Prokaryotic genome

- Genetic material in a cell: All cells have the capability to give rise to new cells and the encoded information in a living cell is passed from one generation to another. The information encoding material is the genetic or hereditary material of the cell.
-

- Prokaryotic genetic material: The prokaryotic (bacterial) genetic material is usually concentrated in a specific clear region of the cytoplasm called nucleiod.

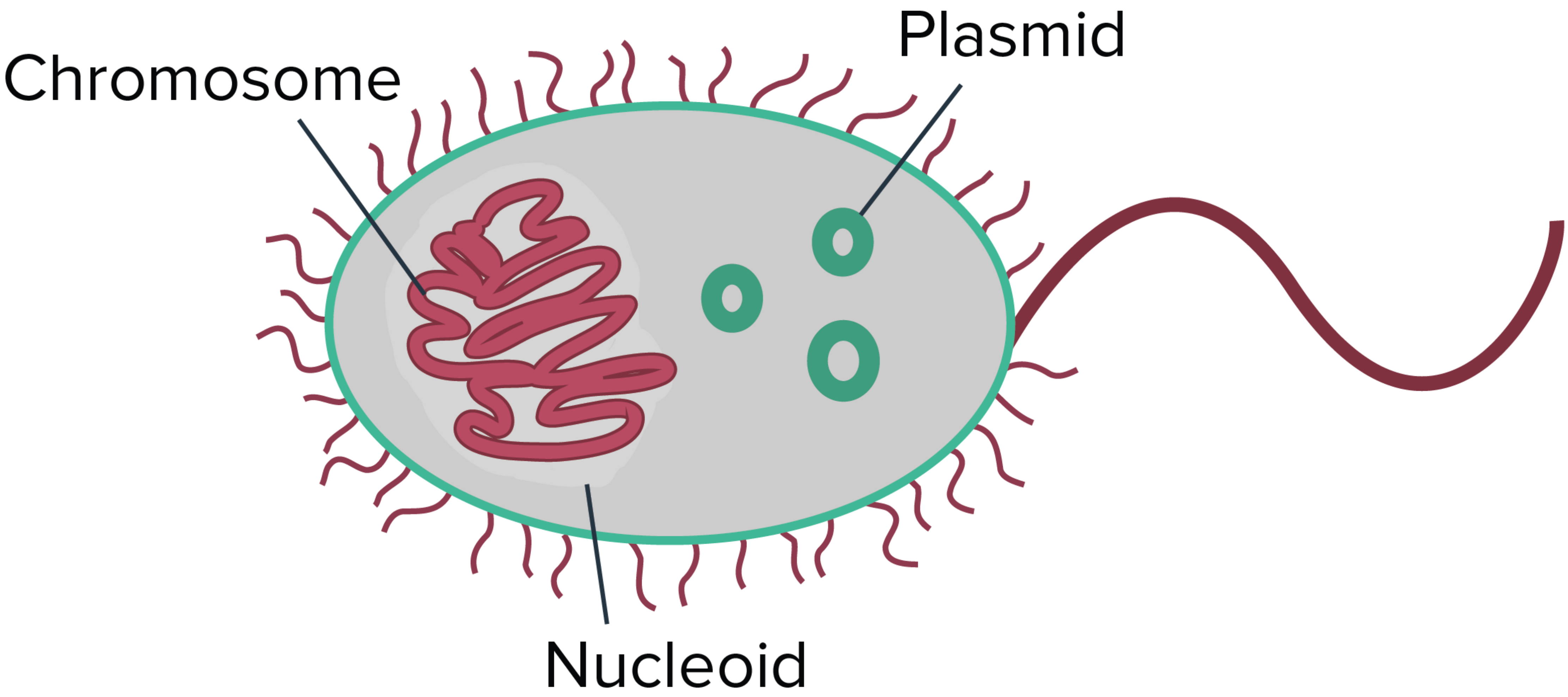
- The bacterial chromosome is a single, circular, double stranded DNA molecule mostly attached to the plasma membrane at one point. It does not contain any histone protein.

- Escherichia coli DNA is circular molecule 4.6 million base pairs in length, containing 4288 annotated protein-coding genes (organized into 2584 operons), seven ribosomal RNA (rRNA) operons, and 86 transfer RNA (tRNA) genes.

- Certain bacteria like the Borrelia burgdorferi possess array of linear chromosome like eukaryotes.

