computational Biology
  - Bioinformatics
  - High-throughput technologies
  - …

Today's topics

- Engineering Biology
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- Applications in day-to-day life

Slide from Lecture 1

De-constructing biological systems

Serendipity (*noun*): luck that takes the form of finding valuable or pleasant things that are not looked for

- Serendipity – smartness to understand the implications of an observation
- In the 21st century, Biology is all about
  - Being observant, extremely clever thinking, choosing the right system, designing clever experiments, ...
  - NOT memorization, drawing, large vocabulary, ...

Instruction manual of life

How was it discovered?

Key takeaways

Choose your system wisely!

What if you are ahead of your time?

http://clipart-library.com/clipart/558290.htm

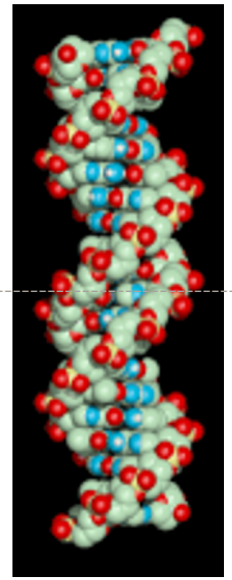
Slide from Lecture 1

BB101 Biology
March – June 2023
Lecture 01

40

DNA is like Coca Cola but… it carries information

Coke	DNA	Solubility
Water	Water	Not applicable
Sugar (sucrose)	Sugar (deoxyribose)	Very high
Phosphate	Phosphate	Moderate
Caffeine (a nitrogenous base)	A, C, G, and T (nitrogenous bases)	Extremely low



DNA is THE manual

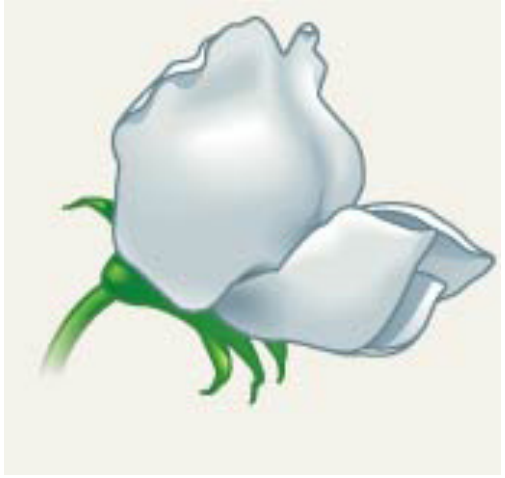
https://commons.wikimedia.org/wiki/File:CocaColaGlassBottle.jpg
DNA image – from Prof. Swati Patankar

How did we arrive at this conclusion?

DNA is the genetic material for all organisms except for some viruses

Phenotype

Purple flowers



White flowers

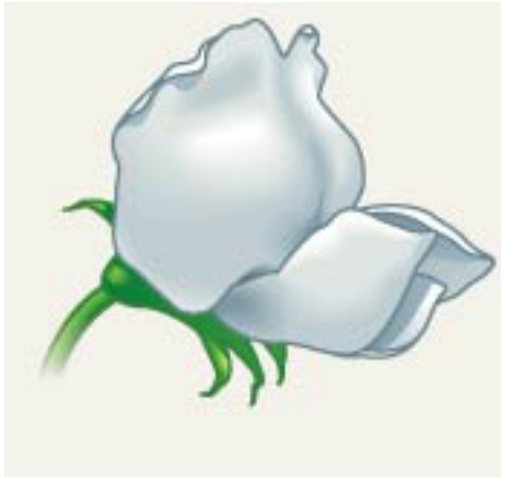
Phenotype of flowers (observable property)

Observable output of a computer program

Genotype

- An organism's full hereditary information
- Now we know this to be the genome, consisting of DNA

Purple flowers

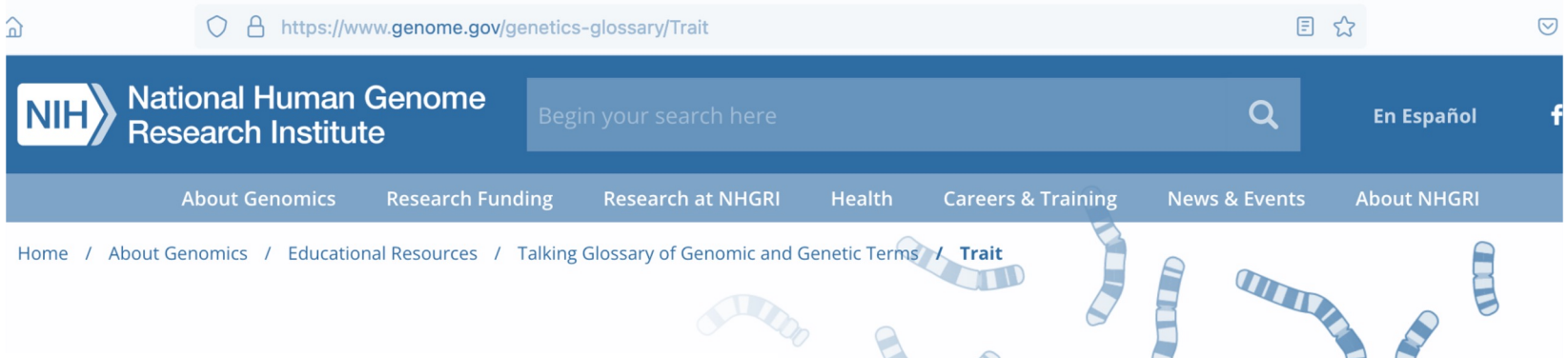


White flowers

Phenotype of flowers (observable property)

The computer program itself

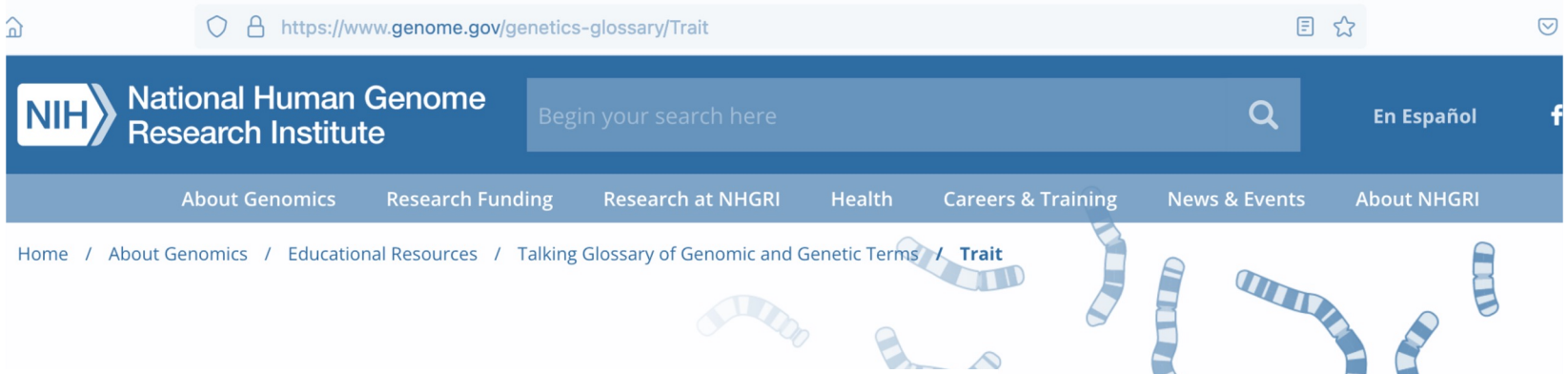
Trait

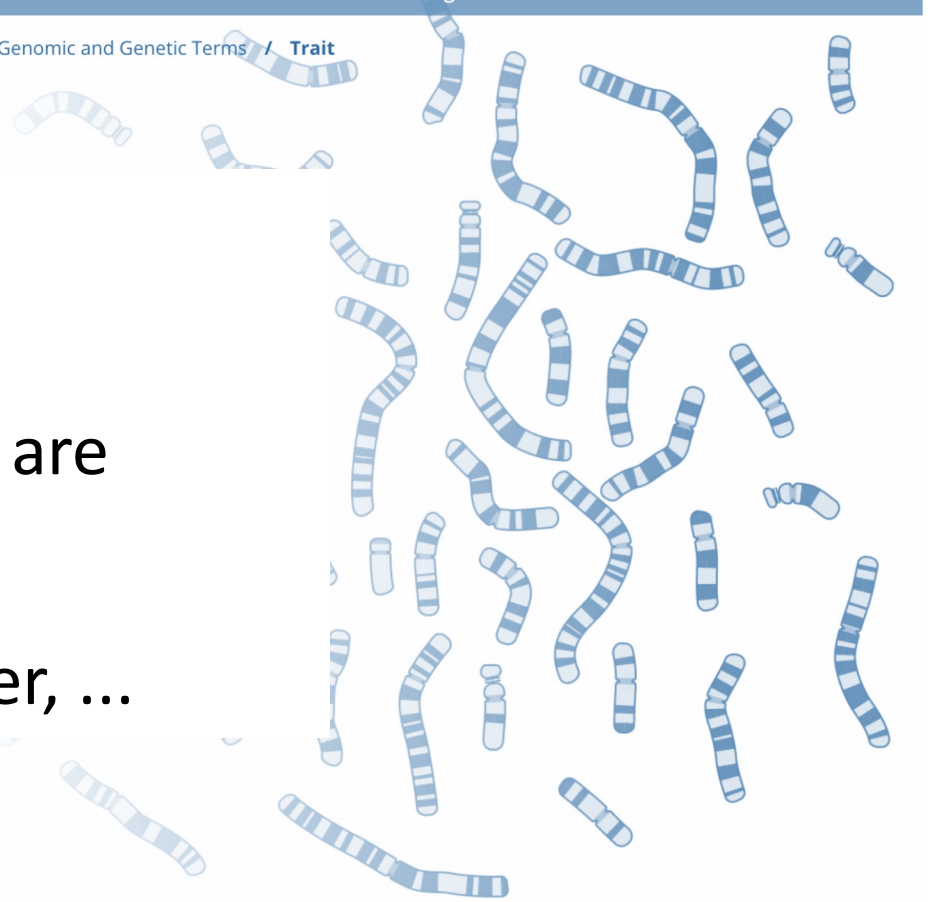


- A trait is a specific characteristic of an individual
- Traits can be qualitative (such as eye colour) or quantitative (such as height or blood pressure)
- A given trait is part of an individual's overall phenotype

https://www.genome.gov/genetics-glossary/Trait

Heritable traits





- Heritable traits were the most obvious visible manifestations before we knew about DNA
- Heritable traits are phenotypic characters that are passed on from parents to offspring
  - Eye color, hair color, propensity to get cancer, ...

https://www.genome.gov/genetics-glossary/Trait

https://www.nationalgeographic.com/science/article/how-inbreeding-killed-off-a-line-

SCIENCE | NOT EXACTLY ROCKET SCIENCE

How inbreeding killed off a line of kings

BY ED YONG

PUBLISHED APRIL 15, 2009 • 7 MIN READ

On November 1st, 1700, an entire dynasty of kings came to a crashing end with the death of Charles II of Spain. Charles had neither a pleasant life nor a successful reign. He was physically disabled, mentally retarded and disfigured. A large tongue made his speech difficult to understand, he was bald by the age of 35, and he died senile and wracked by epileptic seizures. He had two wives but being impotent, he had no children and thus, no heirs. Which is what happens after 16 generations of

https://www.nationalgeographic.com/science/article/how-inbreeding-killed-off-a-line-of-kings

https://www.cdc.gov/genomics/disease/breast_ovarian_cancer/testing.htm

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

Hereditary Breast and Ovarian Cancer

Genetic Testing for Hereditary Breast and Ovarian Cancer

Print

Genetic testing is available for hereditary breast and ovarian cancer. Most breast and ovarian cancer is not caused by inherited mutations, so genetic testing will not help most women with a family health history of breast and ovarian cancer. Genetic testing will not identify the cause for some hereditary breast and ovarian cancers, because the genes affected in these cancers are not yet known.

