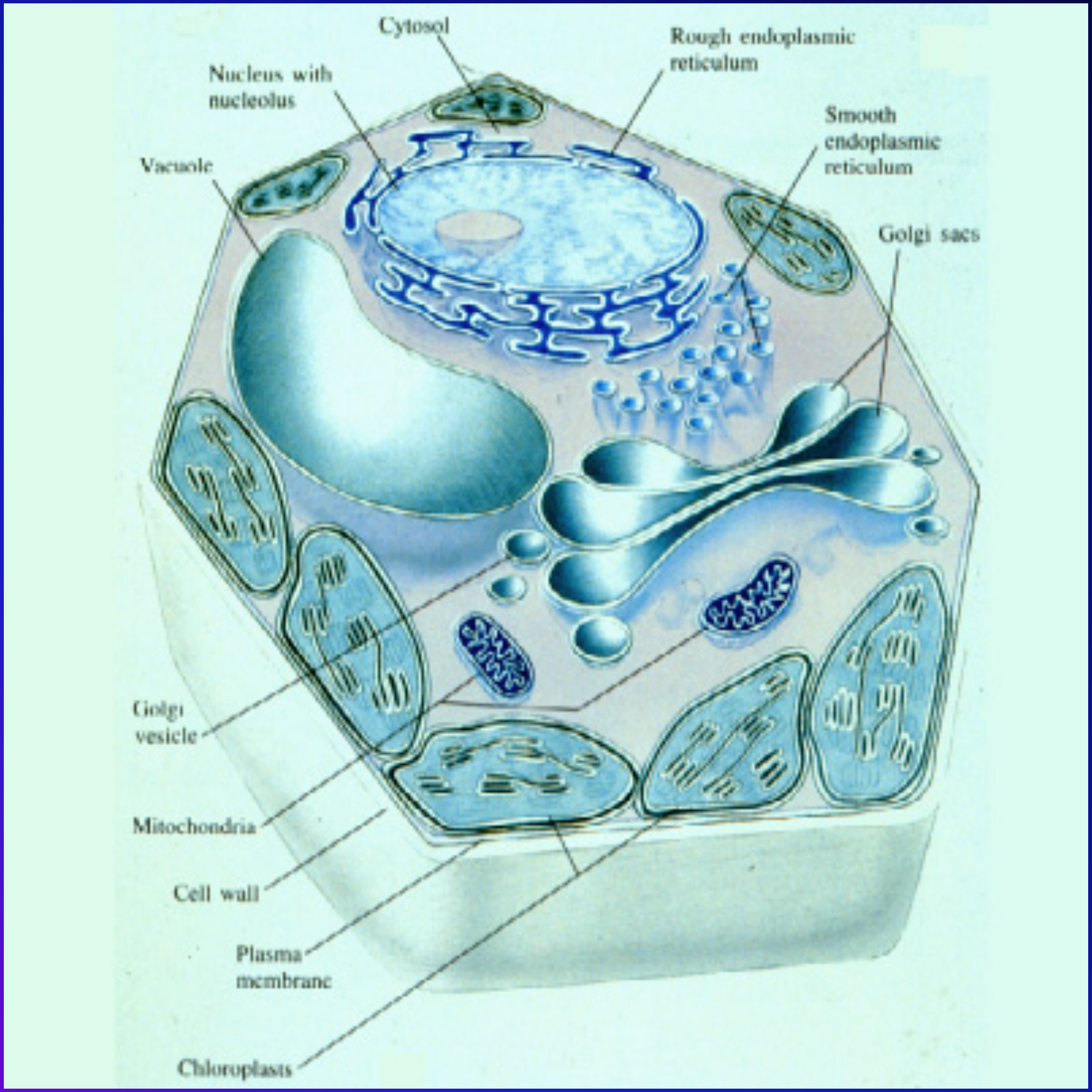
Eukaryotic and Prokaryotic Cells

Prokaryote = without a nucleus
Eukaryote = with a nucleus

Anandi R

Eukaryotic cells



