

JURONG WEST SECONDARY SCHOOL
SECONDARY FOUR – Science BIOLOGY (5088)

Chapter 16: HEREDITY

LEARNING OUTCOMES:

Candidates should be able to:

- distinguish between the terms **gene** and **allele**
- distinguish between **continuous** and **discontinuous variation** and give examples of each
- explain the terms **dominant**, **recessive**, **homozygous**, **heterozygous**, **phenotype** and **genotype**
- predict the results of **simple crosses** with expected ratios of 3:1 and 1:1, using the terms homozygous, heterozygous, F1 generation and F2 generation
- explain why **observed ratios** often differ from **expected ratios**, especially when there are small numbers of progeny
- use **genetic diagrams** to solve problems involving monohybrid inheritance
- describe the **determination of sex** in humans – XX and XY chromosomes
- describe **mutation** as a change in the structure of a gene such as in **sickle cell anaemia**, or in the chromosome number, such as the 47 chromosomes in a condition known as **Down Syndrome**
- name ionising **radiation** (e.g. X-ray) and **chemical mutagens** as factors which may increase the rate of mutation

Introduction

What is heredity?

- The term **heredity** refers to the **passing down of genes or genetic information from the parents to their offspring.**

- The offspring will either display the **physical traits** from either of their parents or a mixture of both.
- Examples:

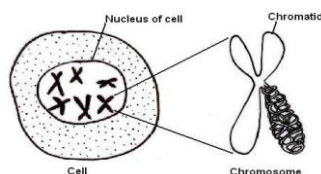


1. What other examples of physical traits did you inherit from your parents?

2. Did you inherit all your physical traits from either of your parents or a **mixture of both?**

How do genes get passed down?

- Recall that the **nucleus** of a cell contains genetic information.
- These genetic information are in the form of **chromosomes.**

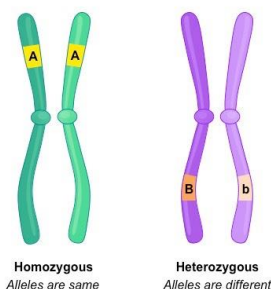


a) distinguish clearly between the terms gene and allele

b) explain the terms dominant, recessive, homozygous, heterozygous, phenotype and genotype

GENETIC TERMS (Glossary)

- Genetics is the scientific study of heredity.
 - Chromosome** is made up of the molecule DNA (deoxyribonucleic acid) which are visible during cell division.
 - A **gene** is a **unit of inheritance** born on a particular locus of a chromosome. It is a **sequence of DNA nucleotides** that controls the formation of a **single polypeptide**.
 - Alleles** (for example, T or t) are **different forms of the same gene**. They occupy the **same** relative **positions** on a pair of homologous chromosomes.
 - Homologous chromosomes** are chromosomes that are **similar in size and shape** (except for sex chromosomes). In a single pair of homologous chromosomes, one comes from the male parent and one comes from the female parent.
 - Phenotype** refers to the **expressed trait** of an organism. E.g. blood group, double eyelids.
 - Genotype** is the **genetic make-up** of an organism, i.e. of genes in an organism. It is normally expressed by **two letters** (e.g. **TT, Tt or tt**).
- For a single trait,
- AA** – **homozygous dominant** (because both are dominant alleles)
 - aa** – **homozygous recessive** (because both are recessive alleles)
 - Aa** – **heterozygous**
- Homozygous** means the organism carries **two copies** of the same allele. I.e. **homozygous dominant** means **TT** but **homozygous recessive** means **tt**.
 - Heterozygous** means the organism carries **one copy of two different alleles** e.g. **Tt**
 - Dominant allele** (T) is **expressed** which results in the same phenotype in both homozygous and heterozygous organisms. **Tt or TT**
 - Recessive allele** (t) is **not** expressed in the heterozygous condition, which expressing itself only in the homozygous condition, **tt**.



Please use letters where the capital and small letters look different! e.g. Aa, Bb, Tt.
DO NOT USE X and Y because they are reserved for sex chromosomes only!

THINK & EXPLORE

What is the difference between *gene* and *allele* **(JUST DEFINE!)**? Do both terms mean the same thing?

Gene is a small segment of DNA but allele is an alternative form of the same gene.

