

Book Summary:

What Is Life?

by Erwin Schrödinger (1944) ¹

Introduction

What Is Life? The Physical Aspect of the Living Cell is one of the most influential scientific books of the twentieth century. Based on lectures Schrödinger delivered in 1943, the book asked a profound question:

How can living organisms maintain such extraordinary order in a universe governed by increasing disorder (entropy)?

At the time, DNA had not yet been identified as the molecule of heredity. Schrödinger approached biology as a theoretical physicist, seeking universal physical principles that could explain life itself. Although some details have since been superseded by molecular biology, many of his central insights inspired the birth of modern genetics and molecular biology. Scientists such as James Watson, Francis Crick, Maurice Wilkins, and others have acknowledged this book as a major influence.

Chapter 1 – The Classical Physicist's Approach to the Subject

Schrödinger begins by asking whether physics and chemistry can explain living organisms.

Traditional Physics

Classical physics successfully explains:

- planets
- gases
- crystals
- electricity
- chemical reactions

These systems involve enormous numbers of particles.

Statistical laws work because random individual motions average out.

For example:

One gas molecule behaves unpredictably.

A trillion molecules behave predictably.

Living Cells are Different

Living organisms often depend upon remarkably few molecules.

Genes are microscopic.

Individual molecular events matter.

Life cannot simply depend upon averages.

This creates a scientific challenge.

¹ Created using ChatGPT asking the question: Create a detailed summary of the book *What Is Life* by Erwin Schrodinger
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Main Question

How can life remain:

- ordered
- stable
- reproducible

while consisting of tiny structures constantly bombarded by thermal motion?

Chapter 2 – The Hereditary Mechanism

Schrödinger turns toward heredity.

Parents reliably produce offspring resembling themselves.

Genes somehow carry enormous amounts of information.

Yet genes are unbelievably small.

Stability

Genes must satisfy two opposing requirements:

They must be

- extremely stable

yet

- capable of occasional change (mutation).

Without stability: species disappear.

Without mutation: evolution stops.

Puzzle

How can something so tiny possess such remarkable permanence?

Chapter 3 – Mutations

Mutations are rare.

Yet they occur consistently enough to drive evolution.

Schrödinger discusses work showing mutations could be produced through:

- X-rays
- radiation
- energetic particles

This suggested genes were physical objects obeying physical laws.

Important Insight

Genes were not mystical.

They were material structures.

This was a revolutionary concept during the 1940s.

Schrödinger

Chapter 4 – Quantum Theory

Classical physics cannot explain genetic stability.

Quantum mechanics becomes essential.

Atoms possess discrete energy levels.

Chemical bonds have remarkable stability because of quantum effects.

Genes therefore might achieve extraordinary reliability through atomic structure.

The New Idea

Life depends upon quantum stability.

Not merely statistical averages.

This insight helped move biology toward molecular physics.

Chapter 5 – Delbrück's Model

Schrödinger discusses work by Max Delbrück.

Delbrück proposed genes behave like giant molecules.

Their stability comes from atomic bonds.

Small quantum changes can occasionally alter them.

This became one of the conceptual foundations of molecular genetics.

Gene as a Molecule

Rather than an abstract hereditary force,

a gene becomes

a chemical object.

Chapter 6 – Order, Disorder and Entropy

This is perhaps the book's most famous chapter.

The Second Law of Thermodynamics

Entropy always increases.

Everything naturally tends toward disorder.

Examples:

- rust
- decay
- aging
- heat loss

The universe gradually becomes less organized.

Yet Living Organisms Become More Ordered

Babies grow.

Cells divide.

Brains learn.

Forests develop.

Embryos organize themselves.

Life appears to move opposite entropy.

How?

Negative Entropy

Schrödinger introduces his famous concept:

Life feeds upon **negative entropy**.

Today scientists often say:

Life consumes

organized energy.

Examples:

Plants capture sunlight.

Animals consume plants.

