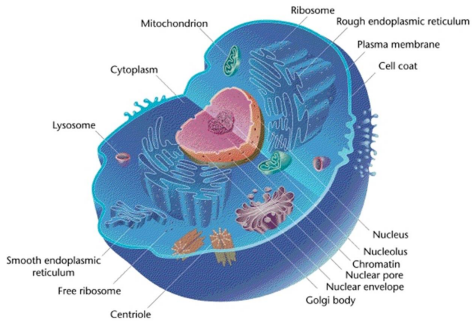
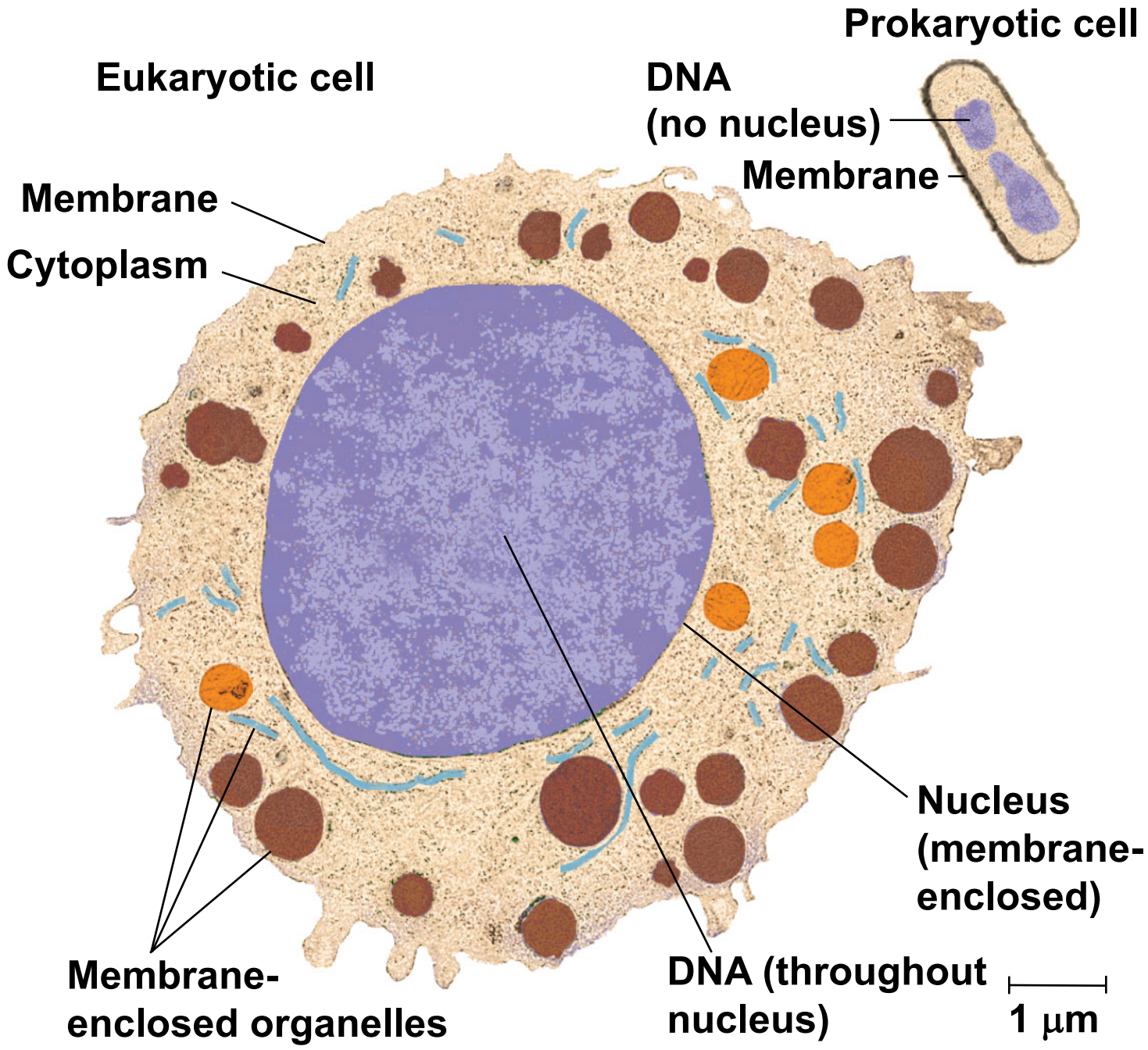
# The cell as the basic unit of life




| Prokaryotic | Eukaryotic |
|---|---|
| Bacteria, most single-celled organisms | All multicellular organisms |