Genetic counseling before genetic testing for hereditary breast and ovarian cancer is important to determine whether you and your family are likely enough to have a mutation that it is worth getting tested. Usually, genetic testing is recommended if you have:

- A strong family health history of breast and ovarian cancer
- A moderate family health history of breast and ovarian cancer and are of Ashkenazi Jewish or Eastern European ancestry
- A personal history of breast cancer and meet certain criteria (related to age of diagnosis, type of cancer, presence of certain other cancers or cancer in both breasts, ancestry, and family health history)
- A personal history of ovarian, fallopian t

https://www.cdc.gov/genomics/disease/breast_ovarian_cancer/testing.htm

CENTER FOR GENETICS AND SOCIETY

Uzbekistan Is Using Genetic Testing to Find Future Olympians

By **Ron Synovitz and Zamira Eshanova,** *The Atlantic* | 02. 06. 2014

Perspectives

Techno-eugenics: Two Books and a Movie, Reviewed

By Pete Shanks | 02.02.2023

Genetic Selection

Do Genes Shape our Politics?

By Pete Shanks | 06.09.2022

Genomics

AGGREGATED NEWS

http://www.theatlantic.com/international/archive/2014/02/uzbekistan-is-using-ge…

The idea of using genetic testing to spot future world-class athletes has been bandied about for years. Now, Uzbekistan hopes to get a jump on the competition by testing children as young as 10 to determine their athletic potential.

Rustam Muhamedov, director of the genetics laboratory at Uzbekistan's Institute of Bioorganic Chemistry, announced the program for "sports selection at the molecular genetic level" on January 5 in the government-owned *Pravda Vostoka* newspaper.

https://www.geneticsandsociety.org/article/uzbekistan-using-genetic-testing-find-future-olympians

Flow of heritable traits and genetic testing

- Genetic testing is available for hereditary breast and ovarian cancer
  - Looks for mutations in the *BRCA1* and *BRCA2* genes
- Most breast and ovarian cancer is **NOT CAUSED** by inherited mutations
  - So genetic testing **WILL NOT HELP** most women with a family health history of breast and ovarian cancer
  - Genetic testing will not identify the cause for some hereditary breast and ovarian cancers
    - Because the genes affected in these cancers are not yet known

https://www.cdc.gov/genomics/disease/breast_ovarian_cancer/testing.htm

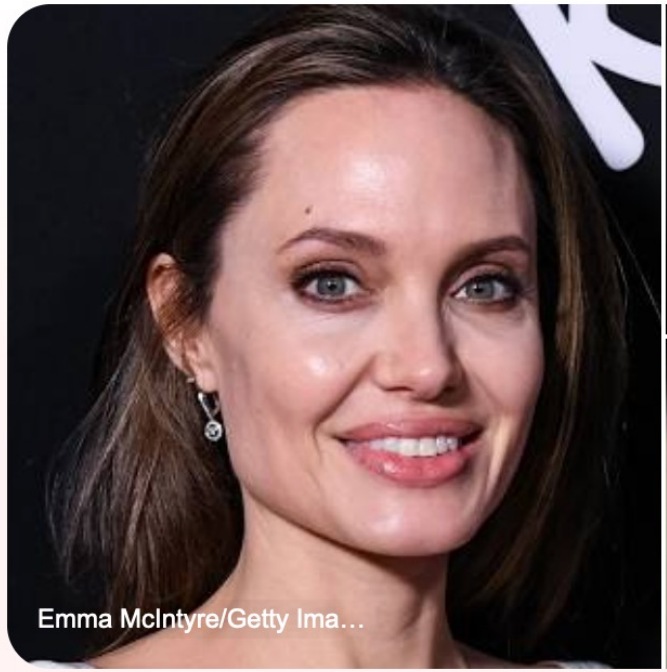
BB1
Mar
Lect

37

Angelina Jolie

Actress

Overview | Movies | Videos | Relationships



Instagram

Angelina Jolie (@angelinajolie) • Instagram photos and videos

14.3m Followers, 9 Following, 69 Posts - See Instagram photos and videos from Angelina Jolie (@angelinajolie)

Age

47 years old (4 June 1975)

Full name

Angelina Jolie Voight

Instagram

Angelina Jolie (@angelinajolie_offiicial) • Instagram photos ...

1.9m Followers

24 Following

1135 Posts

Wikipedia

https://en.wikipedia.org › wiki › Angelina_Jolie

Angelina Jolie - Wikipedia

Angelina Jolie DCMG is an American actress, filmmaker, and humanitarian. The recipient of numerous accolades, including an Academy Award and three Golden ...

Citizenship: : United States; Cambodia;

Other names: Angelina Jolie Pitt

Years active: 1982–present

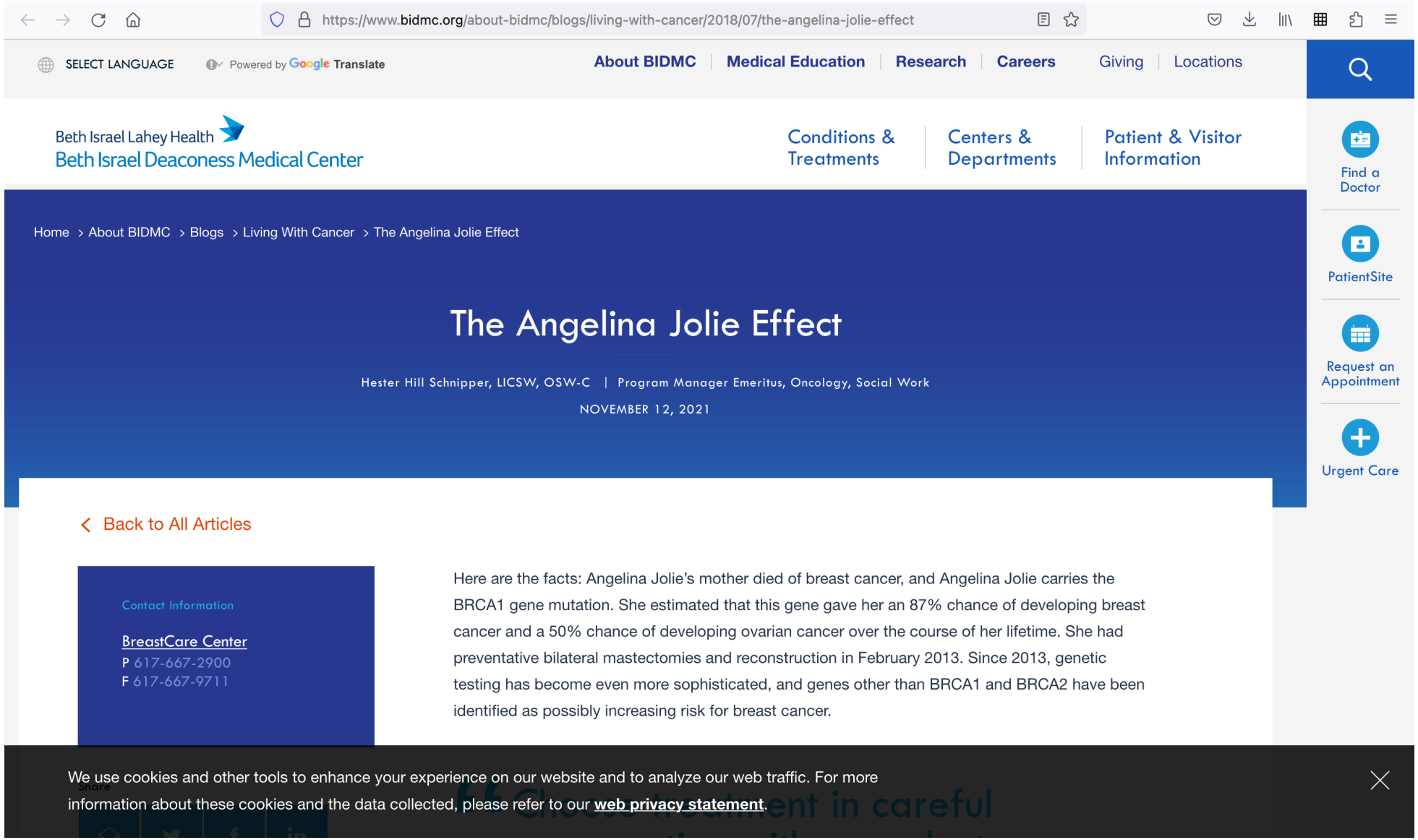
Relatives: James Haven (brother); Barr…

Filmography · Jon Voight · Barry Voight · Lookin' to Get Out

About

Angelina Jolie DCMG is an American actress, filmmaker, and humanitarian. The recipient of numerous accolades, including an Academy Award and three Golden Globe Awards, she has been named Hollywood's highest-paid actress multiple times. Wikipedia

Read, if interested



https://www.bidmc.org/about-bidmc/blogs/living-with-cancer/2018/07/the-angelina-jolie-effect

Read, if interested

https://pubmed.ncbi.nlm.nih.gov/27228984/

An official website of the United States government Here's how you know

National Library of Medicine
National Center for Biotechnology Information

Log in

PubMed®

Search

Advanced User Guide

Save Email Send to Display options

J Genet Couns. 2016 Dec;25(6):1309-1316. doi: 10.1007/s10897-016-9973-6.
Epub 2016 May 26.

