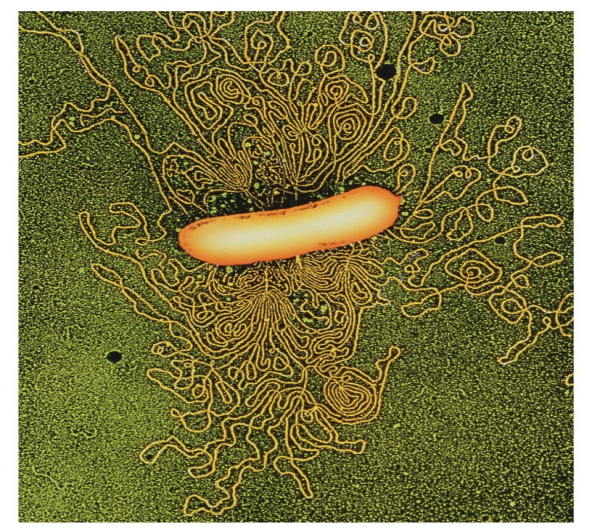
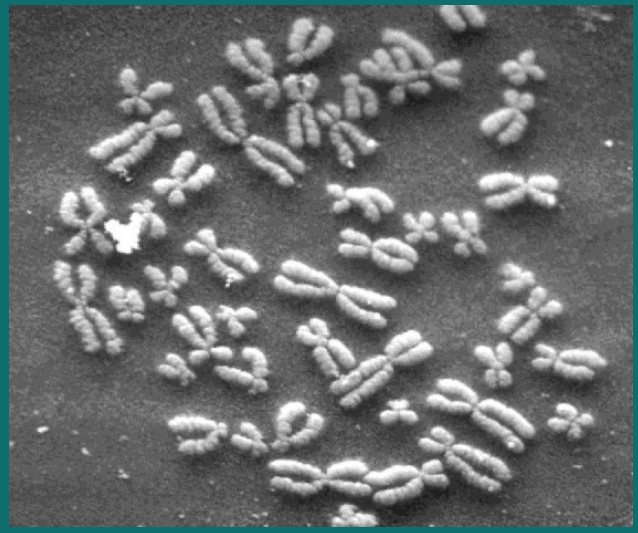
Architecture of Viral, Prokaryotic and Eukaryotic Chromosomes





Zoo 556	Advanced Cytogenetics 2 (1+1)
Objective	To provide zoology graduate students with advanced scientific information about the architecture of chromsomes including viral chromosomes and changes in chromosome structure and number and the diseases or syndromes associated with these changes, especially in humans.
Contents	Architecture of viral, prokaryotic and eukaryotic chromosomes, nature and consequences of altered chromosomal structure, sources and consequences involving chromosome number, karyotype preparation, banding techniques, human chromosomes and the genetic maps.

What Exactly is a chromosome?

Chromosomes are the rod-shaped, filamentous bodies present in the nucleus, which become visible during cell division.

They are the carriers of the gene or unit of heredity.

A chromosome is an organized structure of DNA and protein that is found in cells.

It is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide sequences.

Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions.

Chromosome are not visible in active nucleus due to their high water content, but are clearly seen during cell division.

- Chromosomes were first described by Strausberger in 1875.

- The term "Chromosome", however was first used by Waldeyer in 1888.