- Besides the chromosomal DNA many bacteria may also carry extra chromosomal genetic elements in the form of small, circular and closed DNA molecules, called plasmids.

- They generally remain floated in the cytoplasm and bear different genes based on which they have been studied. Some of the different types of plasmids are F plasmids, R plasmids, virulent plasmids, metabolic plasmids etc.


Plasmid
Chromosome
Nucleoid

- ***E. coli*: A Model Prokaryote**
- Much of what is known about prokaryotic chromosome structure was derived from studies of *Escherichia coli*, a bacterium that lives in the human colon and is commonly used in laboratory cloning experiments.

- In the 1950s and 1960s, this bacterium became the model organism of choice for prokaryotic research when a group of scientists used phase-contrast microscopy and autoradiography to show that the essential genes of *E. coli* are encoded on a single circular chromosome packaged within the cell nucleoid (Mason & Powelson, 1956; Cairns, 1963).

- Prokaryotic cells do not contain nuclei or other membrane-bound organelles. In fact, the word "prokaryote" literally means "before the nucleus." The nucleoid is simply the area of a prokaryotic cell in which the chromosomal DNA is located.

- This arrangement is not as simple as it sounds, however, especially considering that the *E. coli* chromosome is several orders of magnitude larger than the cell itself. So, if bacterial chromosomes are so huge, how can they fit comfortably inside a cell—much less in one small corner of the cell?

- **DNA Supercoiling**
- The answer to this question lies in DNA packaging.

- Whereas eukaryotes wrap their DNA around proteins called histones to help package the DNA into smaller spaces, most prokaryotes do not have histones (with the exception of those species in the domain Archaea).

- Thus, one way prokaryotes compress their DNA into smaller spaces is through supercoiling.

- Imagine twisting a rubber band so that it forms tiny coils. Now twist it even further, so that the original coils fold over one another and form a condensed ball. When this type of twisting happens to a bacterial genome, it is known as supercoiling.

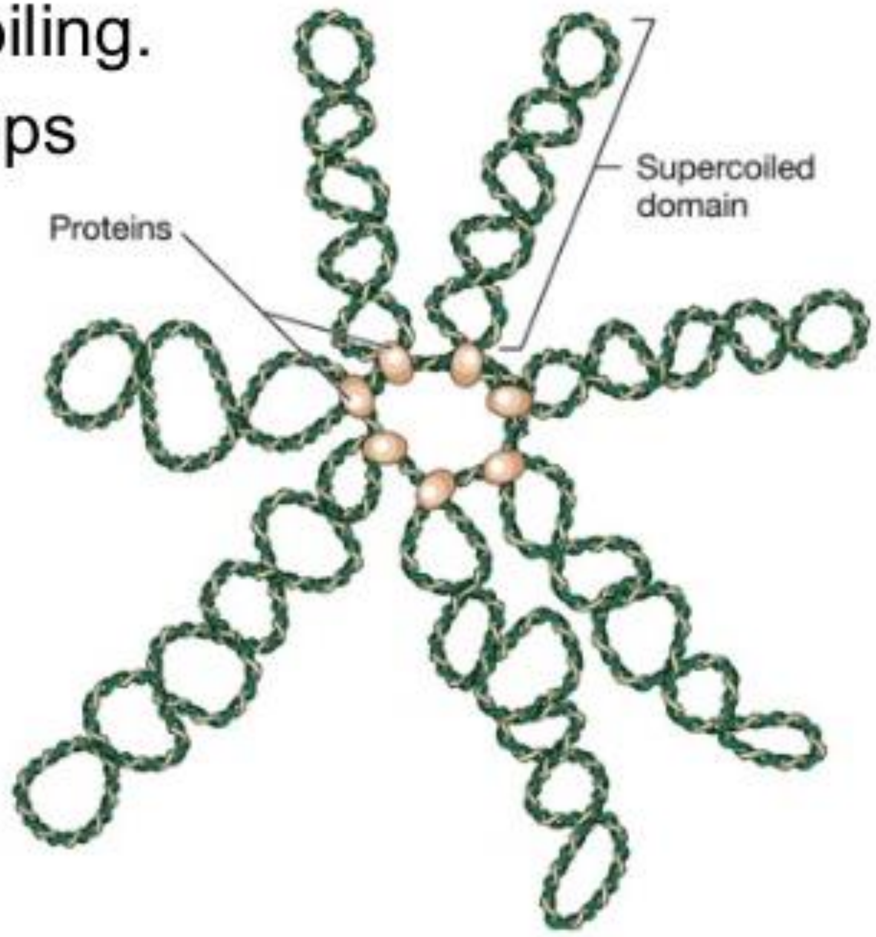
- Genomes can be negatively supercoiled, meaning that the DNA is twisted in the opposite direction of the double helix, or positively supercoiled, meaning that the DNA is twisted in the same direction as the double helix.