A gene codes for a specific characteristic such as eye colour but alleles codes for different traits such as brown eye colour or black eye colour.

Offspring inherit genes from their parents but the traits they display are dependent on the alleles.

AfL in Class

[Individual work]:

Use your knowledge about the new genetic terms and test yourself without reference.

Use the information provided and your knowledge of genetics to answer each question.

- For each genotype below, indicate whether it is **heterozygous** OR **homozygous**.
- Circle the genotype that is considered as **purebred**.

<u>TT</u> Homozygous dominant	Bb heterozygous	<u>DD</u> Homozygous dominant	Ff hetero	<u>BB</u> Homozygous dominant
Dd heterozygous	<u>ff</u> Homozygous recessive	Tt heterozygous	<u>bb</u> Homozygous recessive	<u>FF</u> Homozygous dominant

- Determine the **phenotype** for each genotype. Let B be allele for brown. Let b be allele for black.

* Brown body color is dominant to black.

BB brown

Bb brown

bb Black

* Round shape is dominant to square.

RR Round

Rr Round

rr square

(d) Predict the results of **simple crosses** with expected ratios of 3:1 and 1:1, using the terms **homozygous**, **heterozygous**, **F1 generation** and **F2 generation**

(e) Explain why **observed** ratios often **differ** from **expected** ratios, especially when there are **small** numbers of progeny

(f) use genetic diagrams to solve problems involving monohybrid inheritance

GENETIC CROSS

Genetic crosses are performed to show how two different individuals bring about offspring that carry part of genetic material of each parent. It shows the **probability** of the offspring attaining certain traits.

There are two methods of genetic cross:

1. Genetic diagram

2. Punnett Square

1. GENETIC DIAGRAM

Mendel's pea plants (read textbook for the full story)

- Mendel crossed tall **homozygous dominant** and dwarf **homozygous recessive** pea plants
- The F1 generation are all **heterozygous**.



Commented [PLX1]: <https://www.youtube.com/watch?v=Mehz7tCxISE>

Worked example:

Parental Phenotype	Tall	x	short
Parental Genotype	TT	x	tt
Gametes	 		 
F ₁ Genotype	Tt	Tt	Tt
F ₁ Phenotype	Tall	Tall	Tall
Phenotypic ratio	All Tall		

Remember
to circle
gametes!

Think!

- Does the term, **heterozygous dominant/recessive**, exist?



Nope! Heterozygous already means the organism carries **one copy of each of the two different alleles** e.g. Tt

- If all the offspring are TALL, should we write the ratio as **4 tall: 0 short**?

nope! Please write it as **all tall**.

2. PUNNETT SQUARE

Using the same question as shown previously, here is how a Punnett square is drawn:

Gametes	T	t
T	Tt (tall)	Tt (tall)
t	Tt (tall)	tt (short)

F1 phenotypic ratio: All tall

AfL in Class

Let's Try!

[Individual work / Pair work]:

Use your knowledge about the new concept and test yourself without reference.

Q1. In humans, dark eye colour is dominant (B) while blue eye colour is recessive (b). Use a genetic diagram to show the cross between a blue-eyed mother and a homozygous dark-eyed father.

parental phenotype dark x blue
 parental genotype BB x bb
 gametes (B) (B) (b) (b) ∴ F₁
 F₁ genotype Bb Bb Bb Bb
 F₁ phenotype dark dark dark dark

Q2. A mouse homozygous for white fur (white is recessive) is mated with a mouse homozygous for grey fur. Draw a genetic diagram. What are the different types of fur that we expect to see?

Grey = _____ White = _____

Number of grey mice _____, number of white mice _____.

If there are 24 offspring how many grey mice do we expect to see? _____

How many white? _____

aa

AA

Q3. In the botanical gardens, pink tiger lilies are dominant to white tiger lilies. The pure-bred pink tiger lilies are then crossed with the white tiger lilies.

- Show the genotypes of the parents. Perform a genetic cross using Punnett Square and show all the genotypes and phenotypes of F_1 generation.
- Two individuals from the F_1 generation are crossed.
Use a Punnett Square to show clearly the phenotypic ratio of the F_2 generation.