The Impact of Angelina Jolie (AJ)'s Story on Genetic Referral and Testing at an Academic Cancer Centre in Canada

Jacques Raphael [1], Sunil Verma [2], Paul Hewitt [3], Andrea Eisen [2 3]

Affiliations + expand

PMID: 27228984 DOI: 10.1007/s10897-016-9973-6

Abstract

In May 2013, Angelina Jolie revealed to the media that she had undergone preventive double mastectomy after testing positive for a BRCA1 gene mutation. Media coverage has been extensive, but it is not clear how such a personal story affected the public and cancer genetics clinics. We conducted a retrospective review using data from the clinical database of the Familial Cancer Program at our centre. The impact of Ms. Jolie's story on genetic counseling referrals and the appropriateness of such referrals were assessed and reported. The number of women referred for

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Abstract

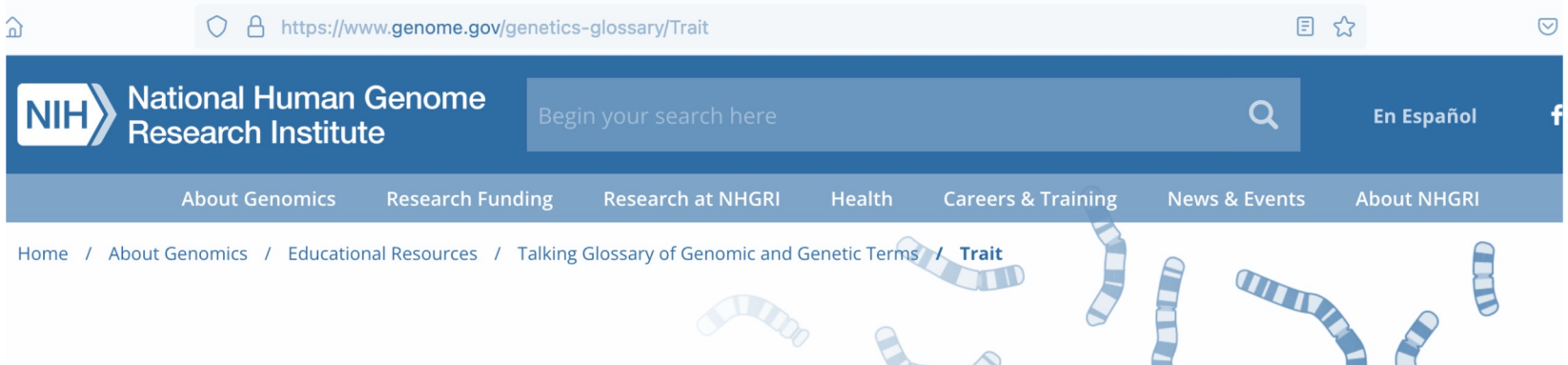
https://pubmed.ncbi.nlm.nih.gov/27228984/

Genetic counselling

- Genetic counselling may be done before genetic testing
  - To determine whether I and my family are likely enough to have a mutation that it is worth getting tested

https://www.cdc.gov/genomics/disease/breast_ovarian_cancer/testing.htm

Heritable traits



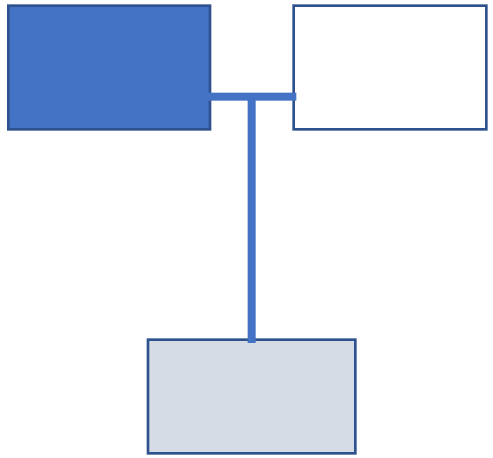
- Traits can be determined by
  - genes,
  - environmental factors,
  - or by a combination of both
- Traits **CAN BE** determined OR traits **ARE** determined?
- Nature and nurture (or nature versus nurture)

https://www.genome.gov/genetics-glossary/Trait

Early hypotheses about heredity

Blending hypothesis - similar to a color palette

Color mixing



Parents

↓

Son/daughter

https://www.collinsdictionary.com/dictionary/english/palette

Particulate hypotheses

- The “particulate” hypothesis is the idea that parents pass on discrete heritable units (genes)
- Gregor Mendel documented a particulate mechanism through his experiments with garden peas

Elucidation of the principle of heredity

- Mendel's choice of experimental system: pea plants
  - He was an avid gardener and mathematician

Figure 14.1 in Biology. A global edition by Campbell and team

Why pea plants?

- Available in many variations
- A short generation time
- Produce large number of offspring in each mating
- Cross pollination is easy
  - Well separated pollen producing and egg bearing organs

Character: a distinct heritable variation

Flower color	Purple 
Seed color	Yellow 
Seed shape	Round 
Pod shape	Inflated 

- Examples of characters
  - Flower color
  - Seed color
  - Seed shape
  - Pod shape

Table 14.1 in Biology. A global edition by Campbell and team

Traits are character variants

Flower color	Purple 	White 
Seed color	Yellow 	Green 
Seed shape	Round 	Wrinkled 
Pod shape	Inflated 	Constricted 

- Purple and white color are traits
  - Variants of flower color
- Yellow and green color are traits
  - Variants of seed color

Table 14.1 in Biology. A global edition by Campbell and team

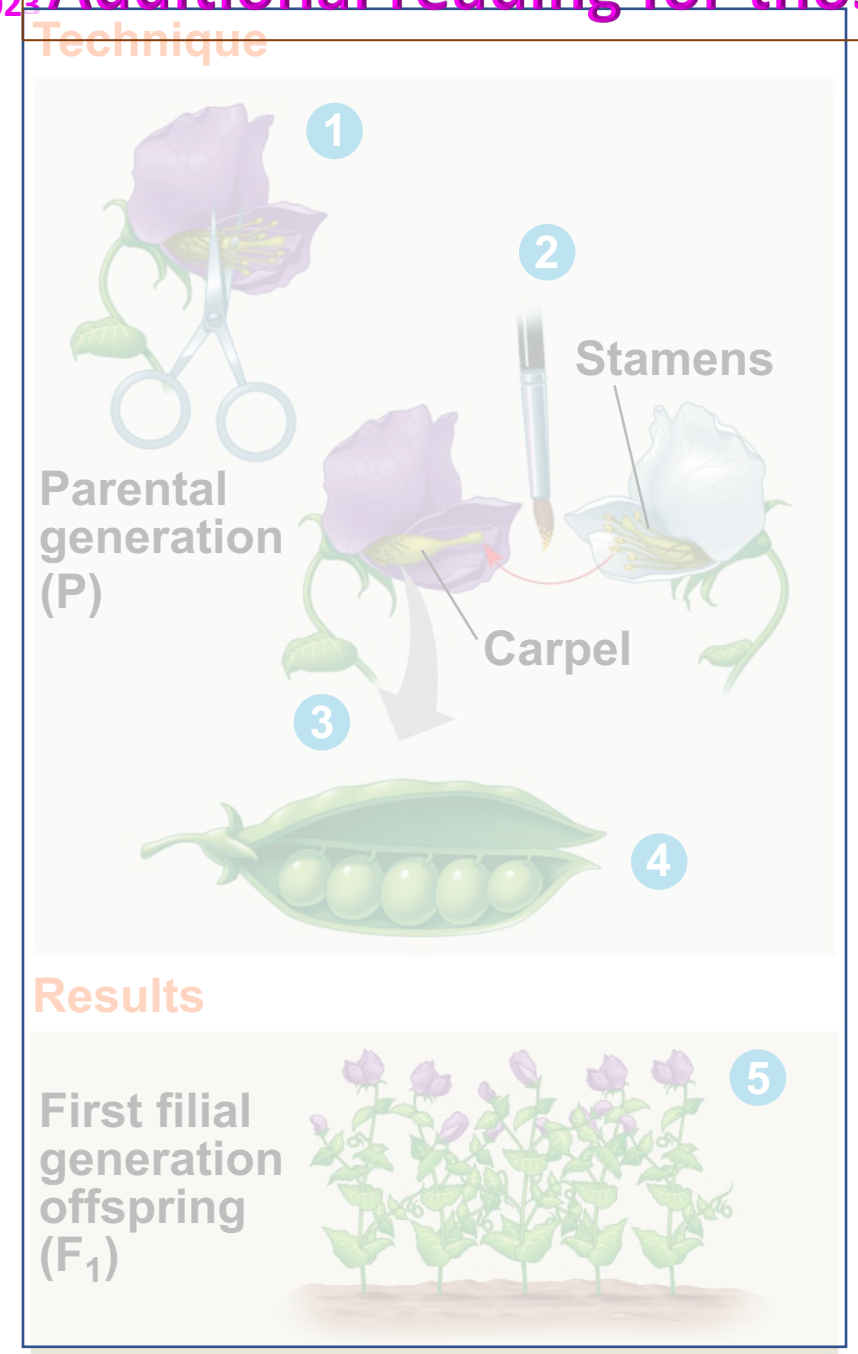
Gregor Mendel's choice of characters: those that show distinct alternate forms

Flower color	Purple	White
Seed color	Yellow	Green
Seed shape	Round	Wrinkled
Pod shape	Inflated	Constricted

Pod color	Green	Yellow
Flower position	Axial	Terminal
Stem length	Tall	Dwarf

Table 14.1 in Biology. A global edition by Campbell and team

Additional reading for those who may be interested



Carpel: ovule and seed producing reproductive organ in flowering plants (like female).

Stamen: pollen-producing reproductive organ of a flower (like male).

Pea flowers have both!

1: Remove the stamens of purple flowers so they cannot pollinate

2 & 3: Pollinate a purple flower carpel with the stamens of a white flower

4: The fertilized purple flower will give rise to seeds which can be planted

5: Observe the offspring for the trait (purple, white or pinkish flowers?)

Figure 14.2 in Biology. A global edition by Campbell and team

True breeding variants

Plant yielding purple flowers

X

Plant yielding purple flowers

Plant yielding purple flowers

True breeding variants

Plant yielding purple flowers

X

Plant yielding purple flowers

Plant yielding purple flowers

Back cross

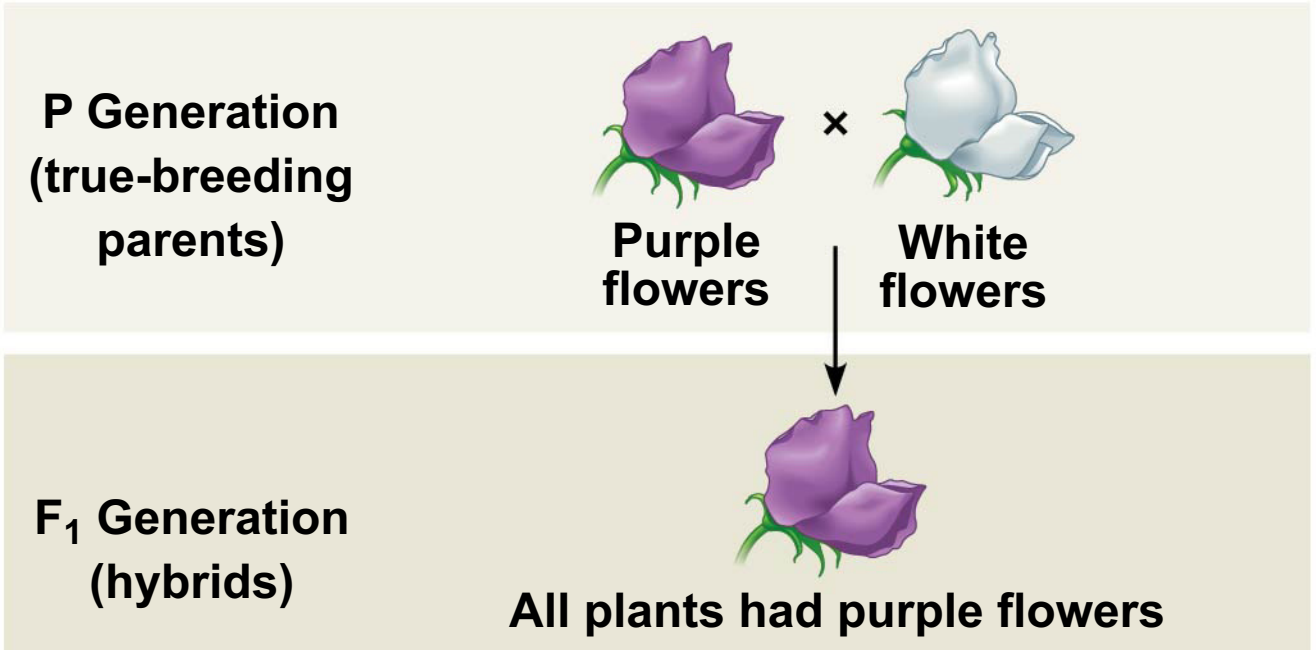
Plant yielding purple flowers

Mendel made sure to choose only true breeding varieties before starting the experiments

Mating (crossing) of two contrasting traits

Figure 14.3 in Biology. A global edition by Campbell and team

Mating (crossing) of two contrasting traits



F1 are all purple!