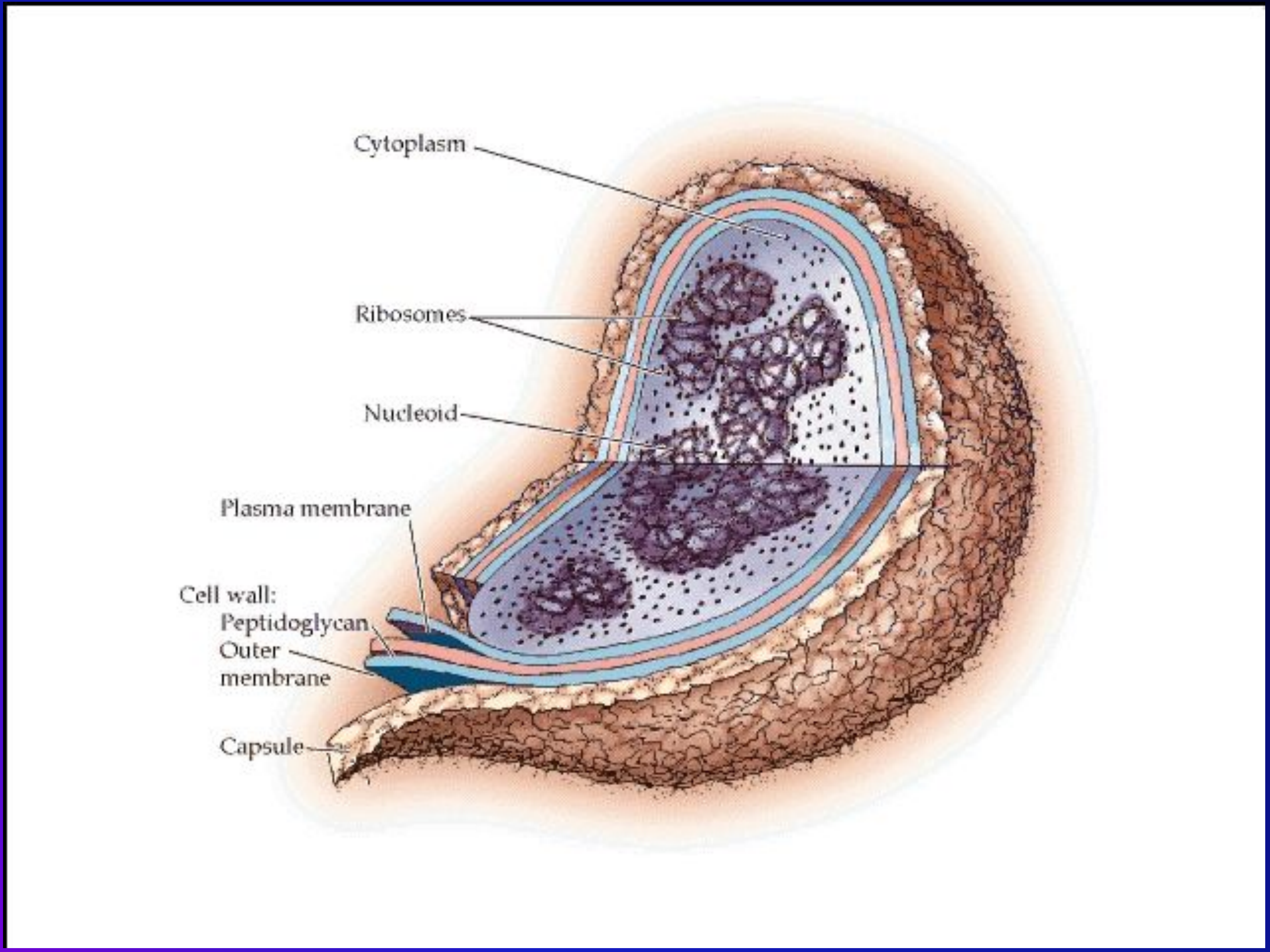
Components

- Cytoplasm
- Nucleus
- Mitochondria
- Chloroplast
- Ribosomes
- RER
- SER
- Golgi body
- Vacuoles

Components cont.