Q4. A daisy is heterozygous for gold flowers and it is bred with a daisy for homozygous for yellow flowers. (yellow is recessive) What are the different types of flower color will the offspring have?
Gold = A Yellow = a

Number of gold flowers 1, number of yellow flowers 1.
If we have 20 offspring how many gold flowering plants do we expect to see? 10 How many yellow? 10

 We expected to see a 1:1 ratio here, but found that in reality, we got 0.96:1 ratio.
State why the observed ratio was different from expected ratio.
The sample size is too small

TEST CROSS (Textbook pg 274-278)

The **genotype of an organism can be determined** by crossing it with an organism that is **homozygous recessive**.

This method is used when the genotype of the starting organism is **unknown**.



- (a) If the unknown organism is **homozygous dominant**, then **all** the offspring should show the **dominant** trait.

Try it out for yourself! Draw a genetic diagram based on the scenario above.

- (b) If the unknown organism is **heterozygous**, then **half** the total number of offspring should show the **dominant** trait and the remaining **half** should show the **recessive** trait.

Try it out for yourself! Draw a genetic diagram based on the scenario above.

AfL in Class

[Individual work / Pair work]:

Use your knowledge about the new concept and test yourself without reference.

Q1. In bears, the allele for short fur is dominant to the allele for long fur. Two bears with different genotype mated and the offspring have the following traits: 3 bears with short fur and 3 bears with long fur.

Use a genetic diagram to show the genotypes of phenotypes of the parents.

$Aa \times Aa$

Let's Try!

Co-dominance (FYI)

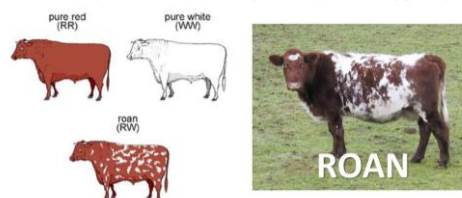
- In Mendel's monohybrid inheritance experiments, one allele was always dominant over the other.
- In the heterozygous, only the dominant allele is expressed.
- There are **some exceptions**, the **heterozygous** form shows the effect of **both alleles**.
- E.g. human blood groups
- **Neither allele is completely dominant over the other.**
- Co-dominance results when the two alleles controlling a trait both express themselves in the organism.

Example 1:



Example 2:

- Red Cattle = RR (homozygous)
- White Cattle = WW (homozygous)
- Roan (Red & White Hair) = RW (Heterozygous)



MULTIPLE ALLELES (FYI)

- Is a term used for a gene that exists in more than two alleles
- Example: Human blood groups
- Human blood group is determined by three alleles – I^A , I^B and I^O .
- I^A and I^B are both **co-dominant**, while I^O is **recessive** to both I^A and I^B .

Blood group	Genotype
A	$I^A I^A$ or $I^A I^O$
B	$I^B I^B$ or $I^B I^O$
AB	$I^A I^B$
O	$I^O I^O$

The genotype $I^O I^O$ is a homozygous recessive

AfL in Class

[Individual work / Pair work]:

Use your knowledge about the new concept and test yourself without reference.

Q1. Is it possible for a couple with blood group A and B to have a child with the blood group O? Explain your answer with a genetic diagram.

True/False AfL

- The sex of an offspring is determined by the mother's gamete. **False**
- Sperms produced by males contain either the X or Y chromosome. **True**
- Eggs produced by females contain the X chromosome only. **True**
- Parents who are both heterozygous for the blood group A ($I^A I^O$) can produce a child with the blood group AB.
False. In order to be blood group AB, the genotype of the child should be $I^A I^B$. The child should receive one I^A and one I^B allele from each parent. However, no I^B allele is present.
- If the father with blood group A and the mother with blood group B produce a child with blood group O, it is likely that both parents are heterozygous for blood groups A and B respectively.
True

(g) describe the determination of sex in humans – XX and XY chromosomes

SEX DETERMINATION

How do we determine the sex of an unborn child?

- Humans have **22 pairs of autosomes** and **one pair of sex chromosomes** in each cell.
 - XY - male
 - XX - female
- Sex chromosomes** are chromosomes that determine the sex of an organism.
- There are two types of sex chromosome – the **X** chromosome and the **Y** chromosome.
- Human females: **two X** chromosomes
- Human males have **one X** chromosome and a shorter **Y** chromosome in each **normal body cell**.
- When male and female gametes fuse during fertilisation, there is an **equal** chance that the offspring could be a male or a female.