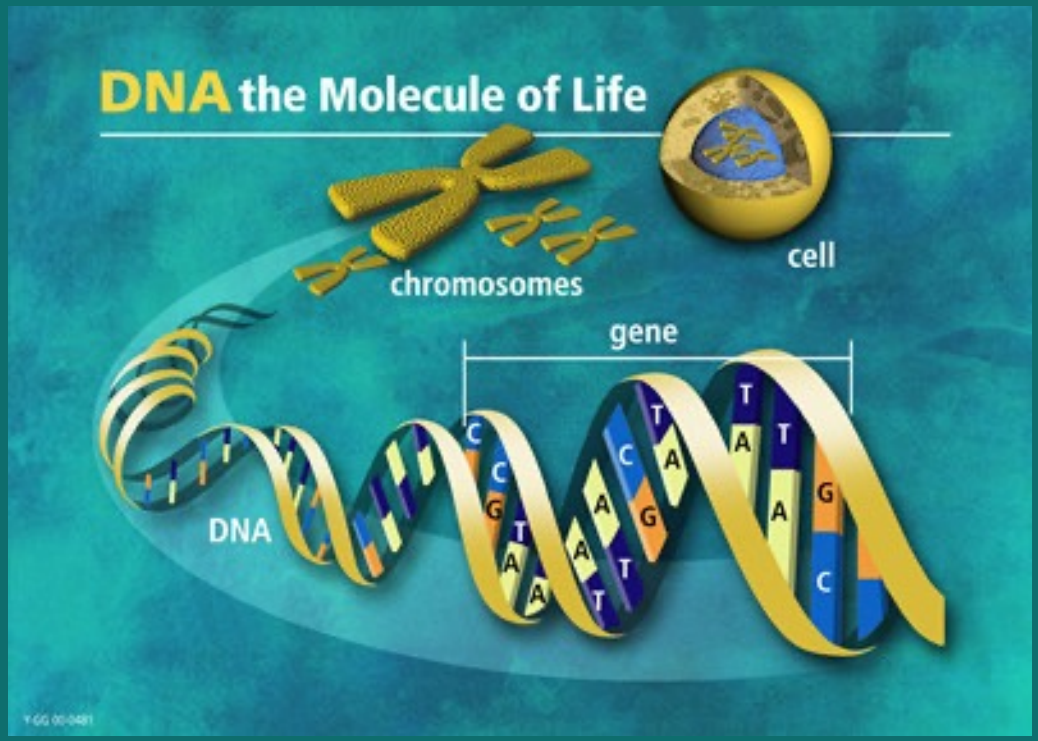
- They were given the name chromosome (Chromo = colour; Soma = body) due to their marked affinity for basic dyes.

- Their number can be counted easily only during mitotic metaphase.

- Chromosomes become readily observable under light microscope.

- Chromosomes are composed of thin chromatin threads called Chromatin fibers.

- Genetic material is located in nucleus
- The genetic information is stored in Deoxyribonucleic acid, DNA
- DNA contains the information needed to build an individual
- The basic function of DNA is to store the information for the synthesis of cellular proteins.



- The main function of the genetic material is to store information required to produce an organism
  - The DNA molecule does that through its base sequence

- DNA sequences are necessary for
  - 1. Synthesis of RNA and cellular proteins
  - 2. Proper segregation of chromosomes
  - 3. Replication of chromosomes
  - 4. Compaction of chromosomes
    - So they can fit within living cells

- The genome comprises all the genetic material that an organism possesses
  - In bacteria, it is typically a single circular chromosome
  - In eukaryotes, it refers to one complete set of *nuclear* chromosomes

- Plants also have a chloroplast genome
- Eukaryotes possess a mitochondrial genome

Chromosomes vary widely between different organisms.

The DNA molecule may be circular or linear, and can be composed of 10,000 to 1,000,000,000 nucleotides in a long chain.

Typically eukaryotic cells (cells with nuclei) have large linear chromosomes and prokaryotic cells (cells without defined nuclei) have smaller circular chromosomes,

Furthermore, cells may contain more than one type of chromosome; for example: mitochondria in most eukaryotes and chloroplasts in plants have their own small chromosomes.

