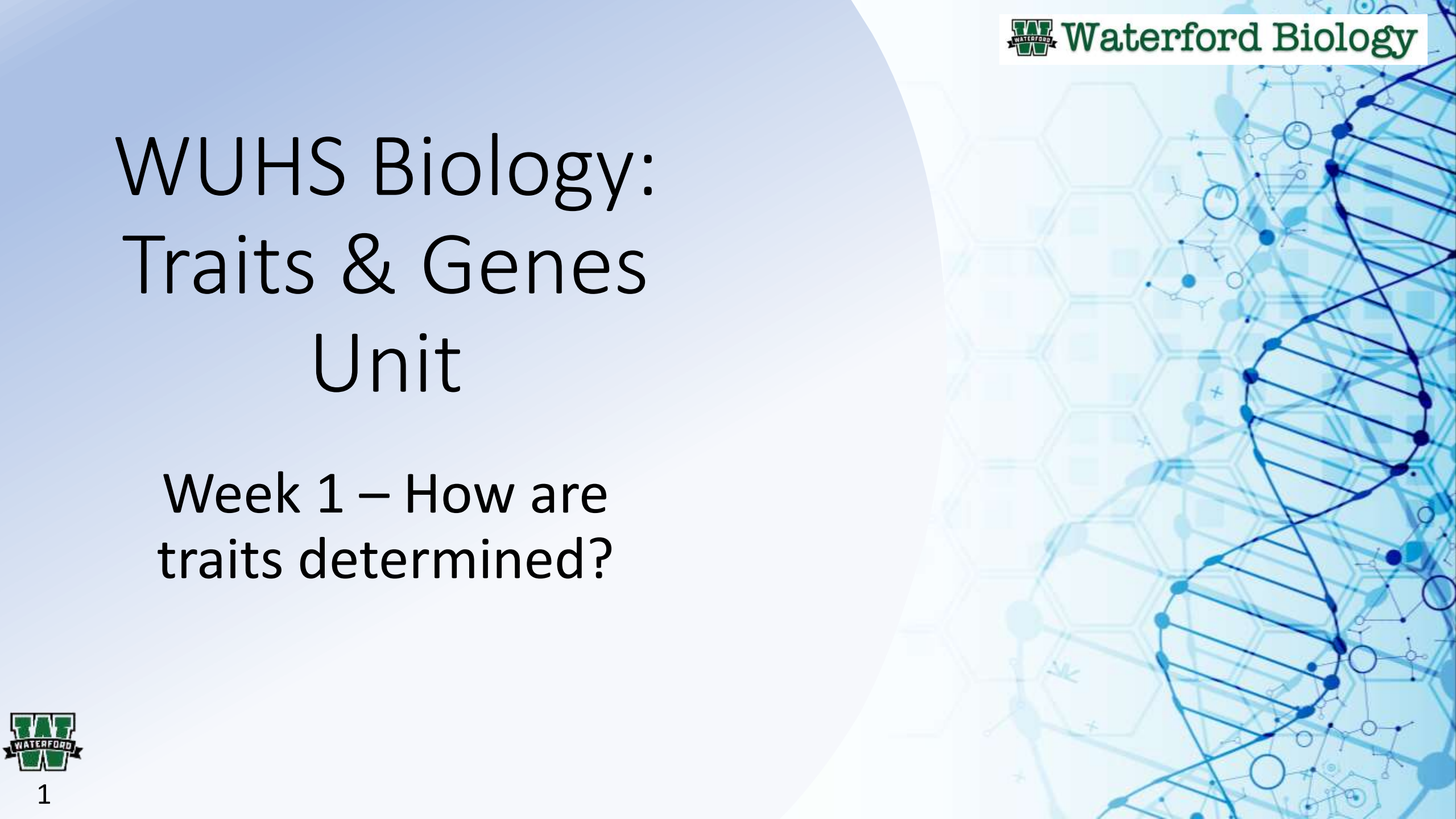
Waterford Biology

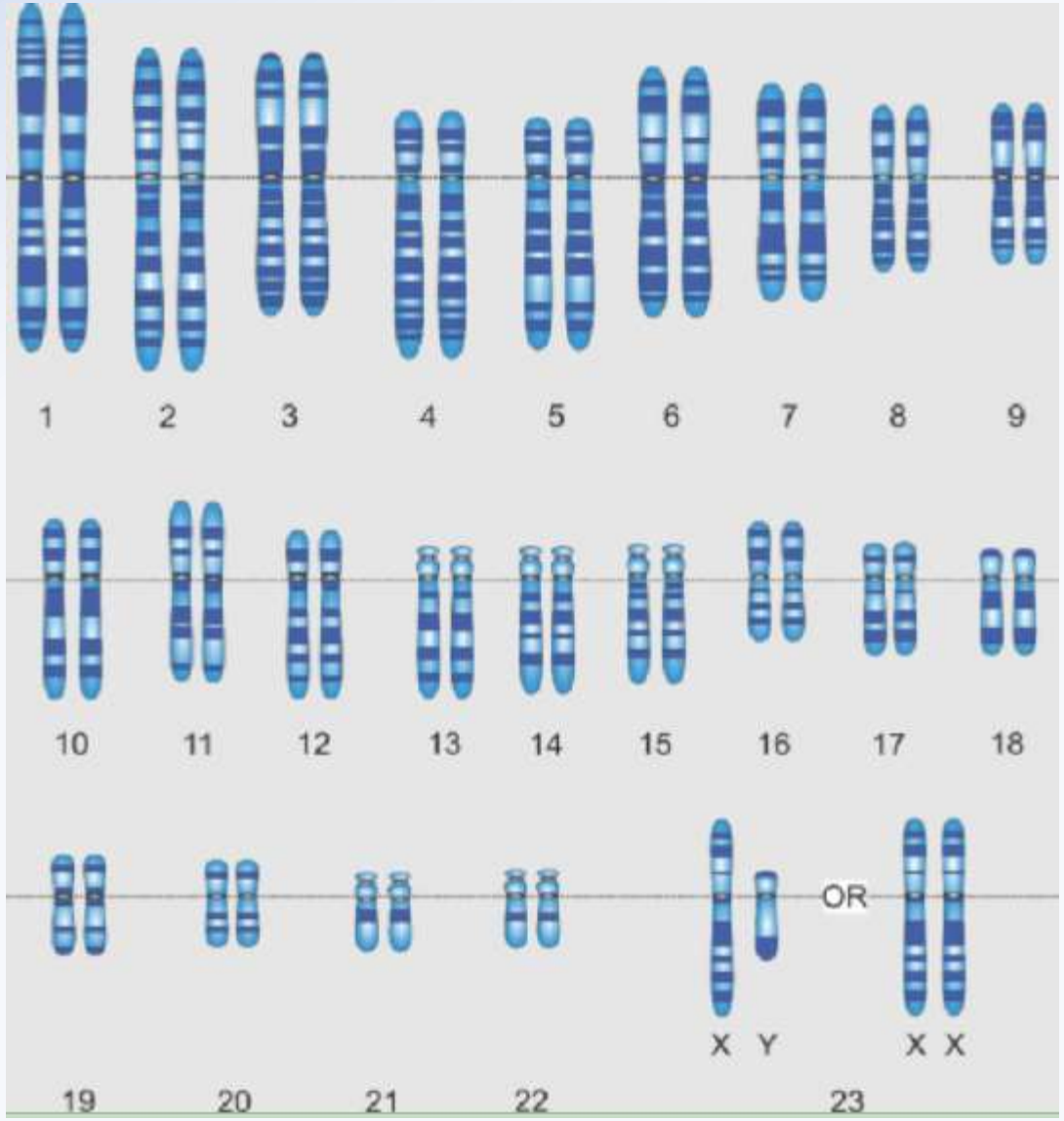
WUHS Biology: Traits & Genes Unit

Week 1 – How are traits determined?



Traits & Genes Unit – W1 Driving Question

- **Driving Question: What determines the traits of an organism?**
- How are the traits of an organism affected by DNA and proteins?
- How do processes at the cellular level determine the observable traits at the organismal level?
- How are the instructions for an organism's traits passed on as cells divide?
- How can one cell become trillions of cells in an organism?

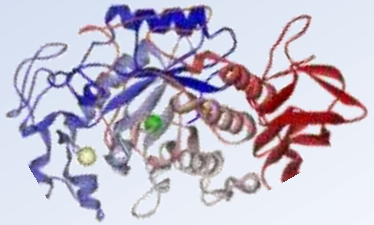


Traits are determined by proteins.

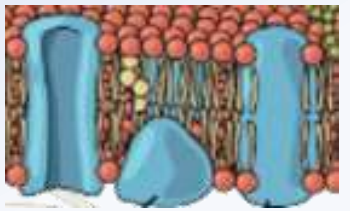
- **All living organisms have physical traits, or observable characteristics.**
  - Examples of traits in your own body include eye color, hair color, height, and all other observable characteristics.
- **An organism's traits are determined by the kinds of proteins assembled in its cells.**
  - Proteins are *macromolecules* (or *polymers*) comprised of long chains of amino acids.
  - Proteins are what perform most cell activities.
