

THE NUCLEUS

Prokaryotic Nucleoid vs. Eukaryotic Nucleus, and the Parts of the Eukaryotic Nucleus

1. Introduction

The **nucleus** is the largest and most conspicuous organelle in a eukaryotic cell, and is often called the "**control centre**" of the cell because it houses almost all of the cell's genetic material (nuclear DNA) and directs cellular activity by controlling gene expression. It was the first cell organelle to be discovered — described by the Scottish botanist **Robert Brown in 1831** while examining orchid cells under the microscope.

- Present in all eukaryotic cells except a few that lose it during maturation (e.g. mammalian red blood cells, sieve-tube cells of phloem).
- Prokaryotic cells (bacteria and archaea) lack a true, membrane-bound nucleus; their DNA instead occupies an irregular region of the cytoplasm called the **nucleoid**.
- Because prokaryotes have no nuclear envelope separating DNA from the cytoplasm, transcription and translation can occur simultaneously in the same compartment — unlike in eukaryotes.

2. Prokaryotic Nucleoid vs. Eukaryotic Nucleus

The defining difference between prokaryotes and eukaryotes is, in fact, named after this very structure: "pro-karyote" (before a nucleus) versus "eu-karyote" (true nucleus).

Prokaryotic Nucleoid vs. Eukaryotic Nucleus

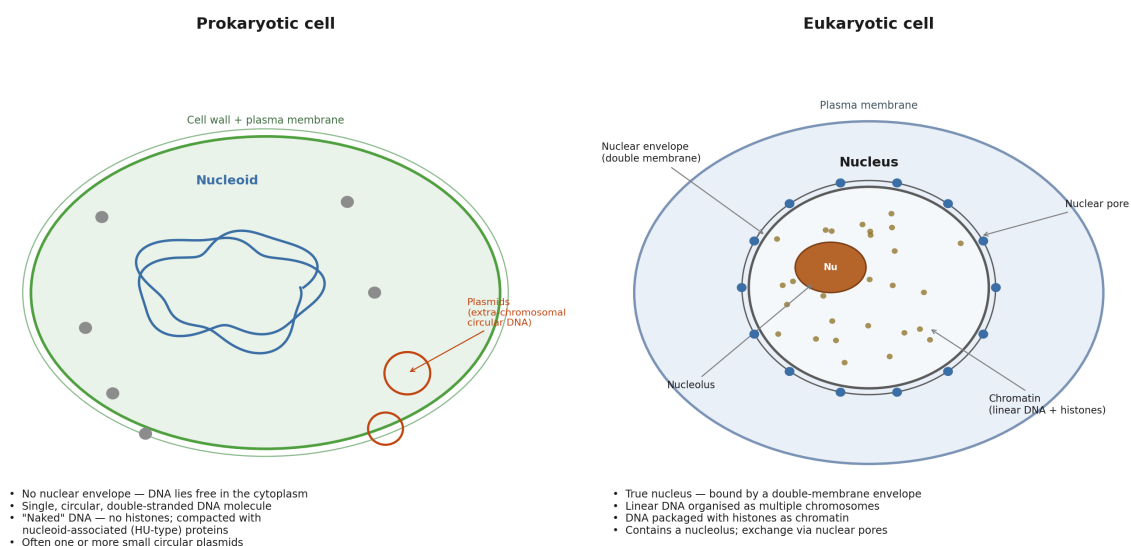


Fig. 1 — The prokaryotic nucleoid (no envelope, circular DNA) compared with the membrane-bound eukaryotic nucleus.

Feature	Prokaryotic nucleoid	Eukaryotic nucleus
Nuclear envelope	Absent — DNA lies free in the cytoplasm	Present — double membrane envelope

Feature	Prokaryotic nucleoid	Eukaryotic nucleus
DNA form	Single, circular, double-stranded molecule	Multiple linear chromosomes
DNA packaging	"Naked" DNA with nucleoid-associated (HU-type) proteins; no true histones	Wrapped around histones as chromatin (nucleosomes)
Extra DNA	Often carries small circular plasmids	Absent (plasmids are not a normal eukaryotic feature)
Nucleolus	Absent	Present — site of rRNA synthesis and ribosome assembly
Transcription & translation	Coupled — occur together in the cytoplasm	Separated — transcription in the nucleus, translation in the cytoplasm
Nuclear pores	Not applicable	Present — regulate transport across the envelope