Number of chromosomes

- Normally, all the individuals of a **species have the same number** of chromosomes.
- Closely related species usually have similar chromosome numbers.
- Presence of a whole sets of chromosomes is called **euploidy**.
- It includes haploids, diploids, triploids, tetraploids etc.
- Gametes normally contain only one set of chromosome – this number is called **Haploid**
- Somatic cells usually contain two sets of chromosome - **2n : Diploid**

Organism	No. chromosomes
• Human	46
• Chimpanzee	48
• Dog	78
• Horse	64
• Chicken	78
• Goldfish	94
• Fruit fly	8
• Mosquito	6
• Nematode	11(m), 12(f)
• Horsetail	216
• Sequoia	22
• Round worm	2

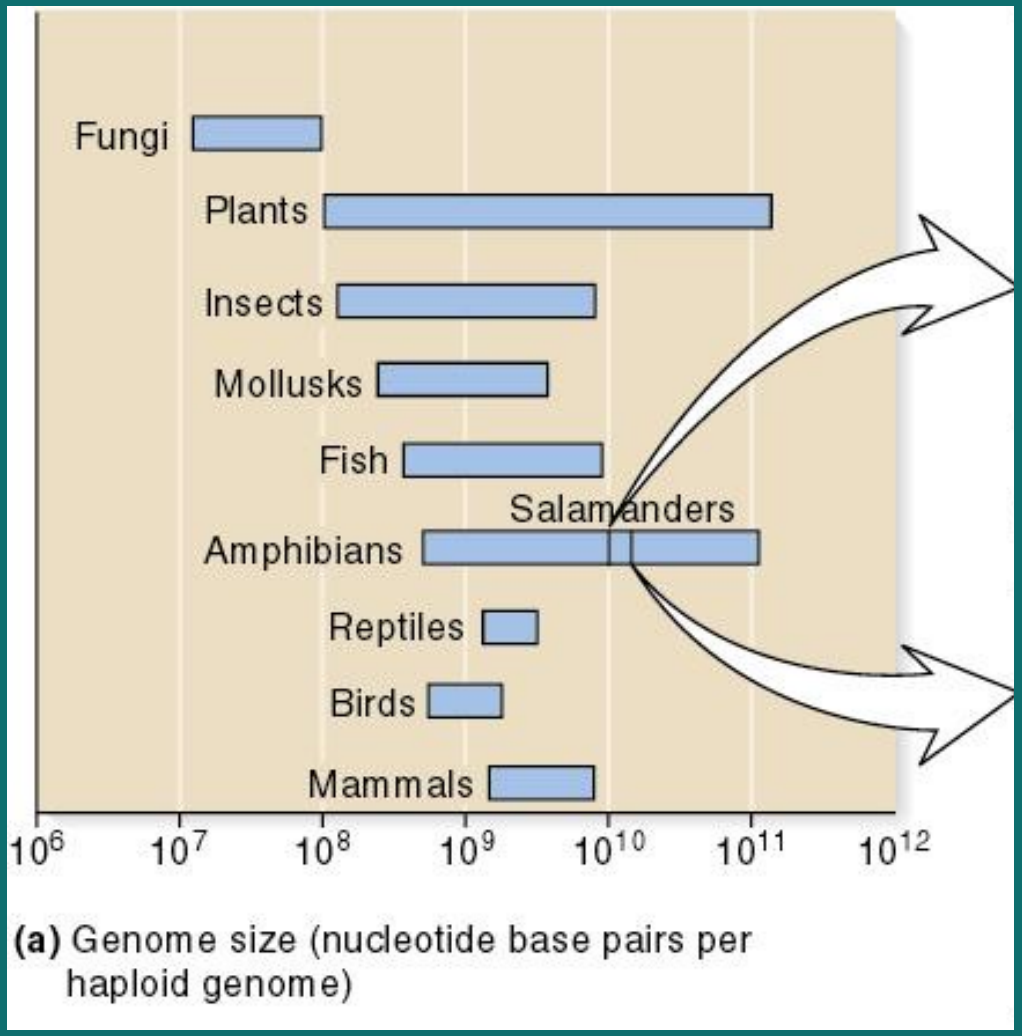
Organism	No. chromosomes
• Onion	16
• Mold	16
• Carrot	20
• Tomato	24
• Tobacco	48
• Rice	24
• Maize	20
• *Haploppus gracilis*	4
• *Crepis capillaris*	6

Chromosome Size

- In contrast to other cell organelles, the size of chromosomes shows a remarkable variation depending upon the stages of cell division.
- **Interphase:** chromosome are longest & thinnest
- **Prophase:** there is a progressive decrease in their length accompanied with an increase in thickness
- **Anaphase:** chromosomes are smallest.
- **Metaphase:** Chromosomes are the most easily observed and studied during metaphase when they are very thick, quite short and well spread in the cell.