  - The order in which amino acids are assembled determines the type of protein.

Functions of Proteins

- **Different kinds of proteins perform different functions within a cell. Examples include:**
  - Enzymes rearrange atoms to form new molecules, or assemble or disassemble polymers.
  - Transporters move atoms or small molecules throughout the cell or the body.
  - Structural Proteins provide physical support and rigidity to shape and hold up an organism's body.
  - Contractile Proteins can lengthen and shorten to allow an organism to move.
  - Signaling Proteins such as hormones send coordinate activities within & among cells.
  - Antibodies attach to viruses & bacteria to protect cells within the body and aid in their identification.

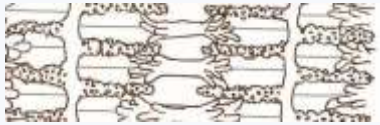


Enzymes such as amylase assemble, disassemble, or re-arrange molecules.

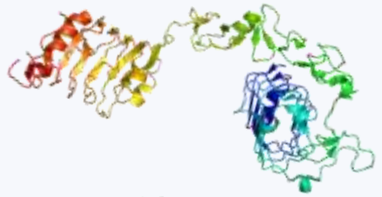


Transport proteins in cell membranes move substances into or out of the cell.

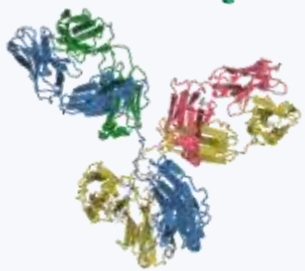
Structural proteins like keratin provide physical support to organisms' bodies.



Contractile proteins like actin & myosin enable muscles to contract & relax.