- Lysosomes
- Cytoskeleton
- Centriole
- Cilium and Flagellum
- Microvilli
- Cell membrane
- Cell Wall

Prokaryotic cells



Components

- Cytoplasm
- Ribosomes
- Nuclear Zone
- DNA
- Plasmid
- Cell Membrane
- Mesosome
- Cell Wall
- Capsule (or slime layer)
- Flagellum

Summary of differences!

Prokaryotic Cells	Eukaryotic cells
small cells (< 5 mm)	larger cells (> 10 mm)
always unicellular	often multicellular
no nucleus or any membrane-bound organelles	always have nucleus and other membrane-bound organelles
DNA is circular, without proteins	DNA is linear and associated with proteins to form chromatin
ribosomes are small (70S)	ribosomes are large (80S)
no cytoskeleton	always has a cytoskeleton
cell division is by binary fission	cell division is by mitosis or meiosis
reproduction is always asexual	reproduction is asexual or sexual

Basic terminology

- **Anticodon**

A sequence of three bases in tRNA that is complementary to a codon in mRNA. Enables tRNA to sequence amino acids in the order specified by mRNA.

- **Autosome**

A non-sex chromosome. Synonymous with *somatic chromosomes* (chromosome pairs 1-22).

Basic terminology

- **Chromosome**

Rod-shaped structures within the cell nucleus that carry genes encoded by DNA.

- **Cis position**

Genes in the cis position are on the same chromosome of a pair of homologous chromosomes.

- **Cloned gene**
- A recombinant DNA molecule with the gene of interest.

Basic terminology

- **Co-dominant**

Genes are co-dominant if both alleles are expressed in the heterozygous state, e.g., *K* and *k* genes

- **Codon**

A sequence of three bases in DNA or RNA that codes for a single amino acid. Enables specific proteins to be made by specific genes.

Basic terminology

- **Crossing over**

The exchange of genetic material between members of a pair of homologous chromosomes.

- **Deletion**

An abnormality in which part of a chromosome (carrying genetic material) is lost.

Basic terminology

- **Diploid number of chromosomes**

The number of chromosomes found in somatic cells, which in humans is 46.

- **DNA**

Deoxyribonucleic acid. Composed of nucleic acids, these molecules encode the genes that allow genetic information to be passed to offsprings.

Basic terminology

- **DNA polymerases**

Enzymes that can synthesize new DNA strands using previously synthesized DNA (or RNA) as a template.

- **DNA probe**

A cloned DNA molecule labelled with a radioactive isotope (e.g., ^{32}P or ^{35}S) or a nonisotopic label (e.g. biotin). Used in molecular genetics to identify complementary DNA sequences by hybridizing to them.

Basic terminology

- **Dominant gene**

A gene is dominant if it is expressed when heterozygous but its allele is not.

- **Functional genes**

Genes that produce proteins, e.g., blood group genes that produce antigens.

- **Gene**

A segment of a DNA molecule that codes for the synthesis of a single polypeptide.

Basic terminology

- **Gene interaction**

The situation in which genes inherited at different loci.

- **Genome**

Term used to denote the entire DNA sequence (gene content) of a gamete, person, population, or species.

Basic terminology

- **Homologous chromosomes**

A matched pair of chromosomes, one from each parent.

- **Linkage**

Genes are linked if they are on the same chromosome within a measurable distance of each other and are normally inherited together.

- **Locus**

The location of allelic genes on the chromosome. (*Plural = loci*)

Basic terminology

- **Messenger RNA (mRNA)**

Type of RNA polymerase using DNA as a template. Contains the codons that encompass the genetic codes to be translated into protein.

- **Nucleic acids**

Polymers of phosphorylated nucleosides, the building blocks of DNA and RNA.

Basic terminology

- **Nucleoside**

The building blocks of RNA and DNA. Compounds consisting of a purine (adenine or guanine) or pyrimidine (thymine or cytosine) attached to ribose (in RNA) or deoxyribose (in DNA) at the 1^{1} carbon.

Basic terminology

- **Operator**

A short sequence of nucleotides that controls the adjacent structural (functional) genes.

- **Operon**

A postulated unit of gene action that consists of an operator and the closely linked functional genes it controls.