Therefore, chromosomes measurements are generally taken during mitotic metaphase.

Variations in DNA Content



The size of the chromosomes in mitotic phase of animal and plants sp generally varies between **0.5 µ and 32 µ** in length, and between **0.2 µ and 3.0 µ** in diameter.

The longest metaphase chromosomes found in ***Trillium*** - **32 µ**.

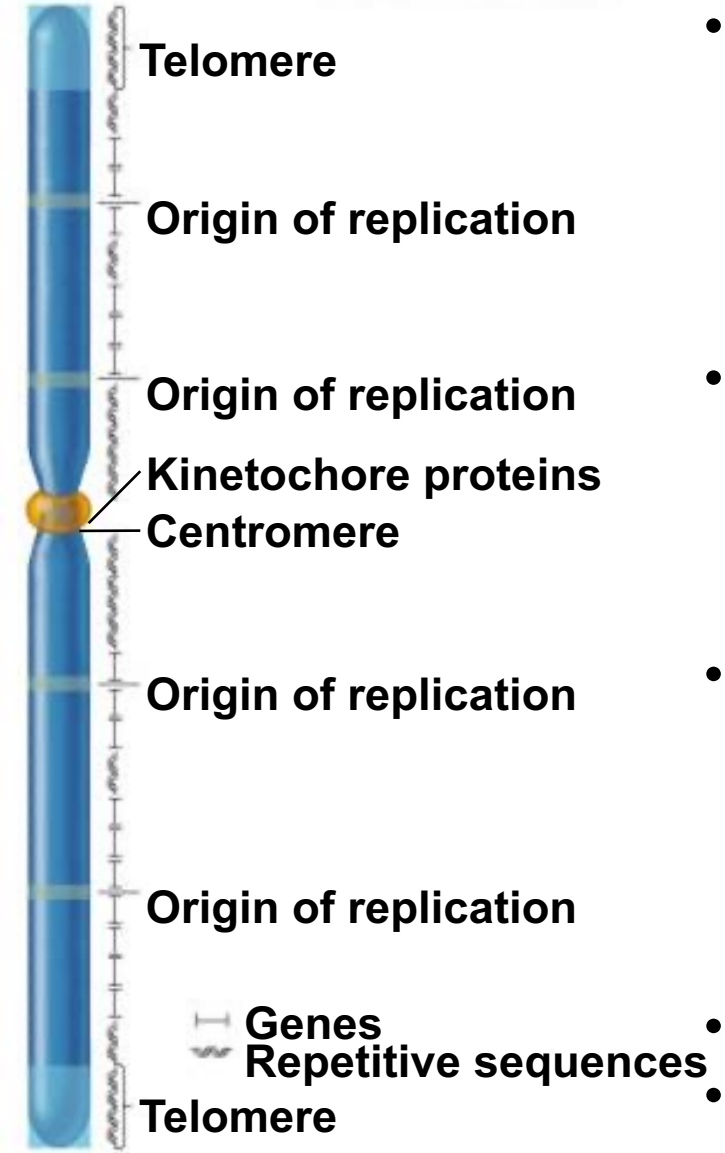
The giant chromosomes found in **diptera** and they may be as long as **300 µ** and up to **10 µ** in diameter.