Humans consume organized food.

Energy entering organisms possesses greater order than energy leaving.

Living Systems Export Disorder

Organisms maintain internal order by exporting entropy to the environment.

This remains a central principle in thermodynamics.

Chapter 7 – Is Life Based on Physical Laws?

Schrödinger argues:

No mysterious "life force" is needed.

Life obeys physical law.

However,

existing physics may not yet fully explain life's organization.

Future discoveries will likely extend physics rather than replace it.

Epilogue – Determinism and Free Will

The final section becomes philosophical.

Schrödinger asks:

What is consciousness?

How does individuality arise?

Unity of Consciousness

Influenced by Eastern philosophy, especially Vedanta,
he argues consciousness may ultimately be one rather than many.
Individual selves could be expressions of one deeper reality.

Ethics

If consciousness is fundamentally unified,
then compassion naturally follows.
Helping others becomes helping oneself.

Central Ideas

1. Life Maintains Order

Living organisms continually create internal organization.
This distinguishes life from non-living matter.

2. Heredity Requires Information Storage

Genes must store immense amounts of information.
This prediction foreshadowed DNA.

3. The "Aperiodic Crystal"

Schrödinger proposed hereditary material must be
an **aperiodic crystal**.

Unlike ordinary crystals:

Salt:

ABABABAB...

Genes:

A unique non-repeating sequence.

This proved astonishingly accurate.

DNA is exactly such a molecule.

Its sequence carries biological information.

4. Information Exists in Chemistry

Before information theory became widespread,
Schrödinger recognized that biology depends upon
stored molecular information.

5. Quantum Mechanics Matters

Life ultimately depends upon atomic stability.
Chemical bonds make heredity possible.

6. Entropy Can Be Managed

Life cannot escape thermodynamics.
Instead,
living systems continuously import order
while exporting disorder.
Modern biology fully agrees.

Influence on Modern Biology

The book profoundly influenced future Nobel Prize winners.

Among them:

- James Watson
- Francis Crick
- Maurice Wilkins
- Sydney Brenner
- Walter Gilbert

Many have stated that reading *What Is Life?* motivated them to pursue biology.

Where Schrödinger Was Correct

Remarkably, he correctly anticipated:

- Genes are molecules.
 - Genetic information is physically encoded.
 - DNA functions as an information-bearing molecule.
 - Living systems maintain order by exchanging energy and matter with their surroundings.
 - Quantum mechanics underlies chemical stability.
 - Biology can largely be explained through chemistry and physics.
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Where He Was Mistaken or Incomplete

Some ideas were later revised:

- "Negative entropy" is now understood more precisely through modern thermodynamics and information theory.
- He underestimated the complexity of proteins, enzymes, gene regulation, and cellular networks.
- He suggested quantum mechanics might play a more direct role in living systems than has generally been demonstrated, though fields such as quantum biology continue to investigate limited quantum effects.

- He could not know the structure of DNA, which was discovered nearly a decade later in 1953. These limitations reflect the scientific knowledge available in 1944 rather than flaws in his reasoning.
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Relevance Today

Although molecular biology has advanced enormously, Schrödinger's core questions remain central:

- How does information emerge from matter?
- How do living systems maintain order while obeying thermodynamics?
- What distinguishes living organisms from complex machines?
- How did life originate from non-living chemistry?
- What is the relationship between life, mind, and consciousness?

These questions continue to shape research in genetics, systems biology, origin-of-life studies, artificial life, and theoretical biology.

Overall Conclusion

What Is Life? is not simply a biology book. It is an interdisciplinary exploration connecting physics, chemistry, biology, and philosophy. Schrödinger proposed that heredity is based on stable information-bearing molecules, that life maintains order by importing usable energy and exporting entropy, and that no special "vital force" is required to explain living systems. While some scientific details have been refined, the book's conceptual vision helped lay the foundation for molecular biology and continues to inspire scientists and philosophers asking how matter gives rise to life.