3. Parts of the Eukaryotic Nucleus

A typical eukaryotic nucleus is a roughly spherical body enclosed by a double membrane and organised into several distinct components, each with a specific role:

Structure of the Eukaryotic Nucleus

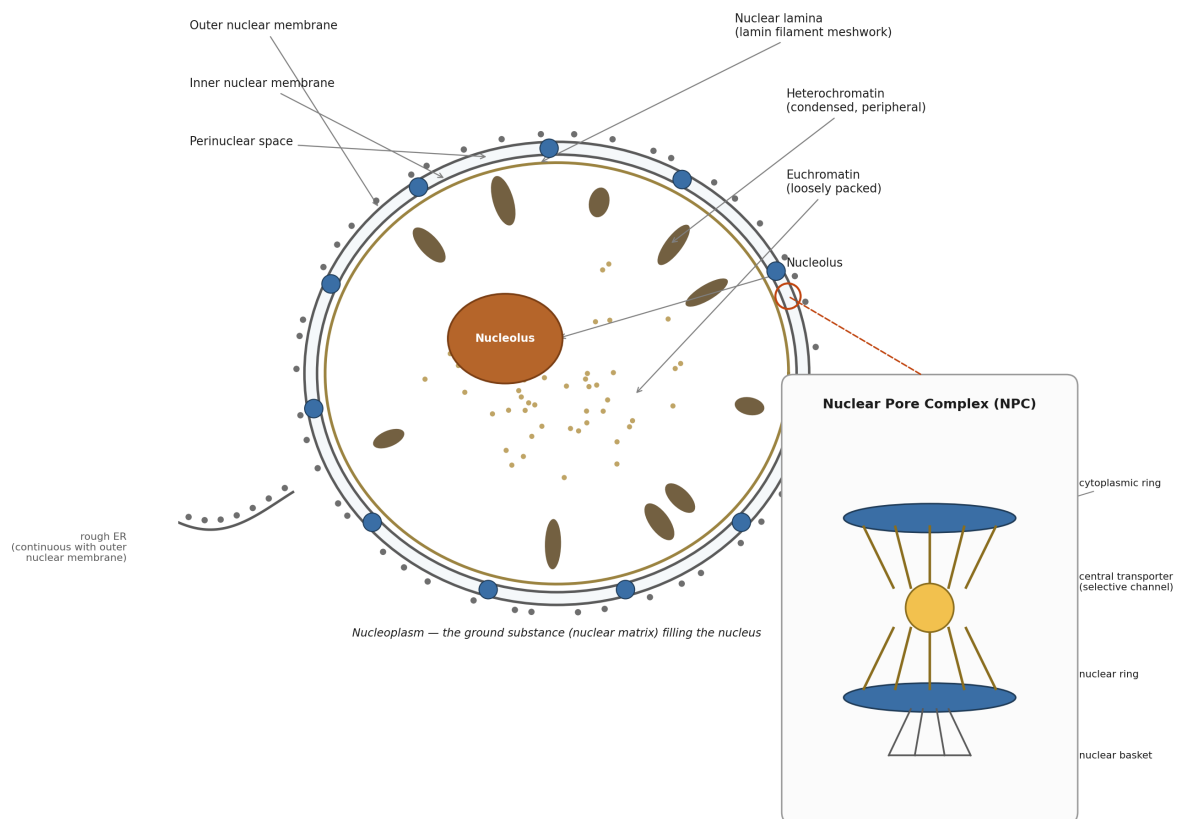


Fig. 2 — Detailed structure of the eukaryotic nucleus, with an inset showing the architecture of a nuclear pore complex (NPC).

(a) Nuclear Envelope

- A **double membrane** — an outer nuclear membrane and an inner nuclear membrane — separated by a fluid-filled gap, the **perinuclear space**, which is continuous with the lumen of the endoplasmic reticulum.
- The **outer nuclear membrane** is studded with ribosomes and is directly continuous with the rough endoplasmic reticulum, linking nuclear and cytoplasmic membrane systems.
- The **inner nuclear membrane** faces the nucleoplasm and is lined on its inner face by the nuclear lamina; it contains proteins that anchor chromatin to the nuclear periphery.
- The envelope disassembles at the start of mitosis (prometaphase) and re-forms around the daughter nuclei at telophase.