In general, **plants have longer chromosomes** than animal and species having lower chromosome numbers have long chromosomes than those having higher chromosome numbers

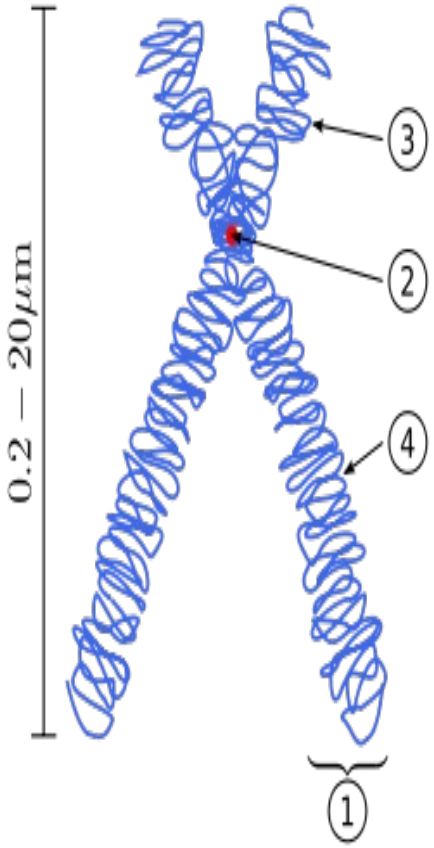
Among plants, **dicots** in general, have a higher number of chromosome than monocots.

Chromosomes are longer in monocot than dicots.

- In order to understand chromosomes and their function, we need to be able to discriminate among different chromosomes.
- First, chromosomes differ greatly in size
- Between organisms the size difference can be over 100-fold, while within a sp, some chromosomes are often 10 times as large as others.
- In a species **Karyotype**, a pictorial or photographic representation of all the different chromosomes in a cell of an individual, chromosomes are usually ordered by size and numbered from largest to smallest.



- Diagram of a duplicated and condensed <u>metaphase</u> eukaryotic chromosome.
- 1. <u>Chromatid</u>– one of the two identical parts of the chromosome after <u>S phase</u>.
- 2. <u>Centromere</u> – the point where the two chromatids touch, and where the microtubules attach.
- 3. Short arm.
- 4 Long arm.



Chromosome Organization

- Genes located between centromere & telomeres
  - hundreds to thousands of genes
  - lower eukaryotes (i.e. yeast)
    - Genes are relatively small
    - Very few introns
  - higher eukaryotes (i.e. mammals)
    - Genes are long
    - Have many introns
- Non-gene sequences
  - Repetitive DNA
    - Telomere
    - Centromere
    - Satellite

Prokaryote Basics

- The largest and most obvious division of living organisms is into prokaryotes vs. eukaryotes.
- Eukaryotes are defined as having their genetic material enclosed in a membrane-bound nucleus, separate from the cytoplasm. In addition, eukaryotes have other membrane-bound organelles such as mitochondria, lysosomes, and endoplasmic reticulum. almost all multicellular organisms are eukaryotes.
- In contrast, the genome of prokaryotes is not in a separate compartment: it is located in the cytoplasm (although sometimes confined to a particular region called a "nucleoid"). Prokaryotes contain no membrane-bound organelles; their only membrane is the membrane that separates the cell form the outside world. Nearly all prokaryotes are unicellular.

Prokaryote vs. Eukaryote Genetics

- Prokaryotes are haploid, and they contain a single circular chromosome. In addition, prokaryotes often contain small circular DNA molecules called “plasmids”, that confer useful properties such as drug resistance. Only circular DNA molecules in prokaryotes can replicate.
- In contrast, eukaryotes are often diploid, and eukaryotes have linear chromosomes, usually more than 1.