Where did the white go?

Figure 14.3 in Biology. A global edition by Campbell and team

Mating (crossing) of two contrasting traits

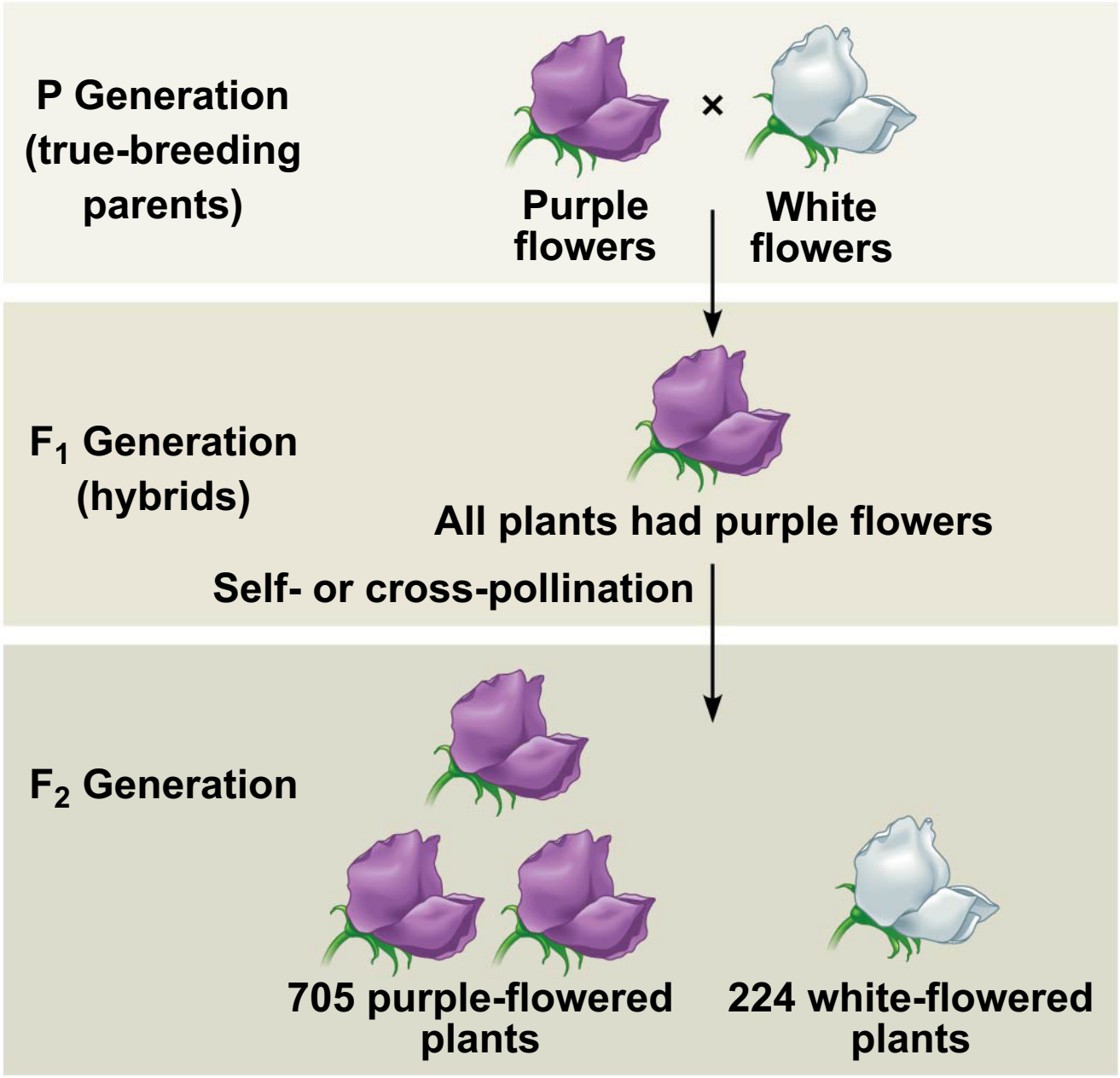


Figure 14.3 in Biology. A global edition by Campbell and team

Mating (crossing) of two contrasting traits

- F2 has white flowers that were missing in F1
- Purple flowers are in larger numbers
  - Dominant trait
- White flowers are fewer
  - Recessive trait

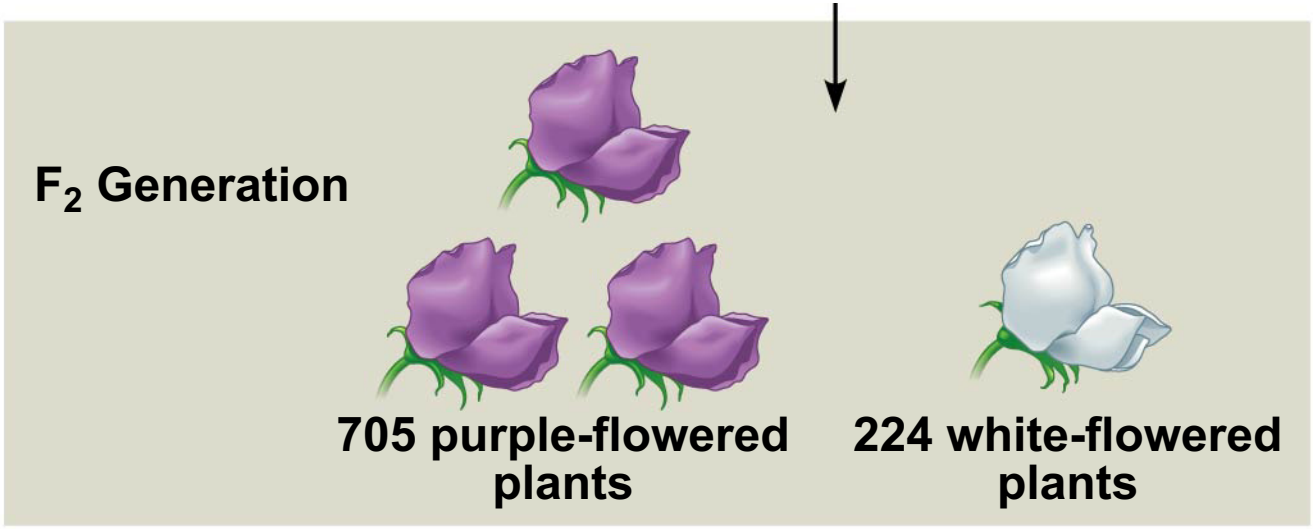


Figure 14.3 in Biology. A global edition by Campbell and team

Results of F1 crosses

Character	Dominant Trait	×	Recessive Trait	F_2 Generation Dominant: Recessive	Ratio
Flower color	Purple 	×	White 	705:224	3.15:1
Seed color	Yellow 	×	Green 	6,022:2,001	3.01:1
Seed shape	Round 	×	Wrinkled 	5,474:1,850	2.96:1

3:1 ratio

Table 14.1 in Biology. A global edition by Campbell and team

Results of F1 crosses

Character	Dominant Trait	×	Recessive Trait	F_2 Generation Dominant: Recessive	Ratio
Pod shape	Inflated 	×	Constricted 	882:299	2.95:1
Pod color	Green 	×	Yellow 	428:152	2.82:1
Flower position	Axial 	×	Terminal 	651:207	3.14:1

3:1 ratio

Table 14.1 in Biology. A global edition by Campbell and team

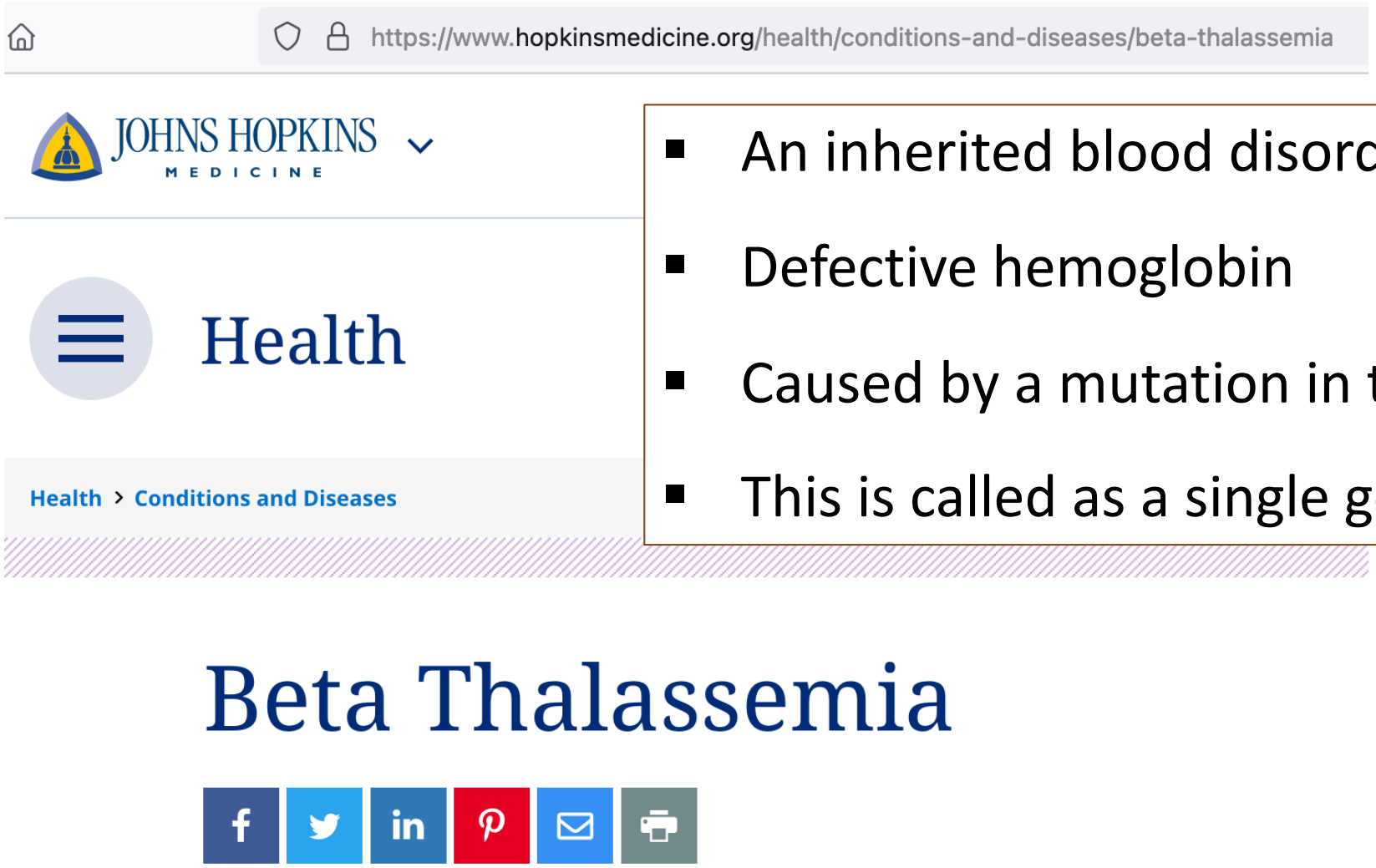
Understanding or explaining Mendel's results