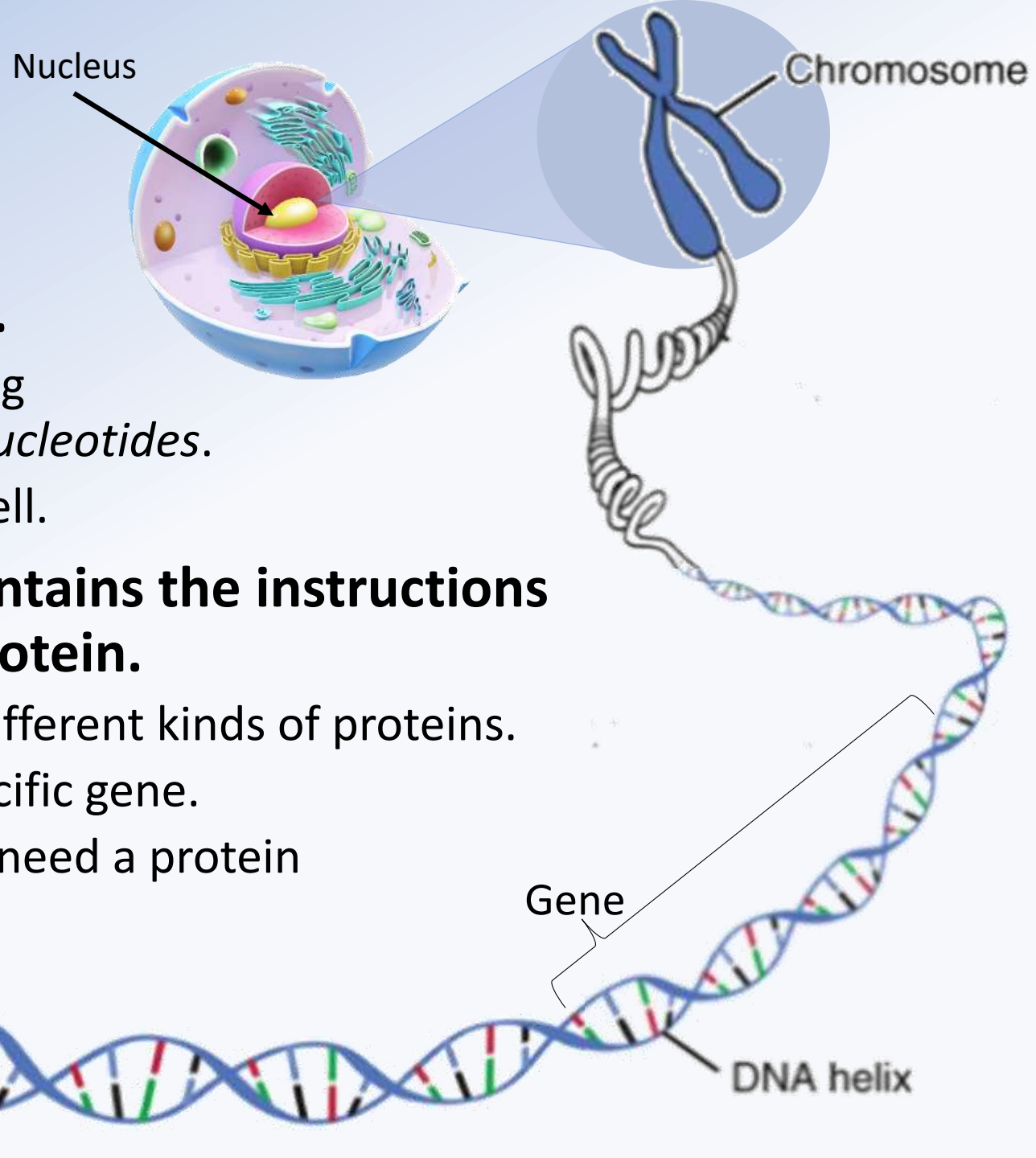


Insulin is a hormone that regulates levels of glucose in the blood.



Antibodies attach to bacteria and viruses in order to protect the body and its cells.

Genes & DNA



- **The instructions for assembling a protein are contained within DNA.**
  - DNA is a macromolecule made of long twisting chains of molecules called *nucleotides*.
  - DNA is stored in the nucleus of the cell.
- **A gene is a section of DNA that contains the instructions for the assembly of a particular protein.**
  - Cells contains tens of thousands of different kinds of proteins.
  - Each protein is associated with a specific gene.
  - For an organism to have a trait, they need a protein and gene specific to that trait*.

*Often traits depend on multiple genes & proteins.

Chromosomes

- **DNA can be coiled into tight packages called <u>chromosomes</u>.**
  - In most cases, a human cell has 23 pairs of chromosomes (or 46 chromosomes altogether) →
  - Animal offspring will inherit one copy of each chromosome from each biological parent.
- **Most of the time, DNA is <u>not</u> found in chromosomes.**
  - DNA is only packed into chromosomes prior to cell division to ensure that it is divided evenly between each cell.
- **Prior to packing DNA into chromosomes, animal cells will duplicate its DNA.**
  - This means a cell will temporarily have four copies of each chromosome before dividing in half →

Humans generally inherit 23 chromosomes from each parent; a cell typically contains 46 chromosomes overall.