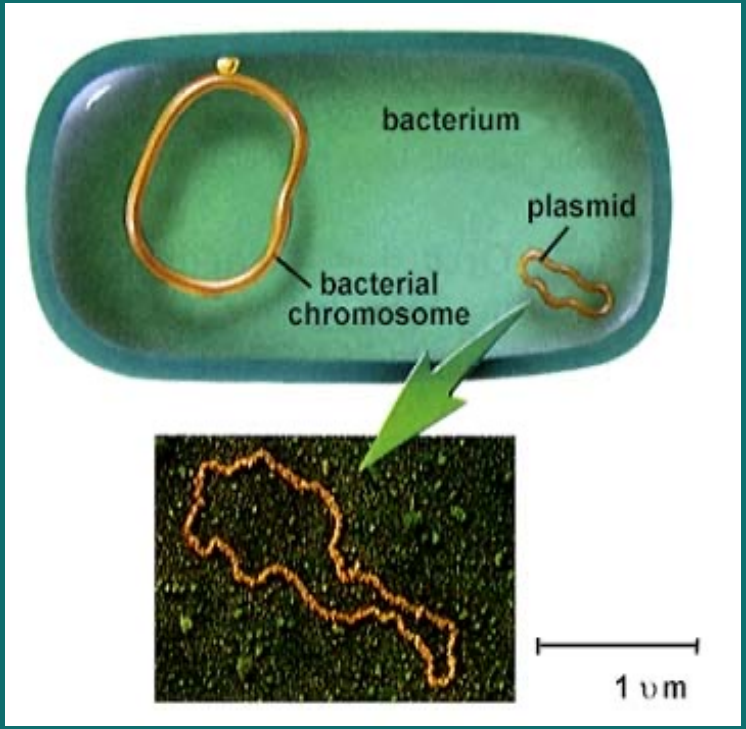
- In eukaryotes, transcription of genes in RNA occurs in the nucleus, and translation of that RNA into protein occurs in the cytoplasm. The two processes are separated from each other.
- In prokaryotes, translation is coupled to transcription: translation of the new RNA molecule starts before transcription is finished.

Chromosomes in eukaryotes and prokaryotes are different

PROKARYOTES	EUKARYOTES
single chromosome plus plasmids	many chromosomes
circular chromosome	linear chromosomes
made only of DNA	made of chromatin, a nucleoprotein (DNA coiled around histone proteins)
found in cytoplasm	found in a nucleus
copies its chromosome and divides immediately afterwards	copies chromosomes, then the cell grows, then goes through mitosis to organise chromosomes in two equal groups

Prokaryotic chromosome

- The prokaryotes usually have only one chromosome, and it bears little morphological resemblance to eukaryotic chromosomes.
- Among prokaryotes there is considerable variation in genome length bearing genes.
- The genome length is smallest in RNA viruses
- In this case, the organism is provided with only a few genes in its chromosome.
- The number of gene may be as high as 150 in some larger bacteriophage genome.



- The DNA of eukaryotic cell is **tightly bound** to small **basic proteins (histones)** that package the DNA in an orderly way in the cell nucleus.
- This task is substantial (necessary), given the DNA content of most eukaryotes
- For e.g., the total extended length of DNA in a human cell is nearly **2 m**, but this must be fit into a nucleus with a diameter of only **5 to 10µm.**
- Although DNA packaging is also a problem in bacteria, the mechanism by which prokaryotic DNA are packaged in the cell appears distinct from that eukaryotes and is not well understood.

- In ***E.coli***, about **3000 to 4000 genes** are organized into its one circular chromosome.
- The chromosome exists as a highly folded and coiled structure dispersed throughout the cell.
- The folded nature of chromosome is due to the incorporation of RNA with DNA.
- There are about 50 loops in the chromosome of E.coli.
- These loops are highly **twisted** or **supercoiled** structure with about four million nucleotide pairs.
- Its molecular weight is about **$2.8 X10^9$**
- During replication of DNA, the coiling must be relaxed.
- **DNA gyrase** is necessary for the unwinding the coils.

BACTERIAL CHROMOSOMES

- The bacterial chromosome is found in a region called the nucleoid
- The nucleoid is not membrane-bounded
  - So the DNA is in direct contact with the cytoplasm