- Most bacterial genomes are negatively supercoiled during normal growth.

Prokaryotic genomes organization

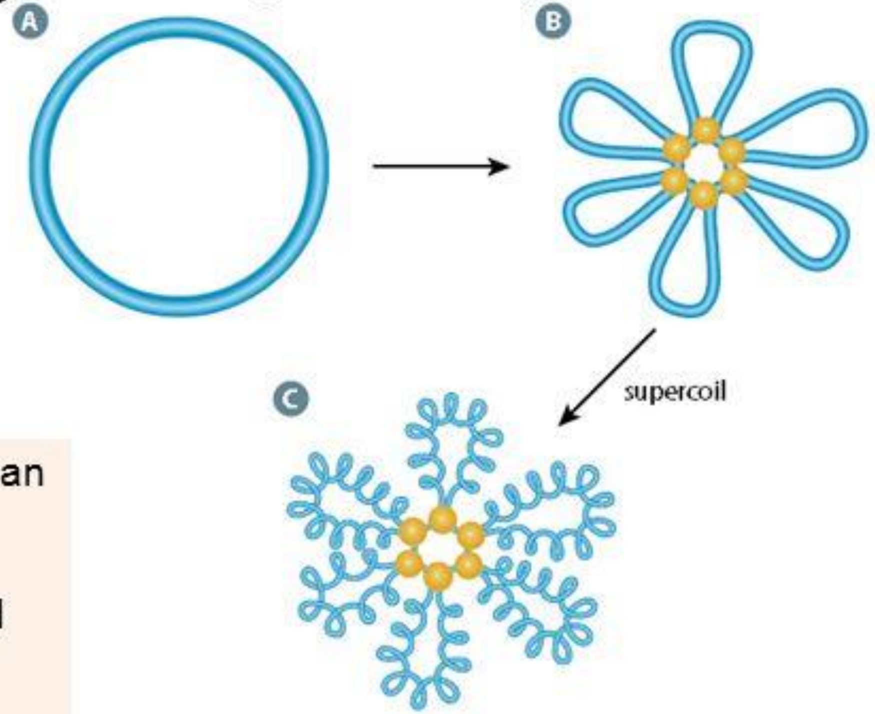
Prokaryote genome organization through:

1. Nucleoid (protein DNA interaction).
2. Supercoiling.
3. DNA loops



DNA of Prokaryotic Cells

Prokaryotic DNA must be tightly packed so that it can fit in the nucleoid. DNA packing is achieved through coiling, compacting, and supercoiling.



(A) The circular chromosomal DNA molecule can be compacted through **(B)** the formation of looped structures.
(C) The looped DNA can be further compacted by DNA supercoiling. Note: the coloured balls represent proteins involved in supercoiling.

