GENERAL STUDIES III

Maternal Effect Inheritance in Snails | UPSC Biology 2027

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Why do some snail shells coil clockwise while others coil in the opposite direction? The answer offers a fascinating example of maternal-effect inheritance, in which the mother's genotype influences the early development and visible characteristics of her offspring. This UPSC Biology explainer examines snail shell chirality, maternal-effect genes, cytoplasmic factors, early embryonic development and the differences between maternal-effect, Mendelian and mitochondrial inheritance. It includes conceptual examples, comparison tables, Prelims MCQs and a model Mains answer.

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Why Do Snail Shells Spiral? Maternal-Effect Genes, Genetic Inheritance and Developmental Biology Explained
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1. Why Are Maternal-Effect Genes in News?

A science-related newspaper-topic index dated 4 November 2026 highlighted how a mother's genes can influence the direction of shell coiling in certain snails.

This phenomenon provides an important example of maternal-effect inheritance in developmental biology.

It demonstrates that the visible characteristics of an offspring may sometimes depend on the genotype of its mother rather than directly on its own genotype.

> **UPSC Relevance:** The topic connects genetics, embryonic development, inheritance patterns, cell biology and scientific reasoning.

2. What Is Maternal-Effect Inheritance?

Maternal-effect inheritance occurs when the genotype of the mother influences the phenotype of her offspring through substances deposited in the egg before fertilization.

These substances may include maternal messenger RNA, proteins and other developmental factors.

They can influence early embryonic development before the offspring's own genome fully directs developmental processes.

> **Key Concept:** In maternal-effect inheritance, the offspring's phenotype for the affected trait is determined by the mother's genotype.

3. Understanding Snail Shell Chirality

Chirality refers to the property of an object whose mirror image cannot be superimposed on the original.

Snail shells may exhibit different directions of coiling.

Dextral Coiling

A dextral shell has its opening on the right when the shell is held with the apex upward and the opening facing the observer.

Sinistral Coiling

A sinistral shell has its opening on the left under the same viewing convention.

In certain classical snail genetics models, shell-coiling direction is influenced by maternal-effect genes.

4. How Does the Mother's Genotype Affect Shell Coiling?

During egg formation, the mother deposits developmental molecules into the egg cytoplasm.

These molecules influence the orientation of early embryonic cell divisions.

The early developmental pattern can subsequently affect the direction of body and shell asymmetry.

Consequently, the offspring's shell-coiling phenotype may reflect the mother's genotype.

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5. Classical Genetic Example

Consider a simplified model in which:

- **D** represents a dominant allele associated with dextral development.
- **d** represents a recessive allele associated with sinistral development.

In this classical maternal-effect model, the offspring's phenotype depends on the genotype of its mother.

Mother's Genotype	Expected Offspring Phenotype
DD	Dextral
Dd	Dextral
dd	Sinistral

This illustrates a delayed relationship between an individual's genotype and the phenotype it produces in the next generation.

6. Why Can the Offspring's Genotype Differ from Its Phenotype?

In ordinary Mendelian examples, students often predict phenotype directly from the individual's own genotype.

Maternal-effect inheritance requires a different approach.

For example, an offspring with genotype dd may display dextral coiling if its mother has genotype Dd.

When that dd offspring later becomes a mother, its own offspring will show the sinistral phenotype under the simplified model.

> **Important Examination Point:** The offspring inherits its nuclear alleles from both parents, but the relevant early developmental phenotype is determined by the maternal genotype.

7. Maternal-Effect Inheritance Across Generations

Consider the following simplified cross:

Generation P: DD mother × dd father.

Generation F1: All offspring have genotype Dd and display dextral coiling because their mother was DD.

Generation F2: When F1 individuals produce offspring through a Dd × Dd cross, the genotypes segregate in a 1 DD : 2 Dd : 1 dd ratio.

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All F2 offspring display dextral coiling because their mothers have genotype Dd.

Generation F3: The F2 mothers with genotype dd produce sinistral offspring, while DD and Dd mothers produce dextral offspring under the simplified model.

> **Remember:** A phenotype ratio may appear one generation later than students expect from ordinary Mendelian inheritance.