Basic terminology

- **Plasmid**
- Extrachromosomal circular DNA in bacteria. Plasmids can independently replicate and encode a product for drug resistance or some other advantage. Used in molecular genetics as vectors for cloned segments of DNA.

Basic terminology

- **Reverse transcriptase**

An RNA-dependent DNA polymerase that synthesizes DNA from an RNA template. Used by retroviruses like the human immunodeficiency virus (HIV) to make proviral DNA from its RNA genome.

- **Transcription**

Synthesis of single-stranded RNA by RNA polymerase using DNA as a template.

Basic terminology

- **Restriction fragment length polymorphisms (RFLP)**

Regions of DNA of varying lengths that can be cut out of DNA by restriction endonucleases. Because the fragment lengths vary among individuals, they are polymorphic and can be used as genetic markers.

Basic terminology

- **Translation**
- The process of translating the codon sequence in mRNA into polypeptides with the help of tRNA and ribosomes.

Eukaryotic and prokaryotic genome

Genome

- The word “genome,” coined by German botanist Hans Winkler in 1920, was derived simply by combining ***gene*** and the final ***chromosome*.**
- An organism’s **genome** is defined as the complete haploid genetic complement of a typical cell.
- In diploid organisms, sequence variations exist between the two copies of each chromosome present in a cell.
- The genome is the ultimate source of information about an organism.

- The number of genomes sequenced in their entirety is now in the thousands and includes organisms ranging from bacteria to mammals.
- The first complete genome to be sequenced was that of the bacterium *Haemophilus influenzae*, in 1995.
- The first eukaryotic genome sequence, that of the yeast *Saccharomyces cerevisiae*, followed in 1996.
- The genome sequence for the bacterium *Escherichia coli* became available in 1997 .
- The much larger effort directed at the human genome was also accelerating

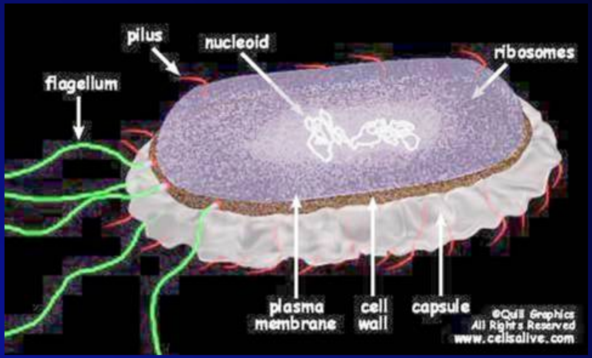
Prokaryotes and Eukaryotes genome

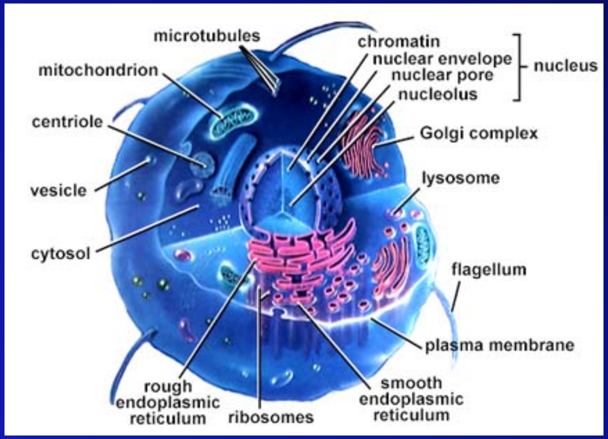
Prokaryotes	Eukaryotes
Single cell	Single or multi cell
No nucleus	Nucleus
One piece of circular DNA	Chromosomes
No mRNA post transcriptional modification	Exons/Introns splicing

Prokaryotic and Eukaryotic Cells
Chromosomal differences

Prokaryotes

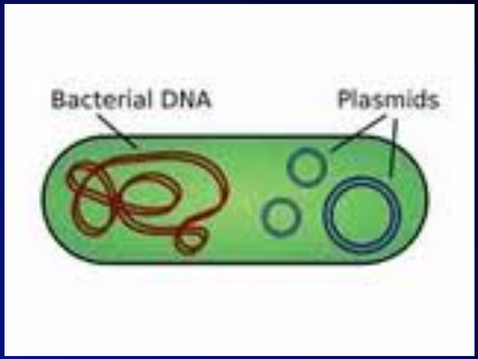
- The genome of E.coli contains amount of $4X10^6$ base pairs
- > 90% of DNA encode protein
- Lacks a membrane-bound nucleus.
  - Circular DNA and supercoiled domain
- Histones not present