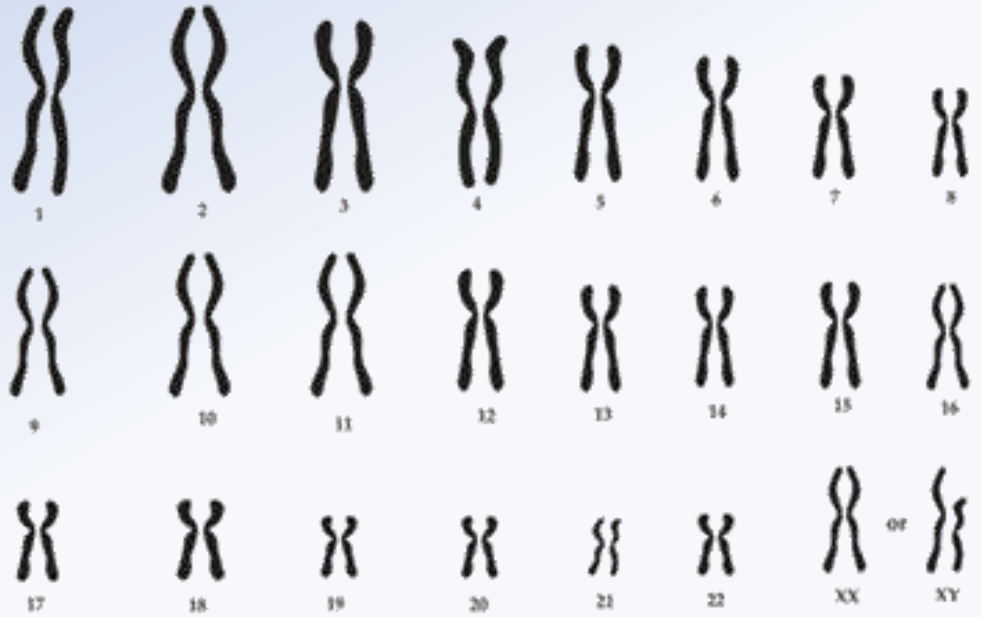
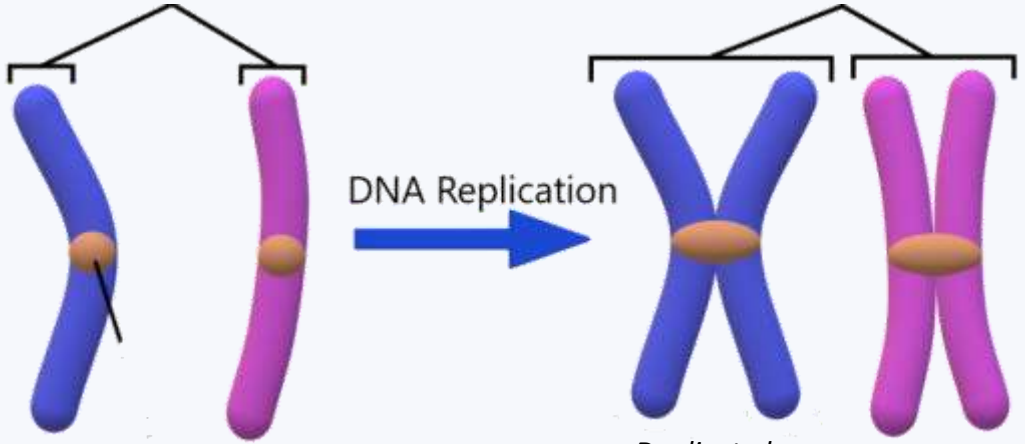


Image Source: Shutterstock

Un-replicated DNA: 2 copies of each gene.

Replicated DNA: 4 copies of each gene.



Genes from male parent

Genes from female parent

Duplicated genes from male parent

Duplicated genes from female parent

Image Source: Wikimedia

Mitosis

- **For an organism to grow, it must acquire atoms from food, assemble new molecules (through *biosynthesis*), and enlarge its cells.**
  - Eventually cells can grow large enough to split into two separate cells.