Proteins Involved in Supercoiling

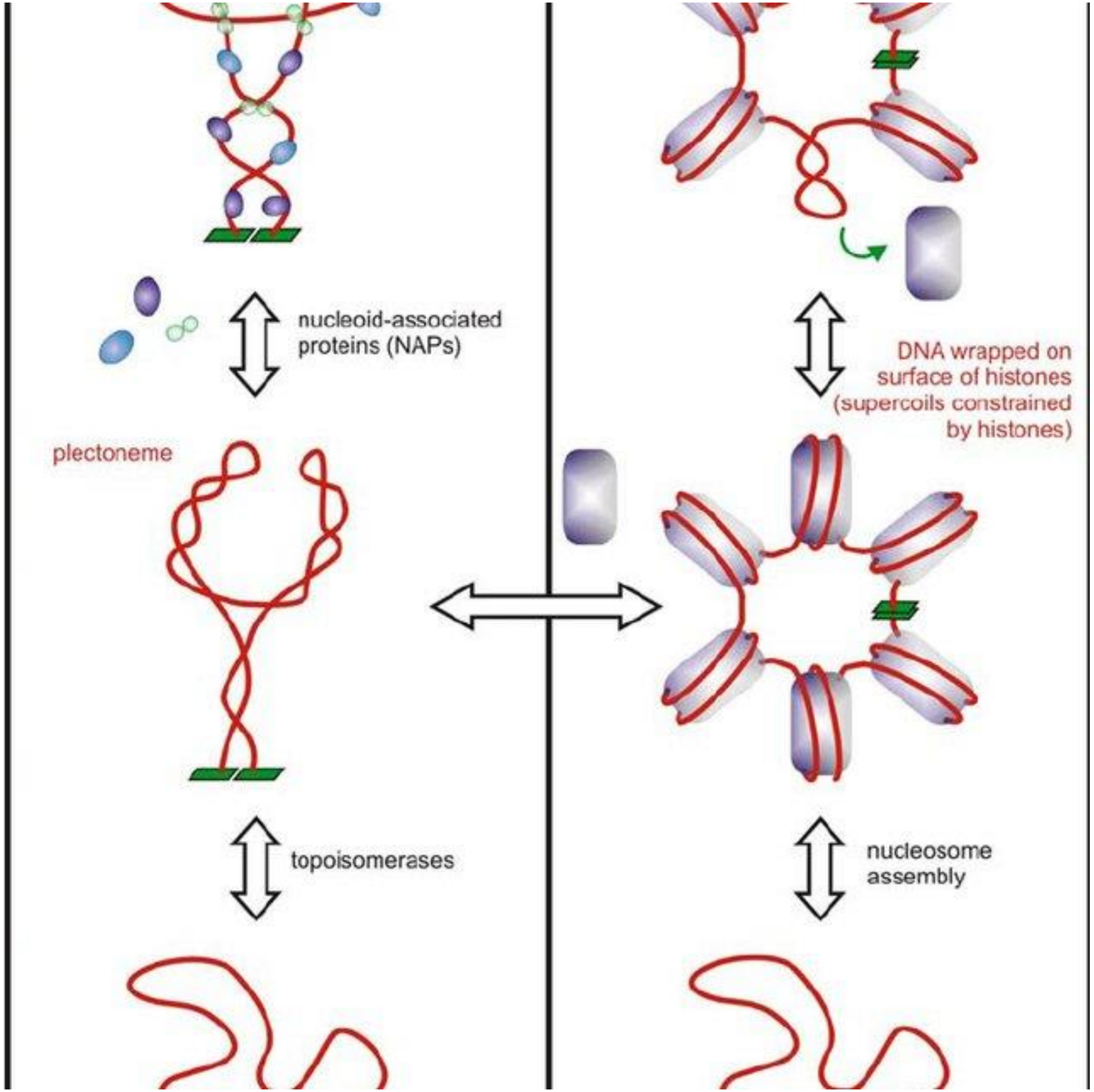
- During the 1980s and 1990s, researchers discovered that multiple proteins act together to fold and condense prokaryotic DNA.
- In particular, one protein called HU, which is the most abundant protein in the nucleoid, works with an enzyme called topoisomerase I to bind DNA and introduce sharp bends in the chromosome, generating the tension necessary for negative supercoiling.

- Recent studies have also shown that other proteins, including integration host factor (IHF), can bind to specific sequences within the genome and introduce additional bends (Rice *et al*., 1996).

- The folded DNA is then organized into a variety of conformations (Sinden & Pettijohn, 1981) that are supercoiled and wound around tetramers of the HU protein, much like eukaryotic chromosomes are wrapped around histones (Murphy & Zimmerman, 1997).

- Once the prokaryotic genome has been condensed, DNA topoisomerase I, DNA gyrase, and other proteins help maintain the supercoils. One of these maintenance proteins, H-NS, plays an active role in transcription by modulating the expression of the genes involved in the response to environmental stimuli.

- Another maintenance protein, factor for inversion stimulation (FIS), is abundant during exponential growth and regulates the expression of more than 231 genes, including DNA topoisomerase I (Bradley *et al*., 2007).


nucleoid-associated
proteins (NAPs)
plectoneme
topoisomerases
DNA wrapped on
surface of histones
(supercoils constrained
by histones)
nucleosome
assembly