Switch from pea plants to answers to a question in Quiz 1 and β-thalassemia

The concept of alleles

Variants of answer to a question in quiz

- Suppose we have a quiz
- Let us consider Question 1
- We look at the answers of all of you to Question 1
- We find that there are three variants
  - Answers are essentially the same
  - But there are three variants



- An inherited blood disorder
- Defective hemoglobin
- Caused by a mutation in the β-subunit gene
- This is called as a single gene trait

https://www.hopkinsmedicine.org/health/conditions-and-diseases/beta-thalassemia

Alleles – variants of a gene

- Suppose we sequence the β-subunit (of hemoglobin) gene from all of us
- Let us say that we find 3 variants
- These three variants are called alleles

We, the humans, are diploids

https://www.genome.gov/genetics-glossary/Karyotype

NIH National Human Genome Research Institute

Begin your search here

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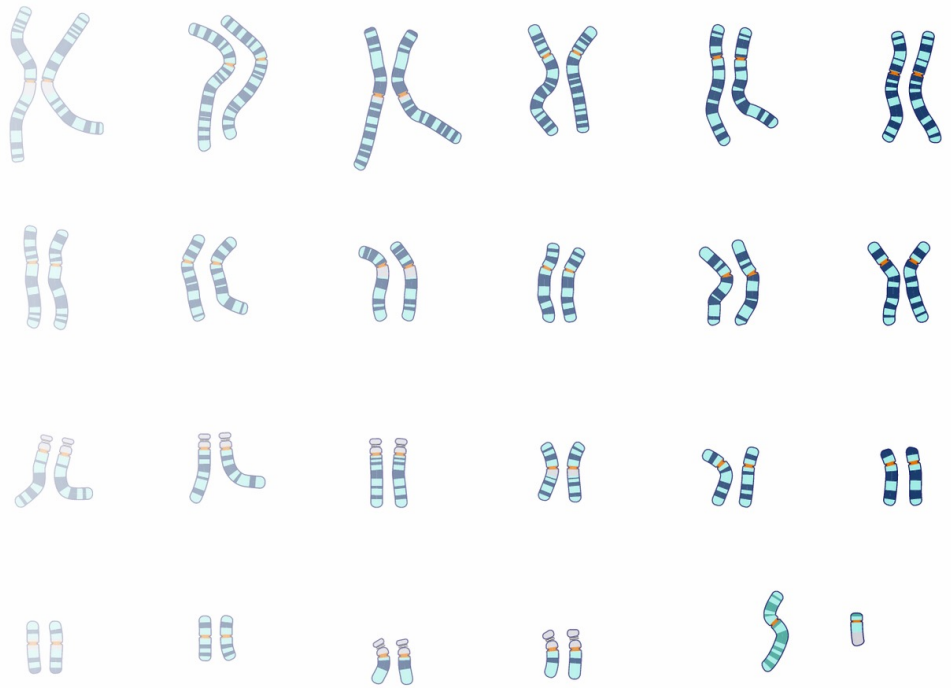
Home / About Genomics / Educational Resources / Talking Glossary of Genomic and Genetic Terms / **Karyotype**

We have two copies of all chromosomes (except sex chromosomes viz., X and Y)

KARYOTYPE

updated: March 15, 2023

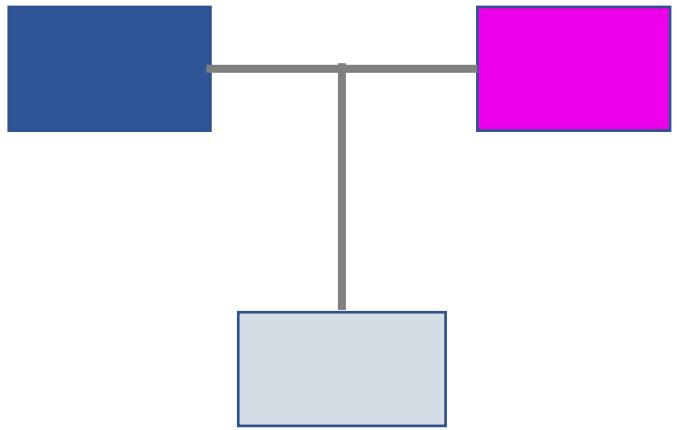


https://www.genome.gov/genetics-glossary/Karyotype

β-thalassemia gene

β-gene from father's sperm

β-gene from mother's egg

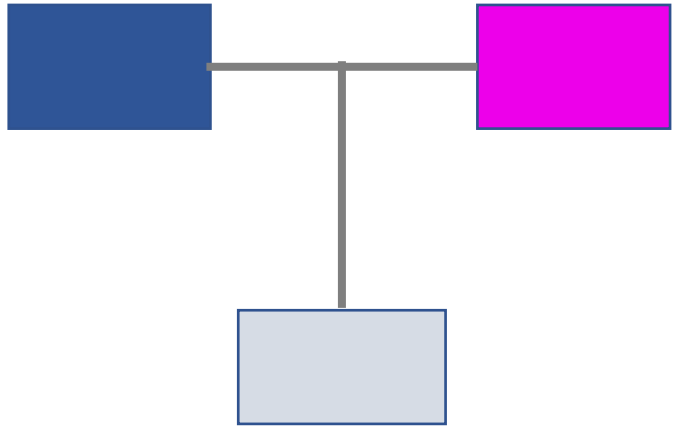


Two copies of β-genes

β-thalassemia gene

β-gene from father's sperm

β-gene from mother's egg



"normal" allele
i.e., does not cause disease

"normal" allele
i.e., does not cause disease

Two copies of β-genes

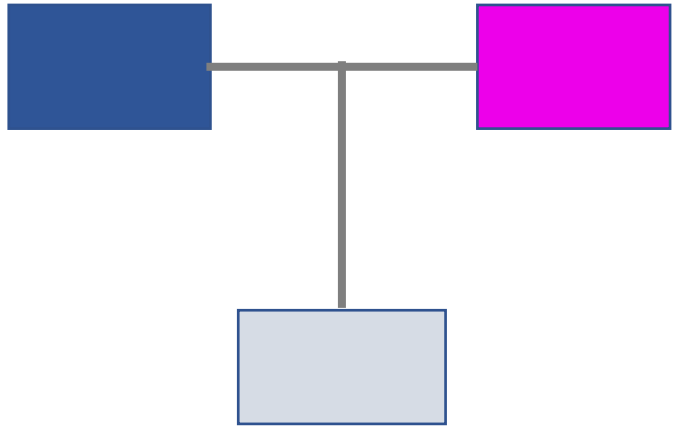
homozygous

Both copies are "normal"
Phenotype: normal, not diseased

β-thalassemia gene

β-gene from father's sperm

β-gene from mother's egg



"disease" allele
i.e., causes disease

"normal" allele
i.e., does not cause disease

Two copies of β-genes

heterozygous

One copy "normal", other copy disease-causing

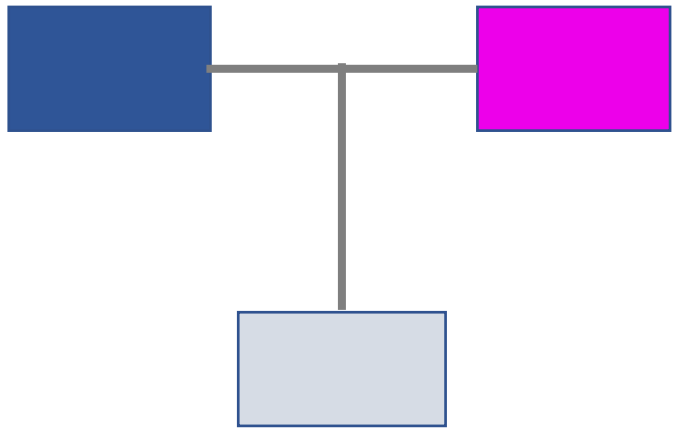
Phenotype: Diseased (mild symptoms)

β-thalassemia gene

β-gene from father's sperm

β-gene from mother's egg

"normal" allele
i.e., does not cause disease



"disease" allele
i.e., causes disease

Two copies of β-genes

heterozygous

One copy "normal", other copy disease-causing

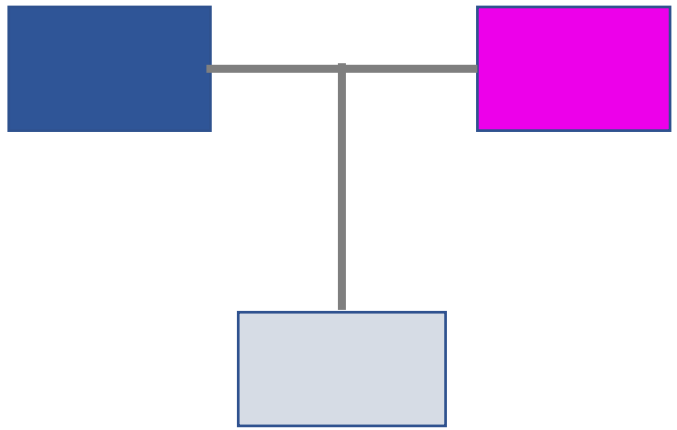
Phenotype: Diseased (mild symptoms)

β-thalassemia gene

β-gene from father's sperm

β-gene from mother's egg

"disease" allele
i.e., causes disease



"disease" allele
i.e., causes disease

Two copies
of β-genes

homozygous

Both copies are disease-causing

Phenotype: Diseased (severe symptoms)