  - The process of creating new cells through cell division is called mitosis.
  - Mitosis is necessary for an organism to grow larger, to replace dying cells, and to repair wounds and damaged tissue.
- **Replication of DNA is an important to mitosis.**
  - Without DNA, a cell would be unable to assemble the proteins that it needs to function.
  - Packing DNA into chromosomes ensures that genes are split evenly between the two cells.

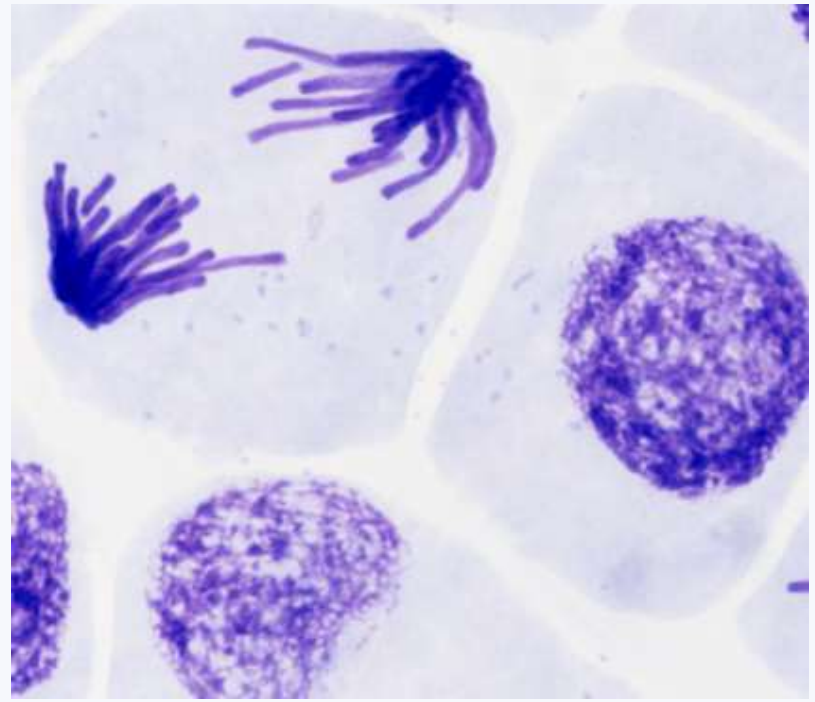
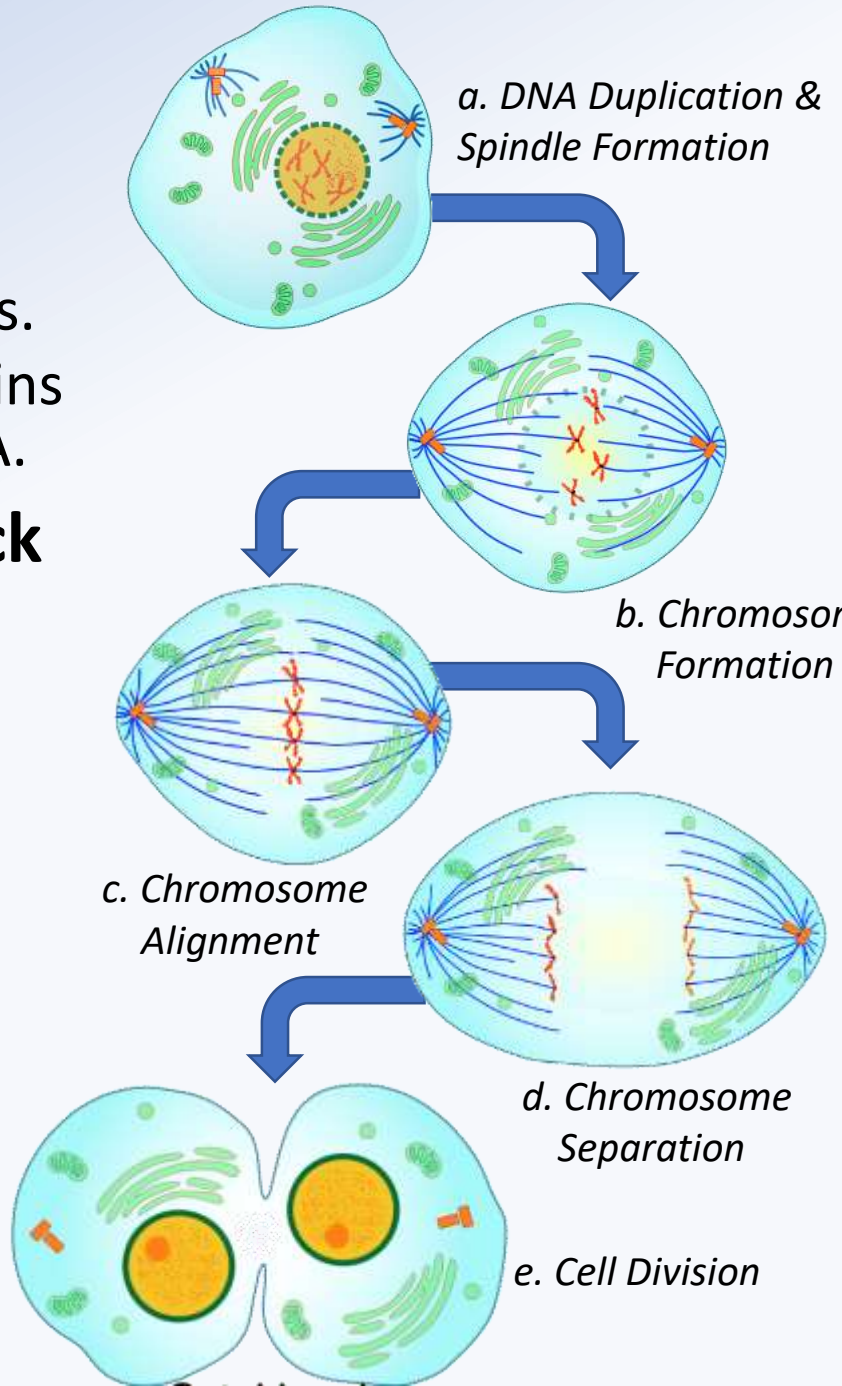