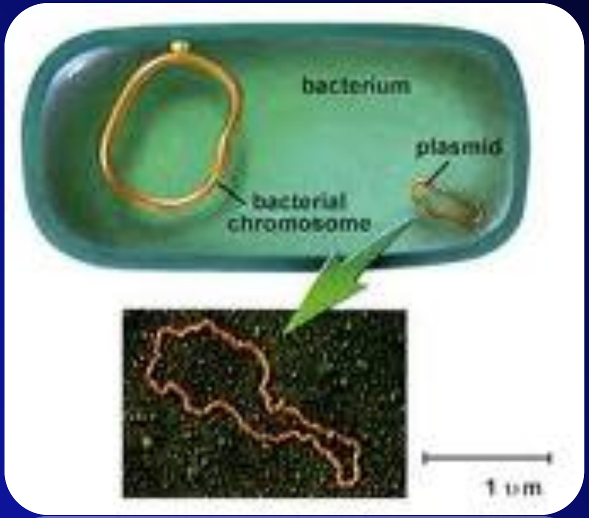
Continue…

- Prokaryotic genomes generally contain one large circular piece of DNA referred to as a "chromosome" (not a true chromosome in the eukaryotic sense).
- Some bacteria have linear "chromosomes".
- Many bacteria have small circular DNA structures called plasmids which can be swapped between neighbors and across bacterial species.



Plasmid

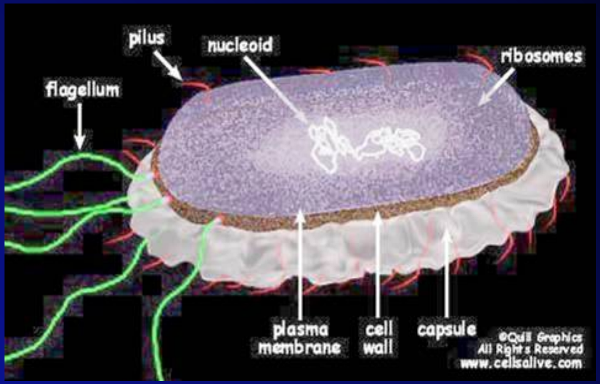
- The term *plasmid* was first introduced by the American molecular biologist Joshua Lederberg in 1952.
- A **plasmid** is separate from, and can replicate independently of, the chromosomal DNA.
- Plasmid size varies from 1 to over 1,000 (kbp).

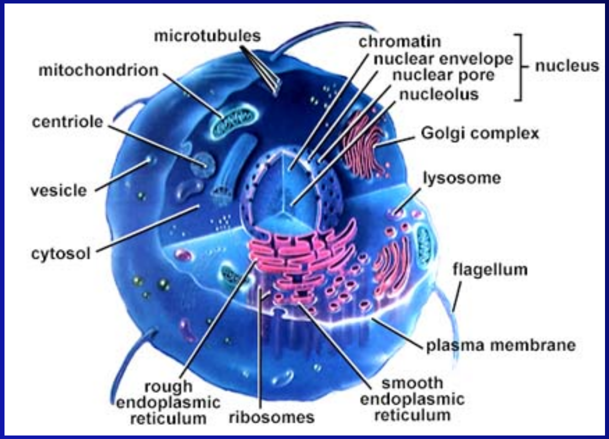


Continue…

Eukaryotes

- The genome of yeast cells contains 1.35×10^7 base pairs
- A small fraction of the total DNA encodes protein.
  - Many repeats of non-coding sequences
- All chromosomes are contained in a membrane bound nucleus
  - DNA is divided between two or more chromosomes
- A set of five histones
  - DNA packaging and gene expression regulation





Karyotype

- The study of chromosomes, their structure and their inheritance is known as *Cytogenetics*.
- Each species has a characteristic number of chromosomes and this is known as *karyotype.*

