Modern Synthetic Theory of Evolution

NEET-UG Biology | Evolution

1. Definition

The Modern Synthetic Theory of Evolution, also called the Neo-Darwinian Theory, explains evolution by combining Darwin's theory of natural selection with Mendelian genetics, population genetics, and molecular biology.

It states that evolution is a change in the frequency of alleles in a population over successive generations.

The theory developed mainly during the 1930s and 1940s.

2. Main contributors

- Charles Darwin: Natural selection.
- Gregor Mendel: Laws of inheritance.
- R. A. Fisher: Mathematical genetics and natural selection.
- J. B. S. Haldane: Mathematical models of evolution.
- Sewall Wright: Genetic drift.
- Theodosius Dobzhansky: Population genetics and evolution.
- Ernst Mayr: Biological species concept and speciation.
- G. G. Simpson: Integration of palaeontology with evolutionary theory.
- G. Ledyard Stebbins: Evolutionary genetics in plants.

3. Main mechanisms of evolution

Genetic variation

Mutation + genetic recombination

Evolutionary forces

Natural selection • Genetic drift • Gene flow • Mutation

Change in allele frequencies

Across generations in a population

Adaptation and speciation

May ultimately lead to the formation of new species

A. Mutation

Mutation is a change in genetic material that can create new alleles.

- Mutations may be spontaneous or induced.
- They may be beneficial, harmful, or neutral.
- Heritable mutations provide new genetic variation for evolution.

Example: A mutation conferring resistance to an antibiotic may help a bacterium survive antibiotic exposure.

B. Genetic recombination

Recombination produces new combinations of existing alleles.

It occurs through:

- Crossing over during meiosis.
- Independent assortment of chromosomes.
- Random fertilisation in sexually reproducing organisms.

Example: Children inherit different combinations of parental alleles, creating variation within a population.

C. Natural selection

Individuals with heritable characteristics that improve reproductive success tend to leave more offspring.

Example: Antibiotic-resistant bacteria survive treatment and reproduce, increasing the frequency of resistance alleles.

D. Genetic drift

Genetic drift is a random change in allele frequencies, especially important in small populations.

Two important examples are:

- Founder effect: A new population is established by a small number of individuals.
- Bottleneck effect: A population undergoes a sharp reduction in size, leaving a non-representative sample of its original genetic variation.

E. Gene flow

Gene flow is the transfer of alleles between populations through migration and reproduction.

It can introduce new alleles into a population and reduce genetic differences between populations.

F. Reproductive isolation

When populations become reproductively isolated, gene exchange between them is restricted. Over time, genetic differences may accumulate and result in speciation.

Examples of isolating mechanisms include geographical barriers, differences in mating behaviour, and reproductive incompatibility.

4. Hardy–Weinberg principle

The principle provides a reference model for a population that is not evolving with respect to a particular gene.

For two alleles, A and a:

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$

Where:

- p = frequency of allele A
- q = frequency of allele a
- p^2 = frequency of genotype AA
- $2pq$ = frequency of genotype Aa
- q^2 = frequency of genotype aa

The assumptions include a very large population, random mating, and no mutation, migration, natural selection, or genetic drift.

A departure from Hardy–Weinberg equilibrium may indicate that evolutionary forces are acting, although sampling effects and other departures from the model must also be considered.

5. Evidence supporting the theory

- Fossils: Document changes in organisms over geological time.
- Comparative anatomy: Homologous structures indicate common ancestry.
- Molecular biology: Similarities in DNA and proteins support evolutionary relationships.
- Biogeography: Geographical distributions reveal patterns of descent and isolation.
- Observed evolution: Antibiotic resistance and changes in insecticide resistance demonstrate evolution in populations.

6. Darwin’s theory versus the Modern Synthetic Theory

Darwin's theory	Modern Synthetic Theory
Emphasised natural selection	Integrates natural selection with genetics and population biology
Did not know the genetic basis of inheritance	Explains inheritance through genes and alleles
Variation was recognised, but its origin was not fully understood	Mutation and recombination explain the origin of genetic variation
Focused on survival and reproduction of individuals	Measures evolutionary change primarily through populations and allele frequencies
Did not adequately explain genetic drift	Recognises genetic drift and gene flow as evolutionary forces

7. Important NEET-UG points

- The modern synthesis is also called Neo-Darwinism.
- The basic unit of evolution is the population, not an individual.
- Mutations introduce new alleles; recombination creates new combinations of alleles.
- Natural selection is non-random with respect to reproductive success, whereas genetic drift is random.
- Gene flow transfers alleles between populations.
- Genetic drift has a stronger effect in small populations.
- Evolution does not necessarily produce greater complexity or perfection.
- Natural selection acts on phenotypes, while evolutionary change is reflected in inherited genetic variation across generations.

8. Practice MCQs

Test your understanding

0/5 answered

1. The basic unit of evolution in the Modern Synthetic Theory is:

Individual
Population
Organ
Species only

2. Which process introduces entirely new alleles into a population?

Mutation
Natural selection
Genetic drift
Independent assortment alone

3. Which evolutionary mechanism is random with respect to an allele's fitness?

Natural selection
Genetic drift
Adaptive selection
Directional selection

4. The Hardy–Weinberg equation for genotype frequencies is:

$p + q = 2$
$p^2 + q^2 = 2pq$
$p^2 + 2pq + q^2 = 1$
$p^2 - q^2 = 1$

5. The founder effect is a type of:

Gene flow
Genetic drift
Mutation
Natural selection only
Check answers

In one sentence: The Modern Synthetic Theory explains evolution as changes in the genetic composition of populations caused by mutation, recombination, natural selection, genetic drift, gene flow, and reproductive isolation.