Image Source: Wikimedia

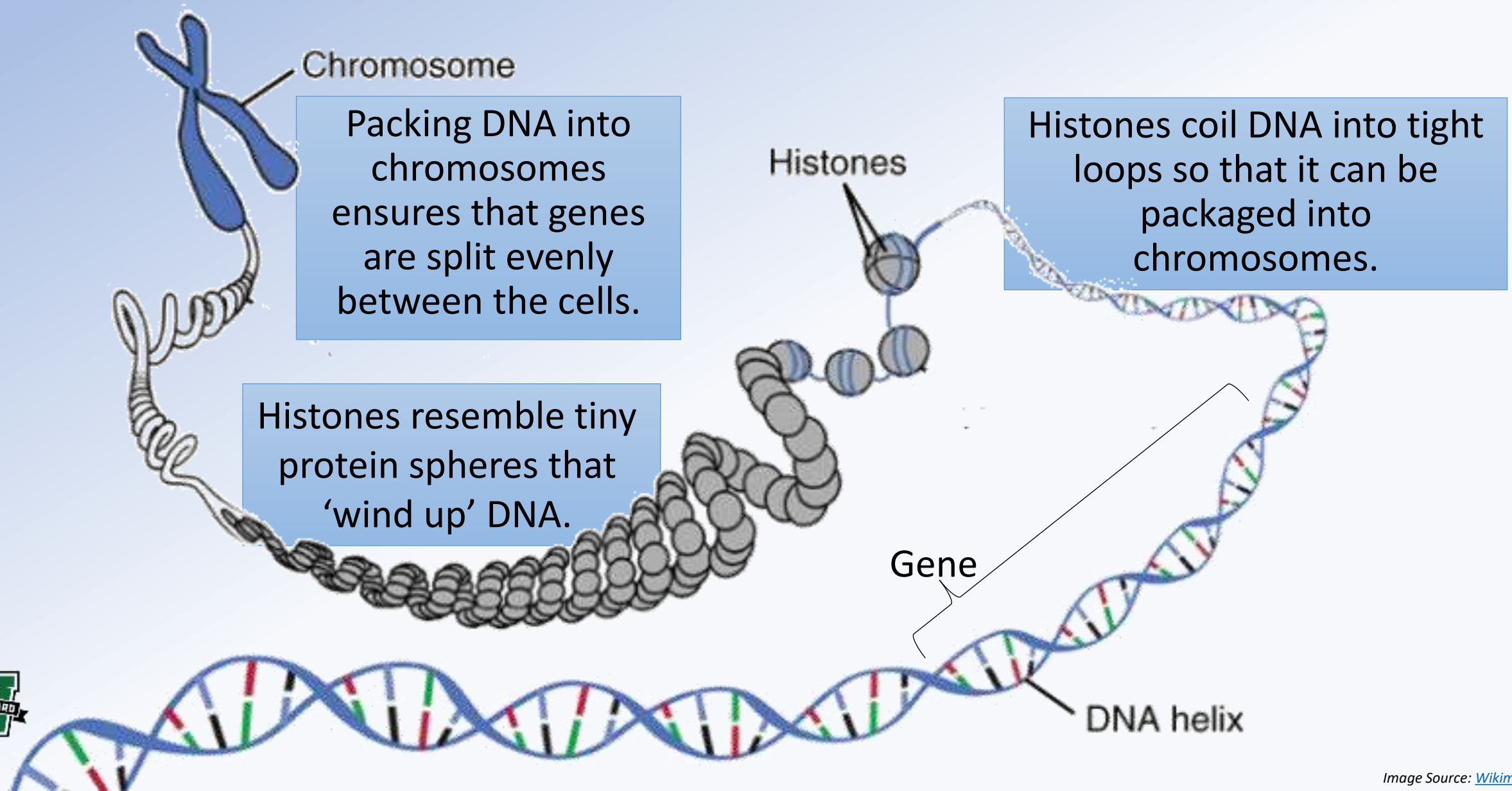
Stages of Mitosis

- **Prior to cell division, a cell must duplicate all its DNA (a).**
  - It must also increase in size and duplicate its organelles.
  - The cell will also assemble specialized structural proteins (called *spindles*) to organize and evenly divide the DNA.
- **The cell then uses proteins called histones to pack the loose DNA into tight packages called chromosomes (b).**
  - Chromosomes then line up on the protein spindles (c).
- **Each chromosome then moves away from its copy (d).**
  - Once separated, the chromosomes unravel from the histone proteins back into loose DNA; the spindle proteins are then disassembled.
  - The large cell then separates into two smaller cells, each with their own copy of DNA (e).

Image Source: Wikimedia



Closer Look at a Histones & Chromosomes



Packing DNA into chromosomes ensures that genes are split evenly between the cells.

Histones coil DNA into tight loops so that it can be packaged into chromosomes.

Histones resemble tiny protein spheres that ‘wind up’ DNA.

Image Source: Wikimedia

Regulation of Mitosis

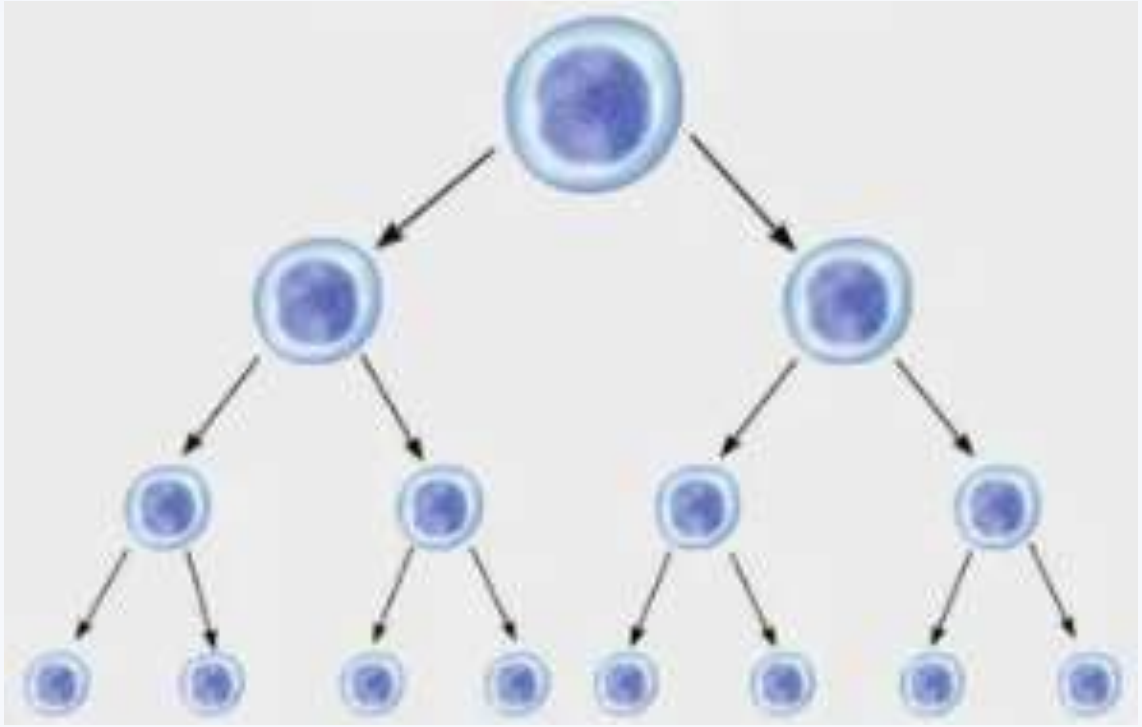
- **An organism must carefully control how rapidly its cells divide.**
  - If cell division is too slow, an organism will struggle to recover from injury and will have a slow rate of growth.
  - If cell division is too rapid, it can disruption bodily function. An extreme form of uncontrolled cell growth and division is cancer.
- **Mitosis and cell division are regulated by specialized proteins such as *cyclin* (which stimulates *spindle* formation) and *growth factors*.**
  - These proteins limit when and how often a cell can divide.
- **Cell growth is also regulated by programmed cell death (or apoptosis).**
  - If a cell is damaged and should not divide, it will produce enzymes that stop cell division and break down the cell →

Image Source: Wikimedia

Exponential Growth

- **Every living organism begins with only one cell; however, most animals have *trillions* of cells.**
  - Exponential growth explains how trillions of cells can form from just one.
- **<u>Exponential growth</u> refers to when an increase in the number of something occurs at a faster and faster rate over time.**
  - For example, when an organism's first cell, divides, it creates 2 cells.
  - These 2 cells will divide into 4 cells.
  - 4 cells can then create 8 cells,
    8 cells can create 16 cells,
    and then 32, then 64, etc.
  - Each time, the number of cells doubles.
- **If each cell divided once a day, it would only take 40 days to reach 1 trillion cells.**

Image Source: Omni



Cell Differentiation

- **Almost all cells in an organism share the same DNA; however, multi-celled organisms require different kinds of cells with different functions.**
  - For example, muscle cells have proteins that contract; nerve cells can send electrical signals; and bone cells can support a body's weight
- **Cells must be able to control which genes are expressed to create different kinds of cells with different jobs and characteristics.**
  - This process is known as cellular differentiation.
  - As cells divide, they receive signals to turn off some genes; within a few days of fertilization, a cell's function is already generally determined.