Switch back to pea plants

All the characters Mendel chose were single gene traits

Phenotype and genotype

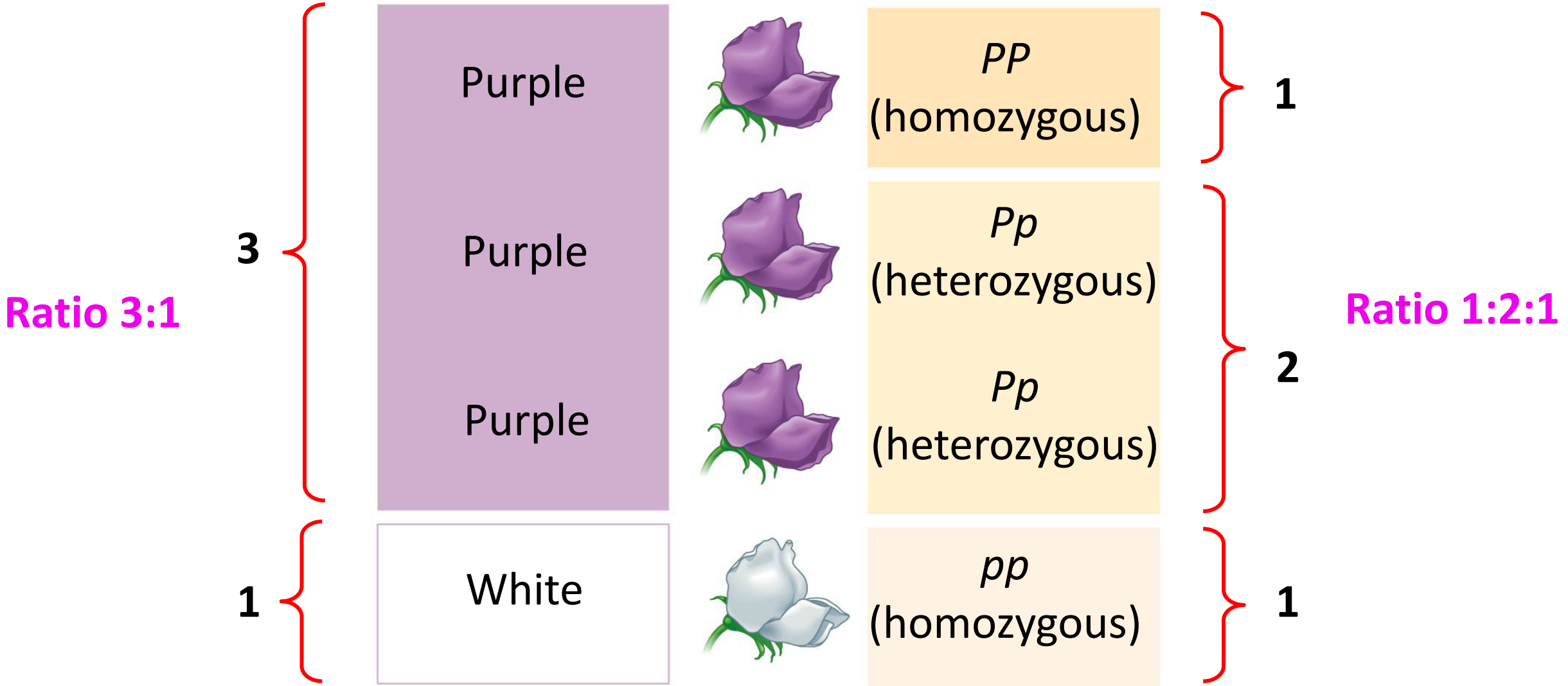


Figure 14.6 in Biology. A global edition by Campbell and team

Phenotype and genotype

- An organism's traits do not always reveal its genetic composition
  - Because dominant and recessive alleles have different effects
- Therefore: distinguish physical appearance from genetic makeup
  - Physical appearance: phenotype
  - Genetic makeup: genotype
- Example of flower color in pea plants

Why did Mendel get 3:1 ratio?

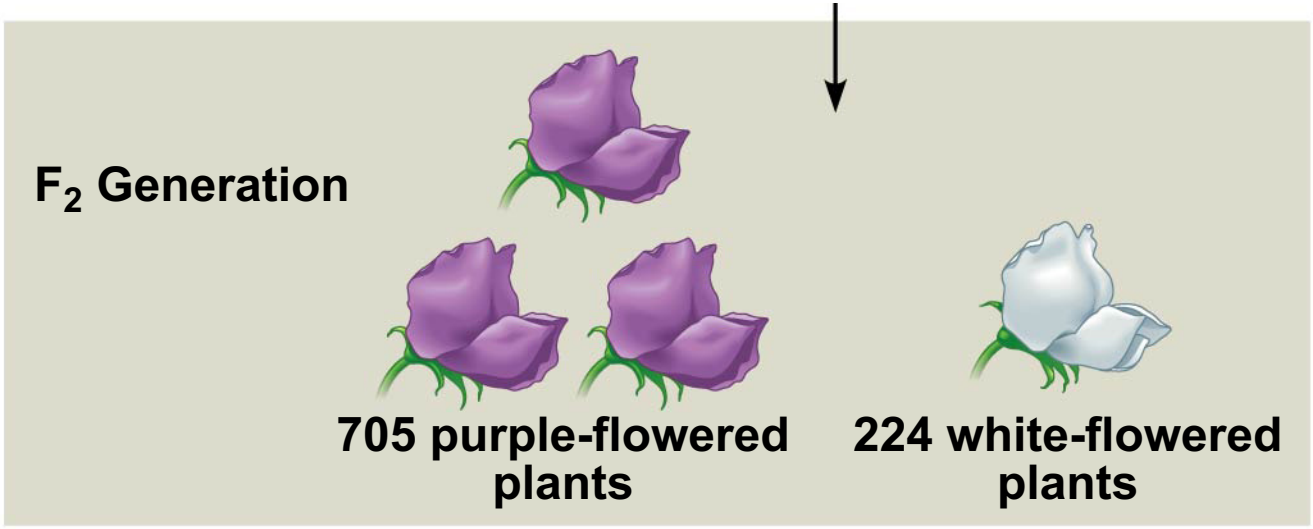
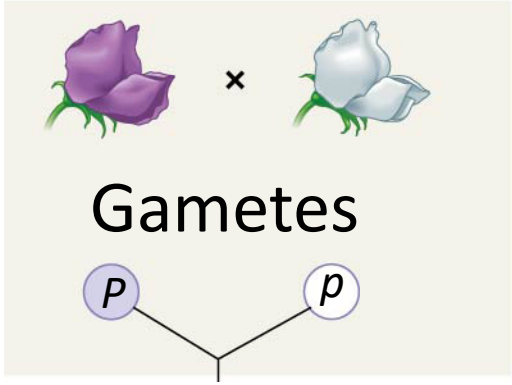


Figure 14.3 in Biology. A global edition by Campbell and team

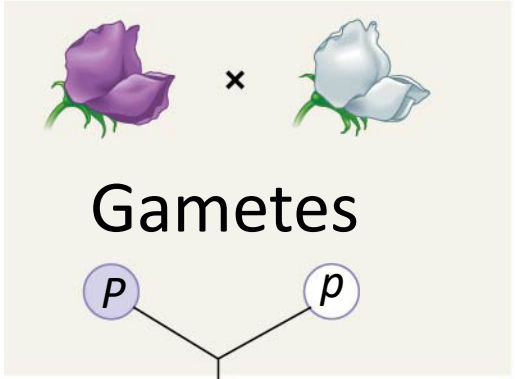
P generation
(true breeding)



		Genetic makeup
Appearance	Purple	*PP*
	White	*pp*

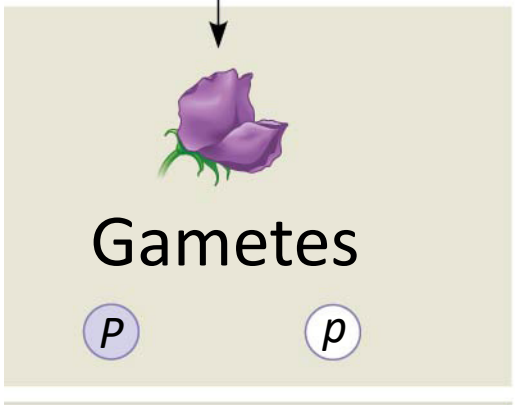
Figure 14.5 in Biology. A global edition by Campbell and team

P generation
(true breeding)



		Genetic makeup
Appearance	Purple	*PP*
	White	*pp*

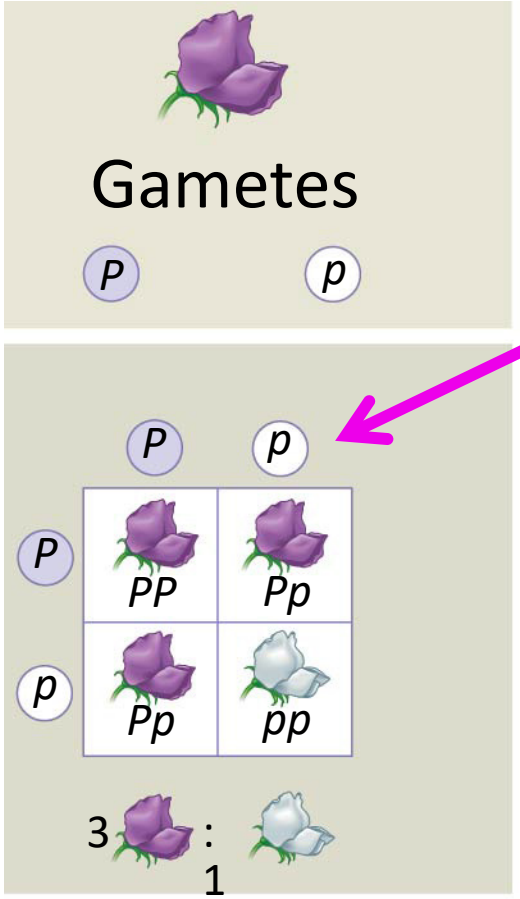
F1 generation



		Genetic makeup
Appearance	Purple	*Pp*

Figure 14.5 in Biology. A global edition by Campbell and team

F1 generation



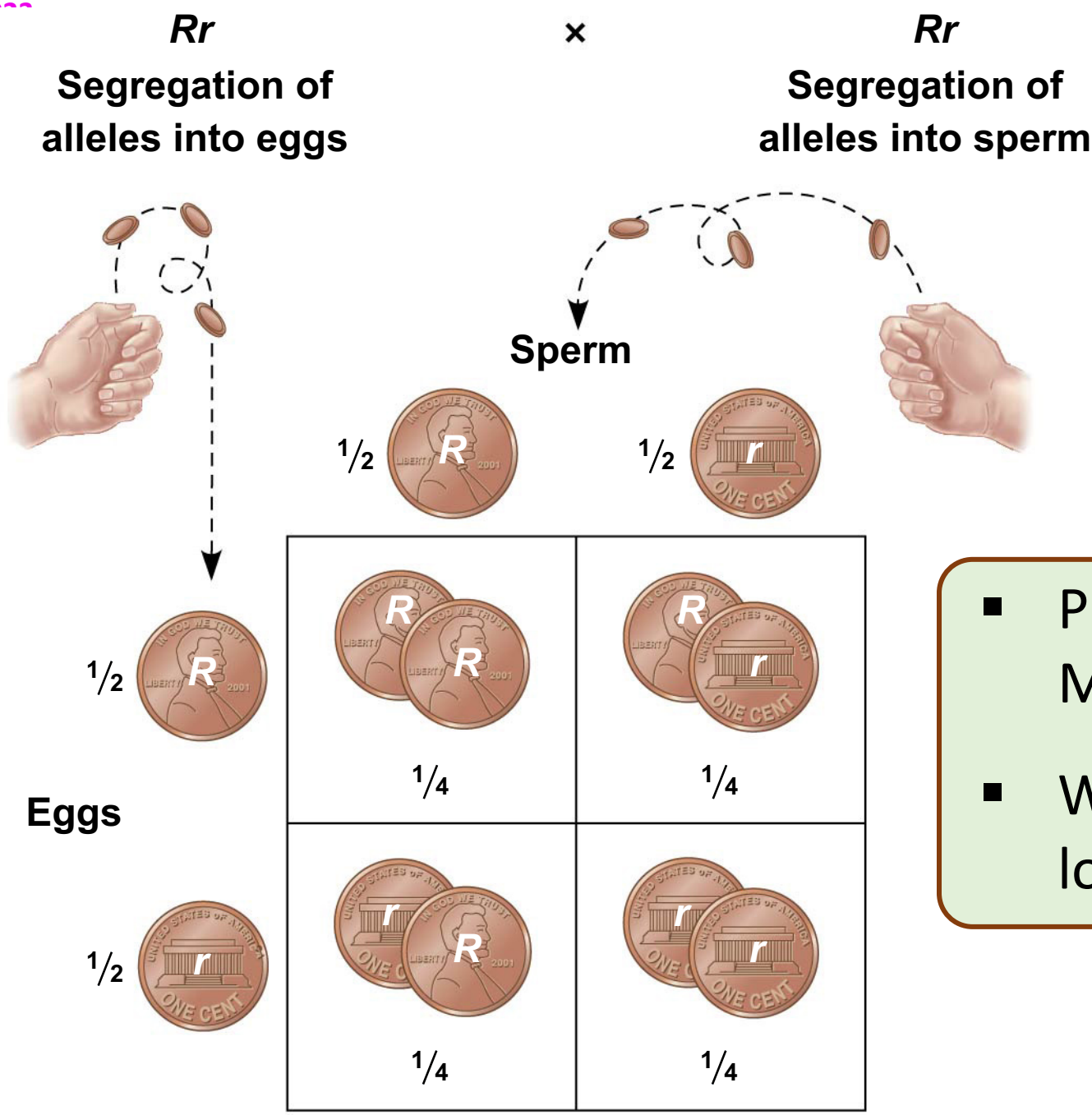
		Genetic makeup
Appearance	Purple	*PP*
	White	*pp*