Let's Try!

A woman wants to find out the chances of having a baby boy so she went to read up on how to determine the sex of the child. Upon knowing that a man has XY chromosomes and a woman has XX chromosomes, she recalls her Biology knowledge on genetics and did a genetic diagram. Please draw the genetic diagram of this cross below

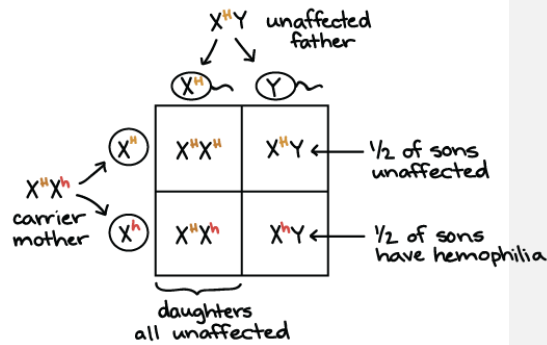
Parental Phenotype	Male		x	Female	
Parental Genotype	XY		x	XX	
Gametes					
F ₁ Genotype	XX	XY		XX	XY
F ₁ Phenotype	Female	Male		Female	Male
Phenotypic ratio	Female : Male			1 : 1	

Sex linked Diseases (FYI)

Hemophilia is caused by a **mutation** in either of two genes, both of which are located on the X chromosome. Both genes encode proteins that help blood clot. Let's focus on just one of these genes, calling the **functional allele X^H** , the disease allele **X^h** .

In our example, a woman who is **heterozygous** for **normal** and hemophilia alleles $X^H X^h$, has children with a man who is hemizygous for the **normal form $X^H Y$** . Both parents have normal blood clotting, but the mother is a **carrier**.

What is the chance of their sons and daughters having hemophilia?



(h) describe **mutation** as a change in the structure of a gene such as in **sickle cell anaemia**, or in the chromosome number, such as the 47 chromosomes in a condition known as **Down Syndrome**

MUTATIONS

Definition: mutation is a **sudden random change** in the **structure of a gene** or in the **chromosome number**

- Genes are **usually** passed on from one generation to another **unchanged**.
- During the replication stage of **mitosis or meiosis** (**cell division**), **occasional error may occur**.
- If a mutation occurs **during gamete production**, the resulting genetic change can be **inherited** by the offspring.
- Mutation that occur in **normal body cells** are known as **somatic** mutations. This form of mutation **cannot** be inherited.
- Two types of mutation:
 - Gene mutation**
 - Chromosomal mutation**

GENE MUTATION

1. Gene mutation—ALBINISM

- Caused by a **mutation in the recessive allele** (homozygous recessive)
- absence** of **pigments** in the skin, hair and eyes
- sensitive** to **sunlight** and skin is **easily sunburnt**
- Rate of mutation for albinism is around 28 per million gametes produced — a probability of 2.8×10^{-5} .

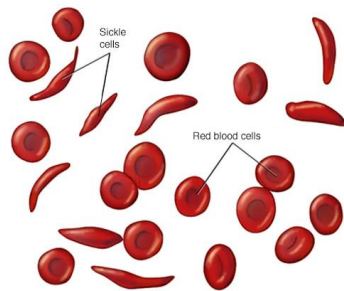


2. Gene mutation—SICKLE-CELL ANAEMIA

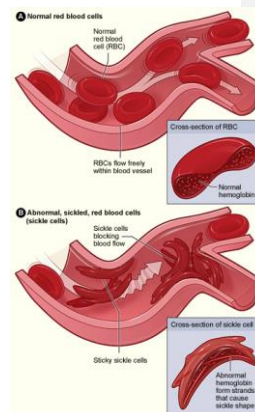
- Mutated gene produces **haemoglobin S (HbS)**, which is almost the same as **normal haemoglobin A (HbA)**, except in **one amino acid**
- HbS molecules **clump together**, making the **red blood cell sickle-shaped**, which **interferes with the oxygen-carrying** property of the cell.
- This mutation can be **fatal**.
- Individuals who are **heterozygous** for the sickle-cell allele are **more resistant to malaria** because **only a small percentage of their red blood cells that are sickle-shaped**. A proportion of their haemoglobin is normal.