Bacteria	1
Fruit fly	8
Garden Pea	14
Yeast	16
Frog	26
Cat	38

Fox	34
Mouse	40
Rat	42
Rabbit	44
Human	46
Chicken	78

Continue…

- Prior to 1950's it was believed that humans had 48 chromosomes but in 1956 it was confirmed that each human cell has *46 chromosomes* (Tjio and Levan, 1956).
- On the chromosomes the genes are situated in a linear order.
- Each gene has a precise position or *locus*.
- The size of bacterial chromosomes ranges from 0.6 -10 Mbp, and the size of Archael range from 0.5 - 5.8 Mbp, whereas Eukaryotic chromosomes range from 2.9 - 4,000 Mbp.

Bacterial genome

- Bacterial genomics can give us a broader understanding of how a bacteria functions, a bacterias origins, and what bacteria live in our world that we can study by their DNA.
- Of medical interest, bacterial genomics is also anticipated to play a significant role in speeding up the development of better therapies and vaccines for controlling disease-causing bacteria.
- It will also be the cornerstone of anticipated DNA- based diagnostic tools that will hopefully enable doctors to make quicker, more accurate diagnoses of infectious disease.

Size of Bacterial genome

- The size of Bacterial chromosomes ranges from 0.6 Mbp to over 10 Mbp
- The smallest Bacterial genome identified thus far is from Mycoplasma genitalium, an obligate intracellular pathogen with a genome size of 0.58 Mbp (580 Kbp).
- M. genitalium is restricted to the intracellular niche because it lacks genes encoding enzymes required for amino acid biosynthesis and the peptidoglycan cell wall, genes encoding TCA cycle enzymes, and many other biosynthetic genes.

Size of Bacterial genome

- The smallest free-living organisms have a genome size over 1 Mbp.
- Currently largest sequenced prokaryotic genome is streptomyces, 8.7 Mbp.
- The average gene content is 3,100 genes per genome.

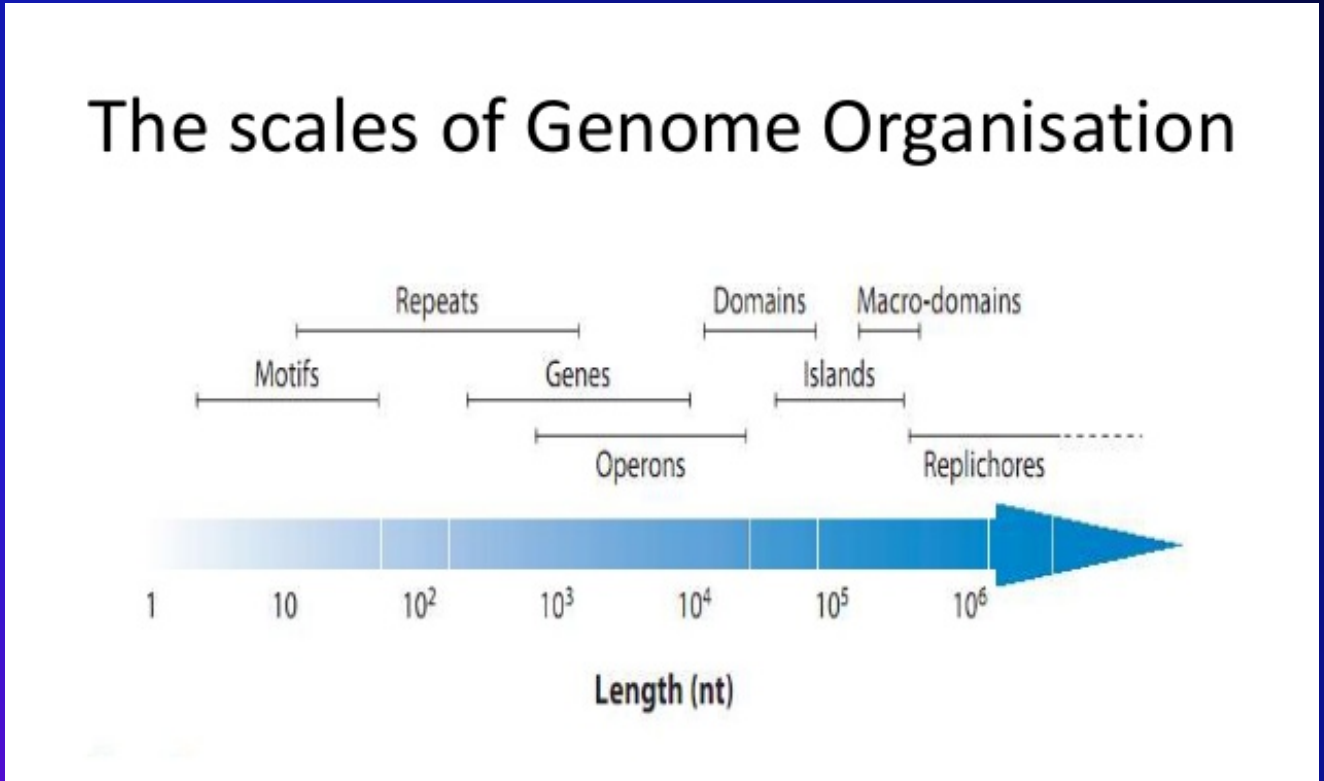
General features of Bacterial Chromosomes