Figure 14.5 in Biology. A global edition by Campbell and team

Mendel's Particulate hypothesis: Inferences from his experiments

- Inheritance of a trait is determined by "units" or "factors"
  - These are passed on to descendants unchanged
- An individual inherits one such unit from each parent and for each trait
- A trait may not show up in an individual

  but can still be passed on to the next generation



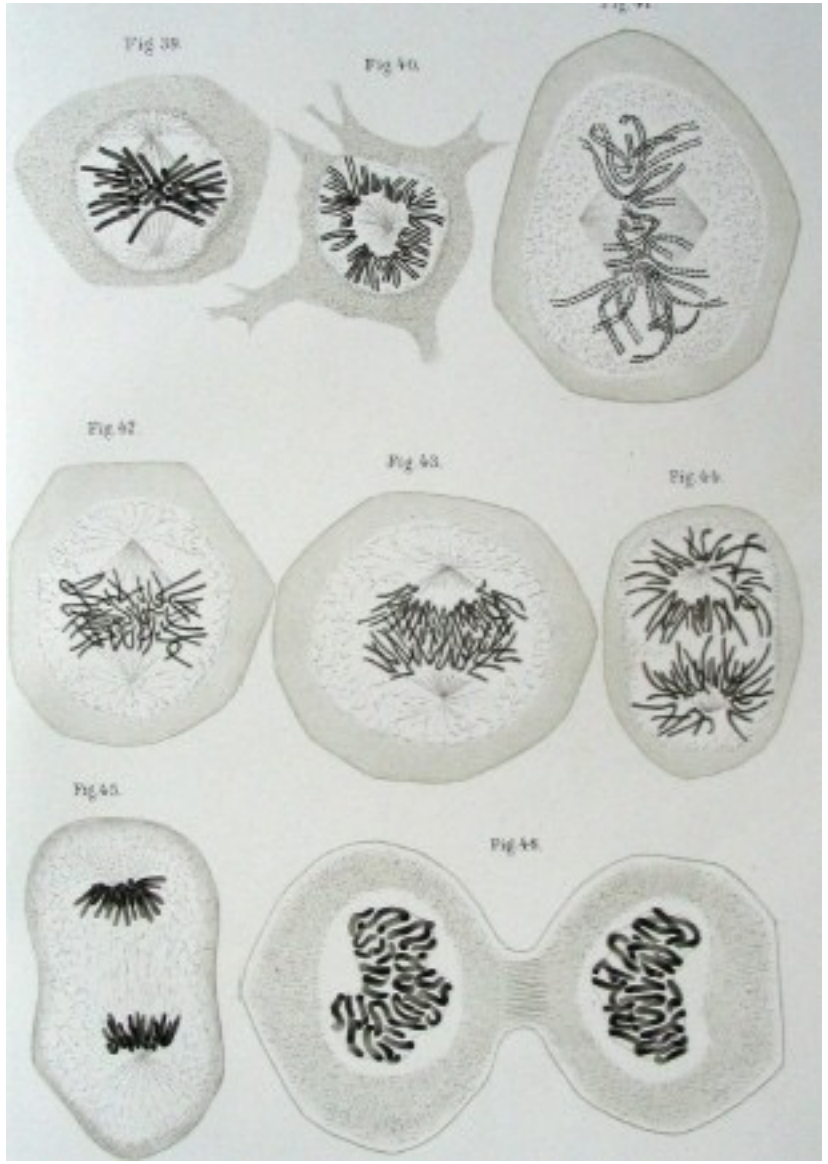
- Probability governs Mendelian inheritance
- We all are results of genetic lottery

Figure 14.9 in Biology. A global edition by Campbell and team

Discovery of chromosomes

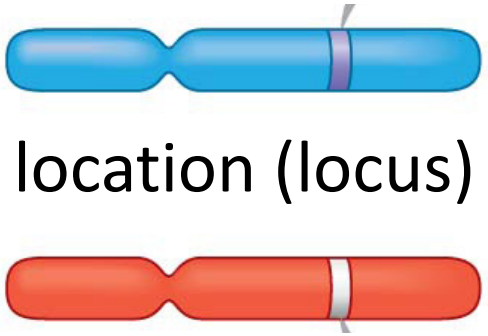
Walther Flemming

Used a staining technique to visualize chromatin (DNA + proteins that together constitute chromosomes)



https://en.wikipedia.org/wiki/Walther_Flemming

Explaining Mendel's results upon discovery of DNA



Gene location (locus)

Homologous chromosomes

Figure 14.4 in Biology. A global edition by Campbell and team

Explaining Mendel's results upon discovery of DNA

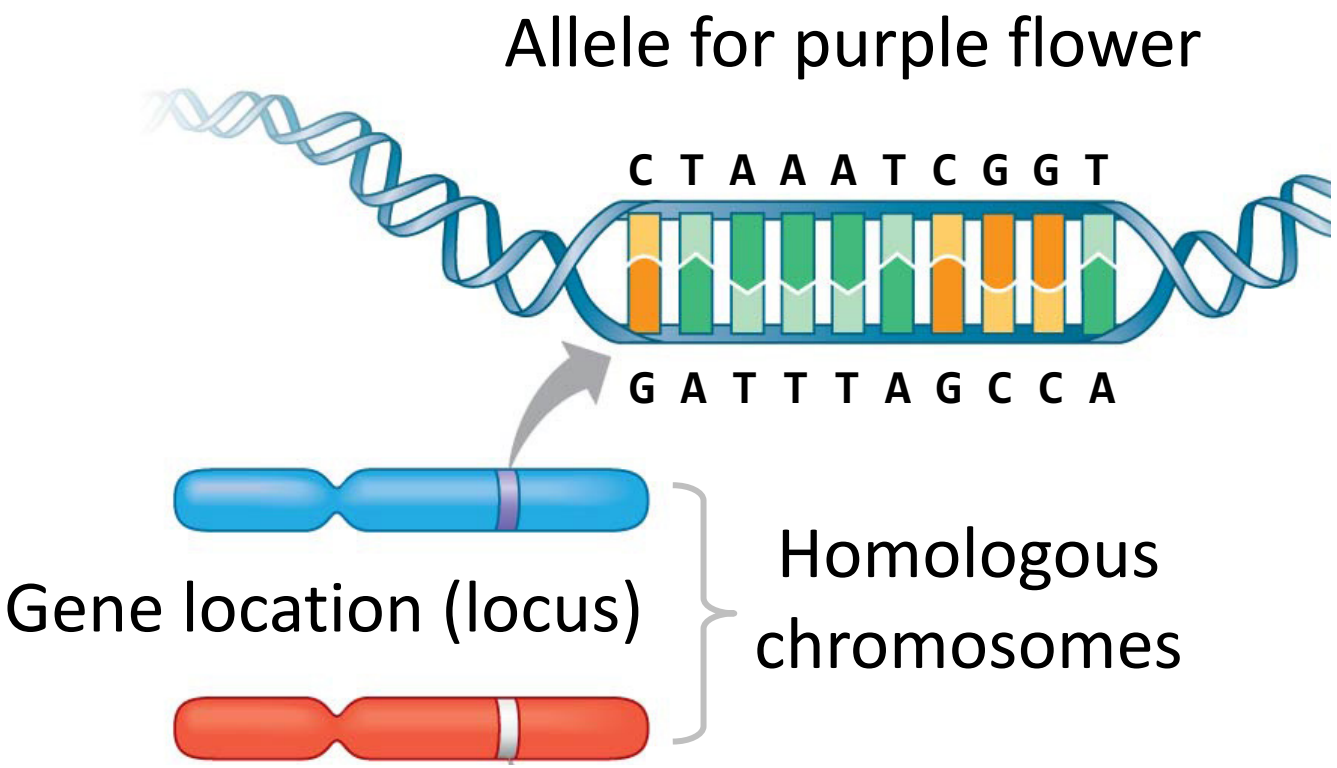


Figure 14.4 in Biology. A global edition by Campbell and team

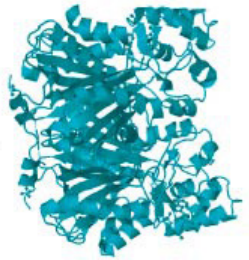
Explaining Mendel's results upon discovery of DNA

Allele for purple flower

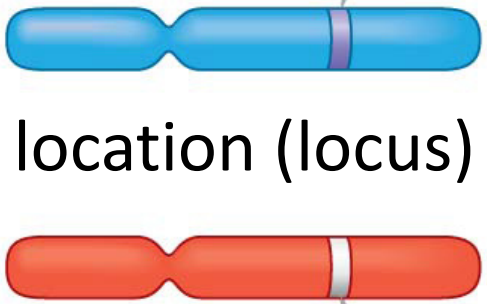
C T A A A T C G G T

G A T T T A G C C A

Active enzyme



Enzyme for the synthesis of purple pigment



Gene location (locus)