Scan to watch a video about Sickle-cell Anaemia



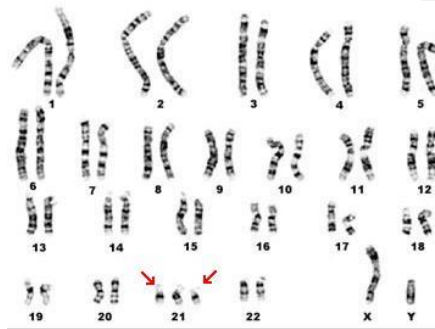
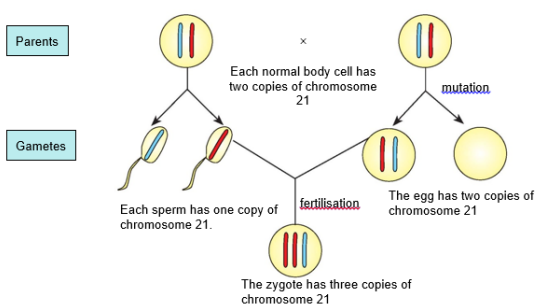
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CHROMOSOMAL MUTATION

1. Chromosomal mutation—DOWN'S SYNDROME

- People with Down's syndrome have **one extra chromosome 21** — they have 47 chromosomes.
- The older the mother, the higher the chance that copies of chromosome 21 will not separate during gamete formation.



karyotype

(i) name ionising radiation (e.g. X-ray) and chemical mutagens as factors which may increase the rate of mutation

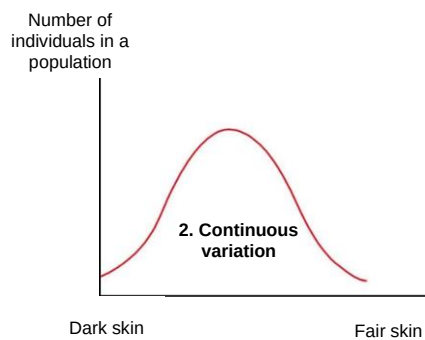
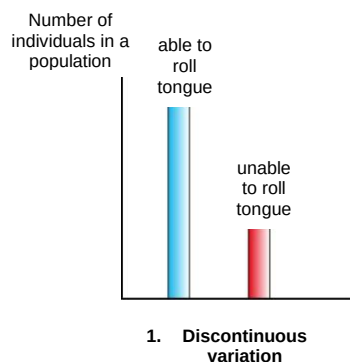
MUTAGENS

- The rate of spontaneous mutation, which is usually very **low**, can be greatly increased with the presence of **mutagens**.
- **Examples of mutagens** are **ultraviolet light**, **alpha**, beta and gamma **radiations**, and **chemicals** such as **mustard gas**, **formaldehyde** and lysergic acid diethylamide (LSD).

b) distinguish between continuous and discontinuous variation and give examples of each

CONTINUOUS vs DISCONTINUOUS VARIATIONS

* Variations are **differences in traits** between individuals of the same species



1. Discontinuous variation	2. Continuous variation
Deals with a few clear-cut phenotypes	Deals with a range of phenotypes, ranging from one extreme to another
Controlled by one or a few genes	Controlled by many genes
Genes do not show additive effect	Genes show additive effects
Not affected by environmental conditions	Affected by environmental conditions For example, a person's height is determined by the genes they have inherited and by the availability of food when they are growing. Milk yield in cows, for example, is determined not only by their genetic make-up but is also significantly affected by environmental factors such as pasture quality and diet, weather, and the comfort of their surroundings.
e.g. Hand used for writing , snapdragon petal colours, eye colour, blood group , gender	e.g. Height , Body Mass , Circumference of left wrist, milk yield, root length of plant, Intelligence, shoe size

IMPACTS OF MUTATIONS (FYI)

Are all mutations bad?

How do the mutations affect the organisms?