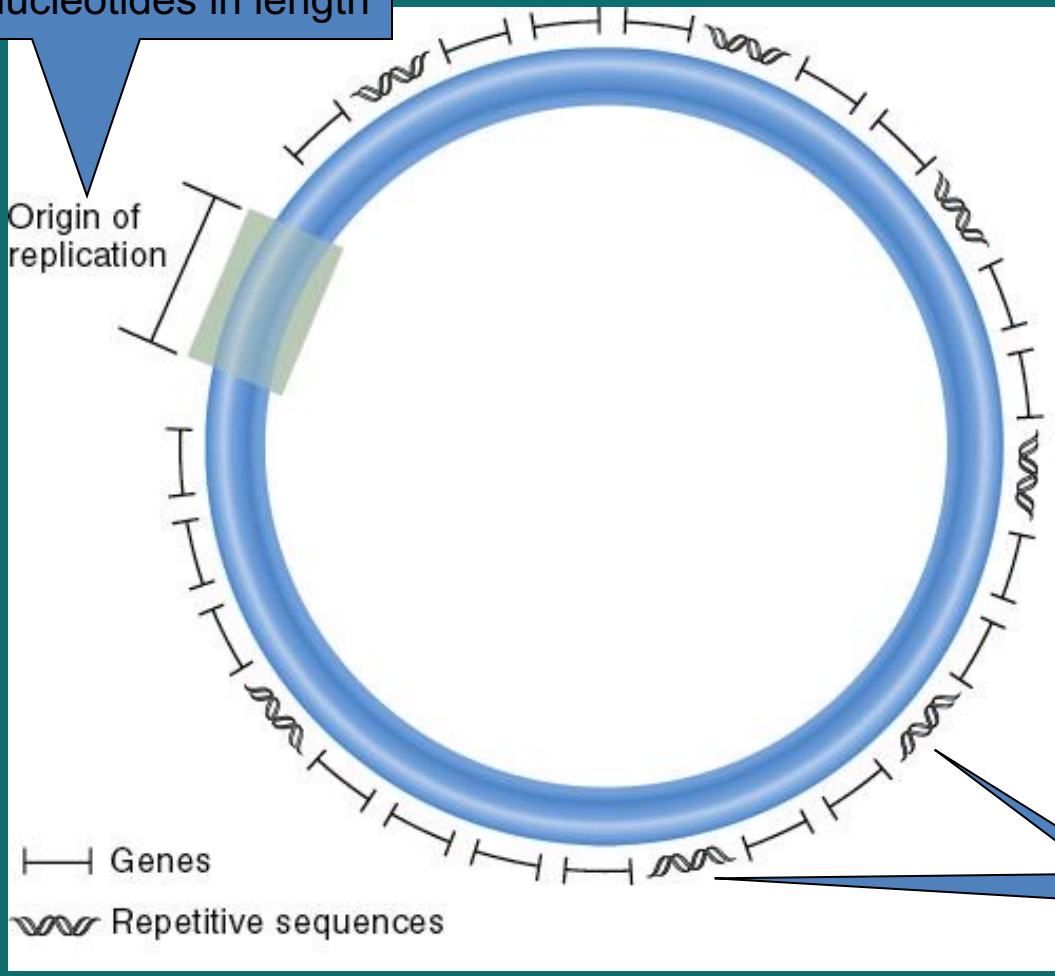
- Bacteria may have one to four identical copies of the same chromosome
  - The number depends on the species and growth conditions

- Bacterial chromosomal DNA is usually a circular molecule that is a few million nucleotides in length
  - *Escherichia coli* → ~ 4.6 million base pairs
  - *Haemophilus influenzae* → ~ 1.8 million base pairs

- A typical bacterial chromosome contains a few thousand different genes
  - Structural gene sequences (encoding proteins) account for the majority of bacterial DNA
  - The nontranscribed DNA between adjacent genes are termed intergenic regions

- Next figure summarizes the key features of bacterial chromosomes

A few hundred nucleotides in length



Key features:

- Most, but not all, bacterial species contain circular chromosomal DNA.
- A typical chromosome is a few million base pairs in length.
- Most bacterial species contain a single type of chromosome, but it may be present in multiple copies.
- Several thousand different genes are interspersed throughout the chromosome.
- One origin of replication is required to initiate DNA replication.
- Short repetitive sequences may be interspersed throughout the chromosome.

These play roles in DNA folding, DNA replication, and gene expression

THANK YOU