Homologous chromosomes

Figure 14.4 in Biology. A global edition by Campbell and team

Explaining Mendel's results upon discovery of DNA

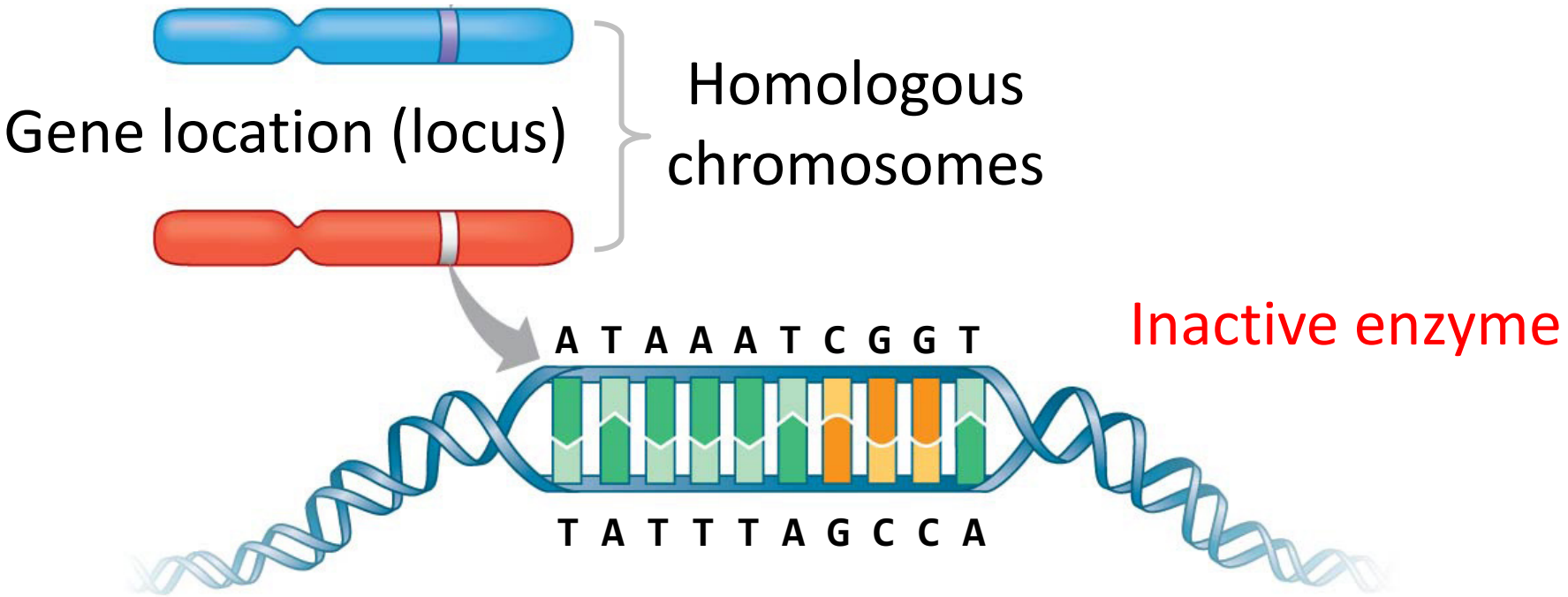


Figure 14.4 in Biology. A global edition by Campbell and team

Explaining Mendel's results upon discovery of DNA

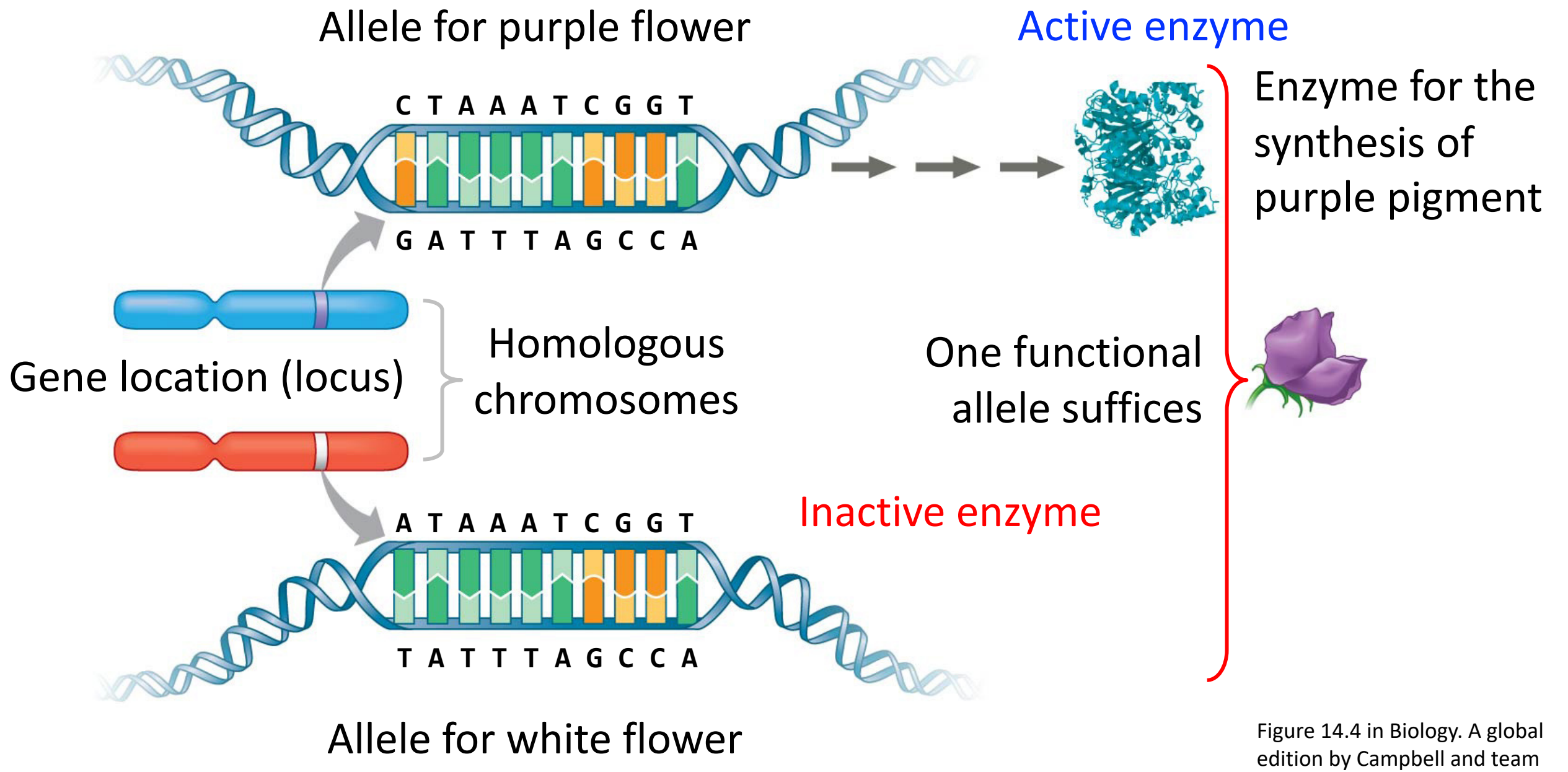


Figure 14.4 in Biology. A global edition by Campbell and team

Human traits that follow Mendelian genetics

https://www.ncbi.nlm.nih.gov/omim 150%

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OMIM

OMIM is a comprehensive, authoritative compendium of human genes and genetic phenotypes that is freely available and updated daily. OMIM is authored and edited at the McKusick-Nathans Institute of Genetic Medicine, Johns Hopkins University School of Medicine, under the direction of Dr. Ada Hamosh. Its official home is omim.org.

https://www.ncbi.nlm.nih.gov/omim

Phenotypes that do not follow Mendelian genetics

- More than two allelic forms exist for most genes in a population
- Example: allelic forms of a gene that determines our blood group

(a) The three alleles for the ABO blood groups and their carbohydrates			
Allele	I^A	I^B	i
Carbohydrate	A △	B ○	none

Figure 14.11 in Biology. A global edition by Campbell and team

Blood group phenotype and genotype

(b) Blood group genotypes and phenotypes				
Genotype	I^AI^A or I^Ai	I^BI^B or I^Bi	I^AI^B	ii
Red blood cell appearance				
Phenotype (blood group)	A	B	AB	O

Figure 14.11 in Biology. A global edition by Campbell and team

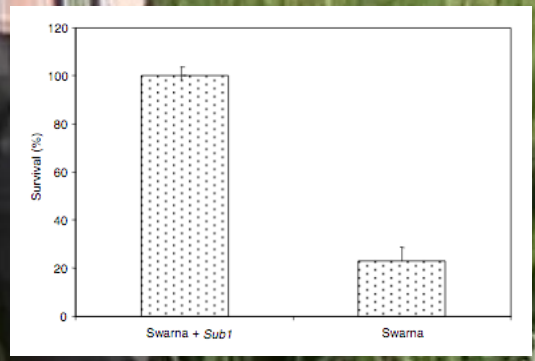
Today's topics

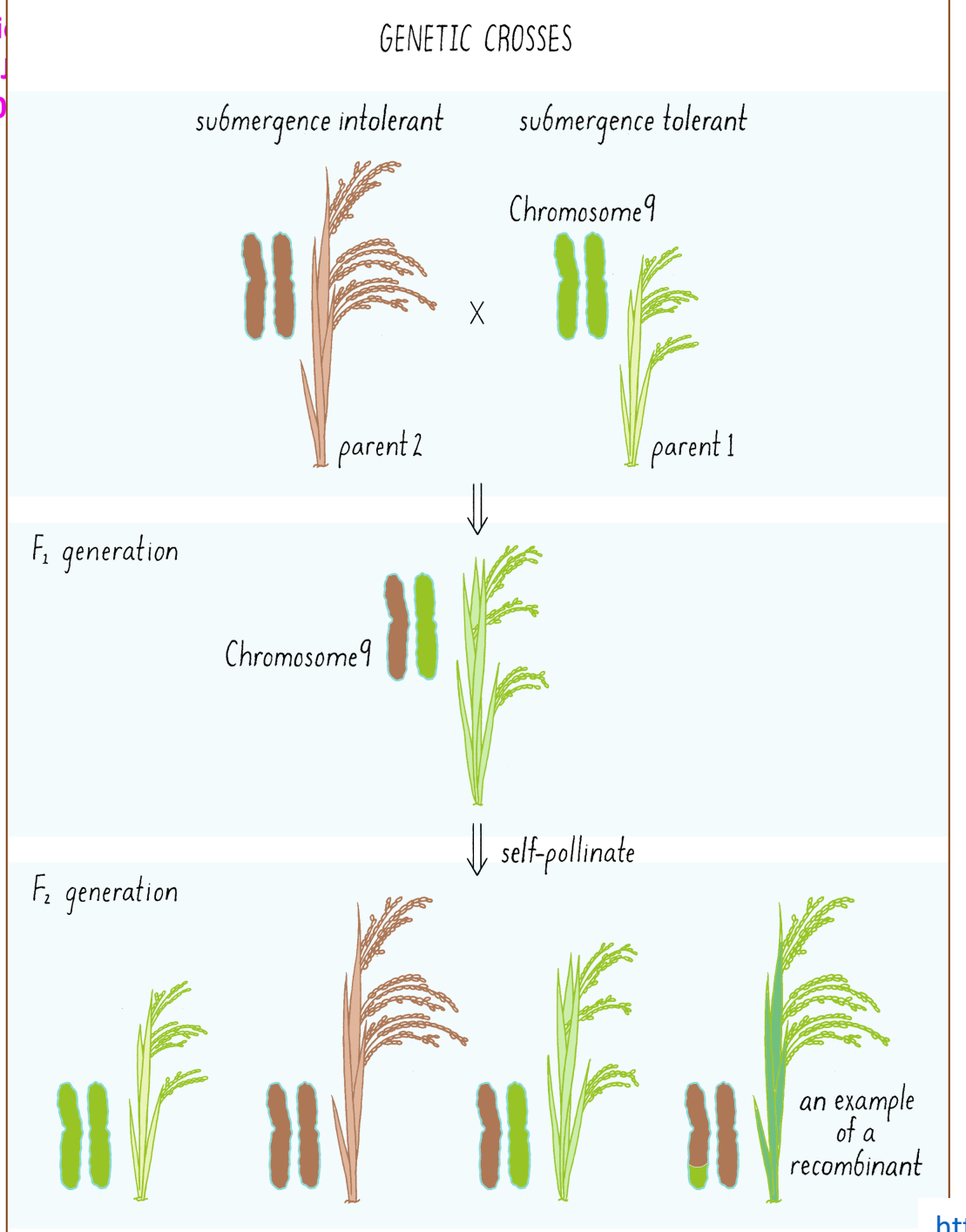
- Engineering Biology
  - iGEM and the idea behind iGEM
- Reverse Engineering Biology
- Heredity
  - Brief digression: β-thalassemia
- Applications in day-to-day life

Flood-affected (10-day submergence) Rice fields of Arun Kumar Singh at village Khuruhuja, District Chandoli, UP, India

Swarna

Swarna + SUB1





- Genetic crossing – rice
  - Tolerant to being submerged
  - Intolerant to submergence
  - "Scuba" – hybrid variety
- Scuba rice has been adopted by farmers in Bangladesh and India
  - Huge impact on livelihood

https://explorebiology.org/collections/genetics/plant-genetics-and-the-future-of-food

Genetics of high-rise rice

Ethylene and flooding-tolerance strategies in rice