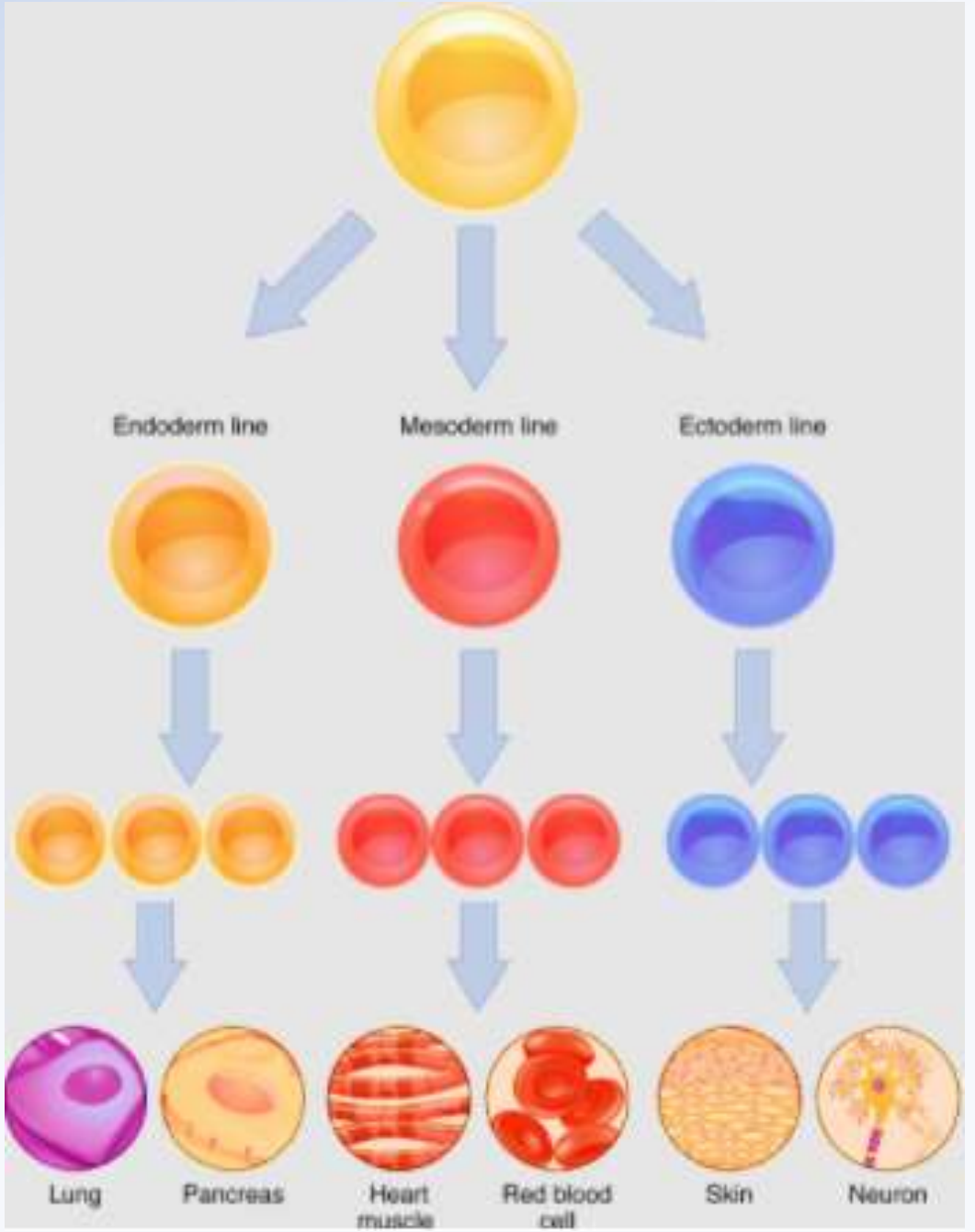
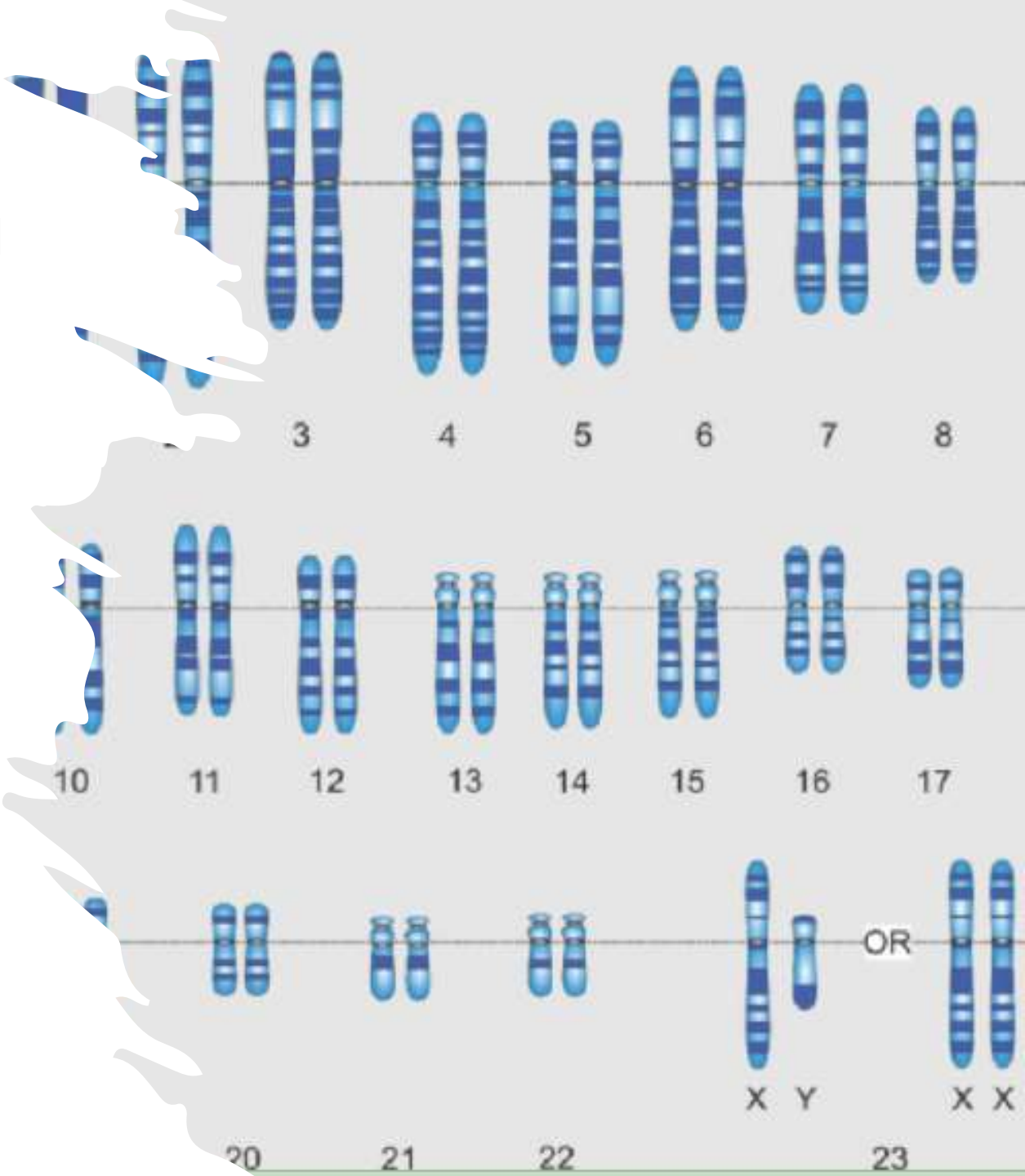