8. Maternal-Effect vs Mendelian Inheritance

Feature	Ordinary Mendelian Trait	Maternal-Effect Trait
Phenotype Determination	Primarily by individual's own genotype	By mother's genotype in the classical model
Allele Transmission	Alleles inherited from both parents	Nuclear alleles still inherited from both parents
Developmental Mechanism	Individual gene expression	Maternal products influence early development
Generation Pattern	Often direct genotype-phenotype relationship	Phenotype can reflect maternal genotype

9. Maternal-Effect vs Mitochondrial Inheritance

Maternal-effect inheritance must not be confused with mitochondrial inheritance.

Feature	Maternal-Effect Inheritance	Mitochondrial Inheritance
Genetic Basis	Usually nuclear genes expressed in the mother	Genes located in mitochondrial DNA
Immediate Mechanism	Maternal products deposited in the egg	Transmission of mitochondrial genomes
Inheritance Pattern	Nuclear alleles can be inherited from both parents	Typically maternal transmission in animals
Classical Example	Shell coiling in certain snails	Some mitochondrial genetic disorders

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10. Role of Early Embryonic Development

Embryonic development begins with a fertilized egg undergoing successive cell divisions.

In many organisms, maternally supplied molecules regulate important early developmental events.

These factors may influence:

- Early cell division patterns.
- Spatial organization of the embryo.
- Developmental polarity.
- Activation of developmental pathways.
- Establishment of body asymmetry.

The precise mechanisms vary among organisms and traits.

11. Maternal-Effect Genes and Developmental Biology

Maternal-effect genes are important in the study of how genetic information influences early development.

They demonstrate that gene action may occur before a visible trait appears.

They also highlight the importance of cellular context, gene expression and developmental timing.

Researchers study maternal effects through controlled genetic crosses and observations across successive generations.

12. Why Reciprocal Crosses Matter

A reciprocal cross involves reversing which parent carries a particular genotype.

In classical maternal-effect inheritance, reciprocal crosses may produce different offspring phenotypes even when the offspring have the same nuclear genotype.

This helps researchers identify whether the mother's genotype influences the trait.

However, reciprocal cross differences alone do not establish a specific mechanism.

Further genetic and developmental experiments may be required.

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13. Scientific Significance of Maternal-Effect Inheritance

- Demonstrates the importance of maternal gene expression.
- Shows that phenotype need not correspond directly to the offspring's own genotype.
- Helps explain developmental asymmetry.
- Illustrates the importance of egg cytoplasmic factors.
- Provides a model for studying early embryonic development.
- Highlights the value of multigenerational genetic analysis.

These principles are useful for understanding developmental genetics beyond simple inheritance ratios.

14. Common Misconceptions

Misconception 1: Only the Mother Contributes Genes

Incorrect. Nuclear genes are inherited from both parents under ordinary sexual reproduction.

Misconception 2: Maternal Effect Is Mitochondrial Inheritance

Incorrect. The mechanisms are distinct.

Misconception 3: All Snails Follow the Same Genetic Model

Incorrect. The classical example applies to certain snail systems and should not be generalized to every species.

Misconception 4: The Offspring's Genotype Is Irrelevant

Incorrect. Its genotype can determine the phenotype of its own offspring when it becomes a mother.

15. UPSC Prelims Quick Revision

- Maternal-effect inheritance depends on the mother's genotype.
- Maternal products deposited in the egg influence early development.
- Snail shell coiling is a classical example in certain species.
- Dextral and sinistral refer to opposite shell-coiling orientations.
- Nuclear alleles are inherited from both parents.
- Maternal-effect inheritance differs from mitochondrial inheritance.
- Reciprocal crosses help investigate parental effects.

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- Genotype-phenotype relationships may appear delayed across generations.

16. UPSC Prelims Practice MCQs

Question 1

Maternal-effect inheritance is primarily determined by:

A. The father's mitochondrial DNA

B. The mother's genotype

C. The offspring's sex alone

D. External shell temperature alone

Correct Answer: B

The mother's genotype influences the offspring's early developmental phenotype.

Question 2

Which statement best distinguishes maternal-effect inheritance from mitochondrial inheritance?