(b) Nuclear Pore Complex (NPC)

- Large, basket-like protein assemblies that perforate the nuclear envelope at sites where the outer and inner membranes fuse.

- Built from multiple copies of about 30 different proteins called **nucleoporins**, organised into a cytoplasmic ring, a nuclear ring, spoke-like connectors, a central transport channel, and cytoplasmic filaments/a nuclear basket.
- Small molecules and ions diffuse through freely, but macromolecules (proteins, RNAs, ribonucleoprotein particles) are moved through the central channel by **selective, signal- and energy-dependent transport** — for example, proteins bearing a nuclear localisation signal (NLS) are escorted in by importins.
- A typical mammalian nucleus has several thousand NPCs studding its envelope.

(c) Nuclear Lamina

- A dense fibrous meshwork lying just beneath the inner nuclear membrane, built mainly from intermediate filament proteins called **lamins (A, B, and C in mammals)**.
- Provides mechanical support to the nuclear envelope, helps determine nuclear shape, and anchors interphase chromatin (particularly heterochromatin) at the nuclear periphery.
- Disassembles (via lamin phosphorylation) when the nuclear envelope breaks down at mitosis, and reassembles afterward.

(d) Chromatin

- The nucleoplasm houses the cell's DNA complexed with histone and non-histone proteins as **chromatin**.
- **Euchromatin** — loosely packed, lightly staining, and generally transcriptionally active; tends to lie more centrally.
- **Heterochromatin** — densely packed, darkly staining, and largely transcriptionally silent; often found at the nuclear periphery, associated with the lamina.

(e) Nucleolus

- A dense, non-membrane-bound body formed around the Nucleolar Organizer Regions (NORs) — the chromosomal loci bearing the rRNA genes.
- The principal site of ribosomal RNA synthesis, processing, and assembly of ribosomal subunits.
- A nucleus may contain one or several nucleoli, and they enlarge in cells that are actively synthesising protein.

(f) Nucleoplasm (Nuclear Matrix)

- The gel-like ground substance filling the interior of the nucleus, in which chromatin and the nucleolus are suspended.
- Contains water, ions, enzymes (e.g. those for DNA replication and transcription), nucleotides, and a fibrous **nuclear matrix/nucleoskeleton** that helps organise chromatin domains and nuclear bodies.

Note — the nuclear envelope is not a single uniform bag

The four components of the envelope system — outer membrane, perinuclear space, inner membrane, and nuclear lamina — work together: the membranes provide the physical barrier and continuity with the ER, the pores provide controlled communication, and the lamina provides structural support and chromatin anchoring.

4. Functions of the Nucleus

- **Storage and protection of genetic material** — safeguards the cell's DNA from mechanical and chemical damage in the cytoplasm.
- **Control of gene expression** — determines which genes are transcribed into RNA at any given time, thereby directing all cellular structure and activity.
- **Site of DNA replication** — chromosomal DNA is duplicated within the nucleus before cell division.
- **Site of transcription and RNA processing** — pre-mRNA, tRNA, and rRNA are synthesised and processed (capping, splicing, polyadenylation) within the nucleus before export to the cytoplasm.
- **Ribosome subunit assembly** — carried out in the nucleolus.
- **Regulation of nucleo-cytoplasmic transport** — nuclear pores control the exchange of macromolecules between nucleus and cytoplasm, keeping transcription and translation compartmentalised.

5. Quick Revision Summary

Aspect	Key point
Discovered by	Robert Brown (1831), in orchid cells
Prokaryotic equivalent	Nucleoid — no envelope, single circular DNA, no histones
Nuclear envelope	Double membrane (outer + inner) with a perinuclear space, continuous with the rough ER
Nuclear pore complex	Nucleoporin-built channel regulating macromolecule traffic across the envelope
Nuclear lamina	Lamin meshwork lining the inner membrane; support + chromatin anchoring
Chromatin	Euchromatin (active, loose) vs heterochromatin (inactive, condensed, peripheral)
Nucleolus	Site of rRNA synthesis and ribosome subunit assembly, formed at the NOR
Nucleoplasm	Gel-like matrix filling the nucleus, housing chromatin, nucleolus, enzymes

Compiled study note — cell biology reference. Figures are original schematic diagrams prepared for this note and are not to scale.