Image Source: Wikimedia

Revising Our Claims

- **Revisit your ideas from Part 1. How could you improve your responses to our Driving Questions?**
  - What determines the traits of an organism?
  - How do DNA and proteins affect the traits of an organism?
  - How do processes at the cellular level determine the observable traits at the organismal level?
  - How are the instructions for an organism's traits passed on as a cell divides?
  - How can one cell become trillions of cells in an organism?



Looking Ahead: Part 3 Investigation

- **In Part 3 you will be conducting two investigations.**
  - In Part A, you will use your understanding of the steps of mitosis to determine the correct order of images of cells dividing.
  - In Part B, you will observe different stages of mitosis in both plant and animal cells using a microscope.

Key Points

- **An organism's traits are determined by the kinds of proteins assembled in its cells.**
- **Different kinds of proteins perform different functions within a cell. Types of proteins include enzymes, transporters, structural, contractile, signaling, and antibodies.**
- **The instructions for assembling a protein are contained within DNA, a long twisting macromolecule.**
- **A gene is a section of DNA that contains the instructions for the assembly of a particular protein. For an organism to have a trait, they need a protein and gene specific to that trait.**
- **DNA can be coiled into tight packages called chromosomes. DNA is packed into chromosomes prior to mitosis to ensure that it is divided evenly between each cell.**

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Key Points

- **The process of creating new cells through cell division is called mitosis.**
- **Replication of DNA prior to mitosis is important to ensure each cell has the instructions needed to assemble the proteins that it needs to function.**
- **Duplicating DNA and packing it into chromosomes before mitosis ensures that genes are split evenly between the two cells.**
- **Mitosis consists of a few key steps, including… a) duplicating DNA and assembling spindle proteins; b) packing DNA into chromosomes using histones; c) lining duplicated chromosomes onto spindles; d) separating the chromosome copies; and e) dividing the cell in half.**

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Key Points

- **Cell division must be carefully regulated. Slow cell division limits the rates of growth and healing. Overly-rapid cell division can result in cancer.**
- **Regulator proteins like *cyclin* (which stimulates *spindle* formation) and *growth factors* limit when and how often a cell can divide.**
- **Exponential growth explains how trillions of cells can form from just one. In only 40 cycles of doubling, one cell can become trillions.**
- **While cells in an organism share the same DNA, multi-celled organisms require different kinds of cells with different functions. Through cellular differentiation, cells receive signals to turn off some genes, which determines a cell's eventual function.**

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Key Vocab

- **Physical traits: the observable characteristics of an organism.**
- **Proteins: a type of macromolecule (or *polymer*) comprised of long chains of amino acids that perform most cell activities.**
- **DNA: a macromolecule made of long twisting chains of molecules called *nucleotides*.**
- **Gene: a section of DNA that contains the instructions for the assembly of a particular protein.**
- **Chromosome: a tightly coiled package of DNA; chromosomes ensure DNA is divided evenly between each cell during mitosis.**
- **Mitosis: cell division with DNA replication.**
- **Spindles: specialized structural proteins that organize & evenly divide DNA.**
- **Histones: proteins that coil the loose DNA into tight packages.**
- **Cancer: an extreme form of uncontrolled cell growth and division.**
- **Apoptosis: programmed cell death.**
- **Exponential growth: an increase in the number of something occurring at a faster rate over time.**
- **Cellular differentiation: changing which genes are expressed to create different kinds of cells with different jobs and characteristics.**

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