A. Maternal-effect genes must always be mitochondrial.

B. Maternal-effect inheritance usually involves nuclear genes acting through maternal products.

C. Mitochondrial inheritance always follows ordinary autosomal dominant ratios.

D. Maternal-effect inheritance excludes paternal allele transmission.

Correct Answer: B

Maternal-effect traits can involve nuclear genes whose products are deposited in the egg.

Question 3

In the simplified snail model, a dd offspring born to a Dd mother is expected to show:

A. Dextral coiling

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B. Sinistral coiling

C. No shell formation

D. An unpredictable trait solely because it is dd

Correct Answer: A

The Dd mother's genotype produces the dextral phenotype under the classical model.

Question 4

Which experimental approach is particularly useful for investigating maternal effects?

A. Reciprocal genetic crosses

B. Measuring atmospheric pressure

C. Studying only adult shell colour

D. Ignoring successive generations

Correct Answer: A

Reciprocal crosses help identify differences associated with the maternal parent.

Question 5

Which of the following is correct about maternal-effect inheritance?

A. The offspring inherits all nuclear alleles from its mother.

B. The mother's genotype can influence the offspring's phenotype.

C. The father's genetic contribution is always absent.

D. The mechanism is identical to sex-linked inheritance.

Correct Answer: B

Maternal-effect inheritance involves maternal genotype-dependent developmental influence.

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17. UPSC Mains Practice Questions

Question 1

Explain maternal-effect inheritance with reference to snail shell coiling. (150 words)

Question 2

Differentiate maternal-effect inheritance from mitochondrial inheritance. (150 words)

Question 3

Discuss the role of maternal gene products in early embryonic development. (250 words)

18. Model UPSC Mains Answer

Question: Differentiate maternal-effect inheritance from mitochondrial inheritance.

Introduction:

Maternal-effect inheritance and mitochondrial inheritance are two distinct genetic phenomena associated with maternal influence.

Body:

- **Genetic basis:** Maternal-effect inheritance usually involves nuclear genes, whereas mitochondrial inheritance involves mitochondrial DNA.
- **Mechanism:** Maternal-effect traits are influenced by maternal products deposited in the egg, whereas mitochondrial traits depend on mitochondrial genome transmission.
- **Parental contribution:** Maternal-effect nuclear alleles may come from both parents; mitochondrial genomes are typically transmitted maternally in animals.
- **Example:** Snail shell coiling illustrates maternal effect, while some inherited mitochondrial disorders illustrate mitochondrial inheritance.

Conclusion:

Both phenomena demonstrate maternal influence, but they differ in genetic location, mechanism and inheritance pattern.

19. Key Takeaways for UPSC Aspirants

- Understand maternal genotype versus offspring genotype.
- Remember the classical D/d snail coiling example.

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- Practice predicting phenotypes across multiple generations.
- Distinguish maternal effect from mitochondrial inheritance.
- Understand the role of egg cytoplasmic factors.
- Use reciprocal crosses to reason about inheritance mechanisms.
- Avoid applying one snail model universally to all organisms.

Frequently Asked Questions

What is maternal-effect inheritance?

It is an inheritance pattern in which the mother's genotype influences the offspring's phenotype through maternally supplied developmental factors.

Why does the mother's genotype determine snail shell coiling?

In certain snail systems, maternally deposited molecules influence early embryonic cell division and subsequent asymmetry.

What is the difference between dextral and sinistral shells?

With the apex upward and aperture facing the observer, dextral shells have the opening on the right and sinistral shells on the left.

Is maternal-effect inheritance the same as mitochondrial inheritance?

No. Maternal effects usually involve nuclear genes expressed by the mother, while mitochondrial inheritance concerns mitochondrial DNA transmission.

Can a dd snail have a dextral shell?

Yes. Under the simplified classical model, a dd offspring of a Dd mother can display dextral coiling.

Is this topic relevant for UPSC Prelims?

Yes. It helps revise genetics, heredity, developmental biology and scientific reasoning in Science and Technology preparation.

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Disclaimer: This article is intended for educational and examination preparation purposes. The classical genetic model is illustrative and should not be generalized to all snail species.

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