- Not all bacteria have a single circular chromosome.
- some bacteria have multiple circular chromosomes.
- Many bacteria have linear chromosomes and linear plasmids.
- In 1989, pulsed field gel electrophoresis had been developed, and this new technique provided convincing evidence that the chromosome of Borrelia burgdoferi was linear.
- Agrobacterium tumefacians: One linear (2.1 Mb) +One circular (3.0 Mb) + Two circular plasmids (450 kb + 200 Kb)

Genome Packaging in Prokaryotes

- Prokaryotic cells donot 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.

The scales of Genome Organisation



The scales of genome organization.

The scales of Genome Organisation

- Replichores

Are the halves of the chromosome between the origin of replication and terminus region in the vicinity of the dif site.

- Sequence motifs

Is a nucleotide or amino acid sequence pattern

- Genomic islands

It’s a code for symbiosis or pathogenesis.

DNA Supercoiling

- One way prokaryotes compress their DNA into smaller spaces is through 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.

Proteins Involved in Supercoiling

- 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.
- Integration host factor (IHF), can bind to specific sequences within the genome and introduce additional bends.

Proteins Involved in Supercoiling

- The folded DNA is then organized into a variety of conformations that are supercoiled and wound around tetramers of the HU protein, much like eukaryotic chromosomes are wrapped around histones.
- Once the prokaryotic genome has been condensed, DNA topoisomerase I, DNA gyrase, and other proteins help maintain the supercoils.

Operons

- When different genes are to be expressed in exactly the same amount because they are part of a complex, transcription of all genes in a single transcript diminishes gene expression.
- Pairs of divergently oriented operons show correlated expression levels this is because sometimes they share bidirectional regulatory regions that allow co regulation of the two operons.

Table : Prokaryotic versusEukaryotic Chromosomes

Prokaryotic Chromosomes	Eukaryotic Chromosomes
•Many prokaryotes contain a single circular chromosome. •Prokaryotic chromosomes are condensed in the nucleoid via DNA supercoiling and the binding of various architectural proteins. •Because prokaryotic DNA can interact with the cytoplasm, transcription and translation occur simultaneously. •Most prokaryotes contain only one copy of each gene (i.e., they are haploid). •Nonessential prokaryotic genes are commonly encoded on extrachromosomal plasmids. •Prokaryotic genomes are efficient and compact, containing little repetitive DNA.	•Eukaryotes contain multiple linear chromosomes. •Eukaryotic chromosomes are condensed in a membrane-bound nucleus via histones. •In eukaryotes, transcription occurs in the nucleus, and translation occurs in the cytoplasm. •Most eukaryotes contain two copies of each gene (i.e., they are diploid). •Some eukaryotic genomes are organized into operons, but most are not. •Extrachromosomal plasmids are not commonly present in eukaryotes. •Eukaryotes contain large amounts of noncoding and repetitive DNA.