- Most mutations are harmful
- But some mutations can turn out to be beneficial, if it gives traits which allow the organism to be well-suited to its environment.
- Mutations give rise to variations within a population
- If a particular variation is suited for the environment, such individuals will **reproduce more** and become more common in the population
- The mutated allele (which gives rise to the mutation) will increase in frequency
- Over many years, the entire population will have this new trait

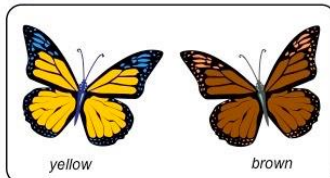


▲ **Figure 22.10 Variation in a population.** Individuals in this population of Asian ladybird beetles vary in color and spot pattern. Natural selection may act on these variations only if (1) they are heritable and (2) they affect the beetles' ability to survive and reproduce.

Natural selection → Evolution (FYI)

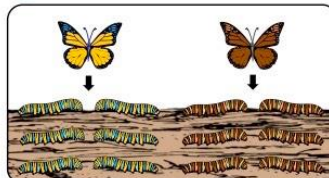
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1 Variation



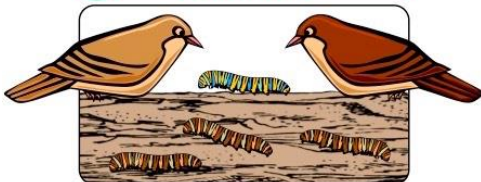
There is genetic variation within a population which can be inherited

2 Competition



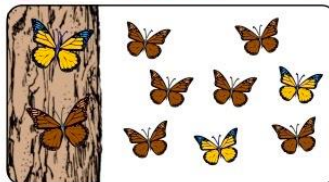
Overproduction of offspring leads to competition for survival

3 Adaptations



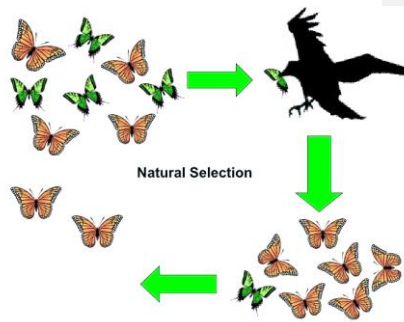
Individuals with beneficial adaptations are more likely to survive to pass on their genes

4 Selection



Over many generations, there is a change in allele frequency (evolution)

- Individuals within a species are all slightly different from each other. These differences are called **variations**. **Mutations give rise to variations within a population**
- As organisms reproduce, there will be competition between individuals for resources (e.g. food).
- Individuals with variations which give them an advantage in getting resources more efficiently may be **better able to survive than others**. Individuals without advantageous variations will die out and not get to reproduce.
- Individuals who have advantageous variations will get to reproduce and pass down the alleles to their offspring. Their offspring may also **inherit** the advantageous traits of their parents and pass it down to their own offspring.
- In time, this particular variety will outnumber and finally replace the original variety, **forming new species over time**.
- This way, the better adapted varieties will be 'selected' by the environment to **survive**.



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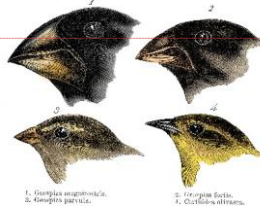


What is natural selection? natural selection simulation game
Prepared by Ms Pui LX



Evolution (Definition)

The process by which the present complex forms of living organisms have risen from simpler ancestral forms



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What is the evidence for evolution?

True/False AfL

1. Inbreeding will likely result in organisms that are homozygous for a particular recessive allele. **TRUE**
2. All mutations are harmful and bring no benefit to organisms. **FALSE**
3. A particular mutation may confer a selective advantage on an organism when environmental conditions change. **TRUE**

Artificial selection (FYI)

- Humans have been carrying out artificial selection for thousands of years to breed animals and plants for **specific characteristics**.
- Individuals with **desirable traits** (and hence, genes) are cross-bred to produce the next generation.
- Offspring with the most desirable traits are then chosen again to continue cross-breeding and this is **repeated over several generations**.
- E.g. Largest tomato fruit is picked and its seeds are planted to grow tomato plants which can produce larger fruits
- E.g. Farmers select calves from high milk yield cows to be used as breeding stock
- **Beneficial genes are kept within the population as they get to reproduce** and pass on the genes to the next generation, while animals without desirable traits do not get to reproduce.



Super cow creators



Normal Cow



Belgian Blue

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