| Simple, smaller | Larger, more complex |
| Lack membrane-bound organelles such as nucleus | Contain membrane-bound organelles such as a nucleus |
| Circular DNA | Linear DNA (chromosomes) |

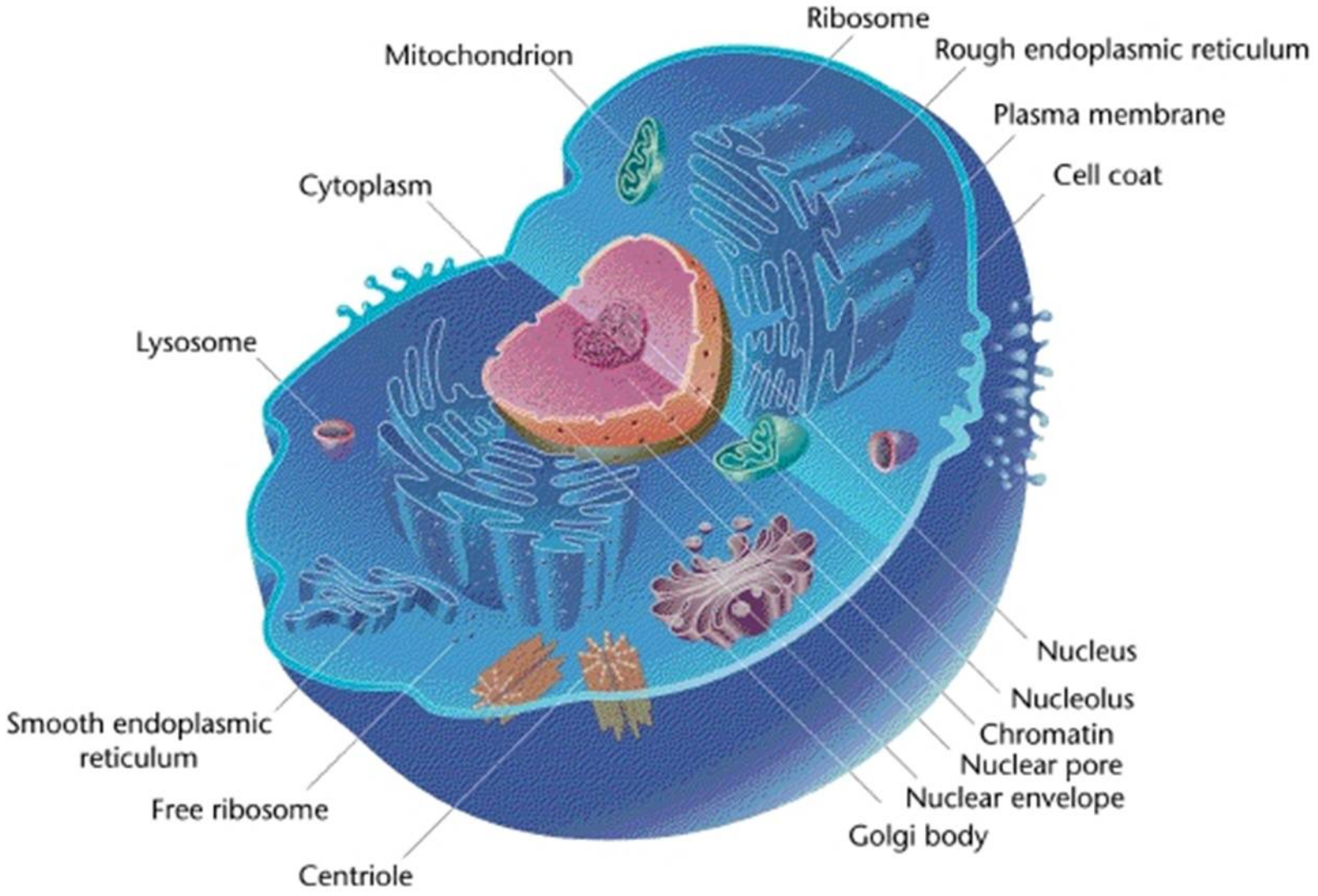
Figure 1.8



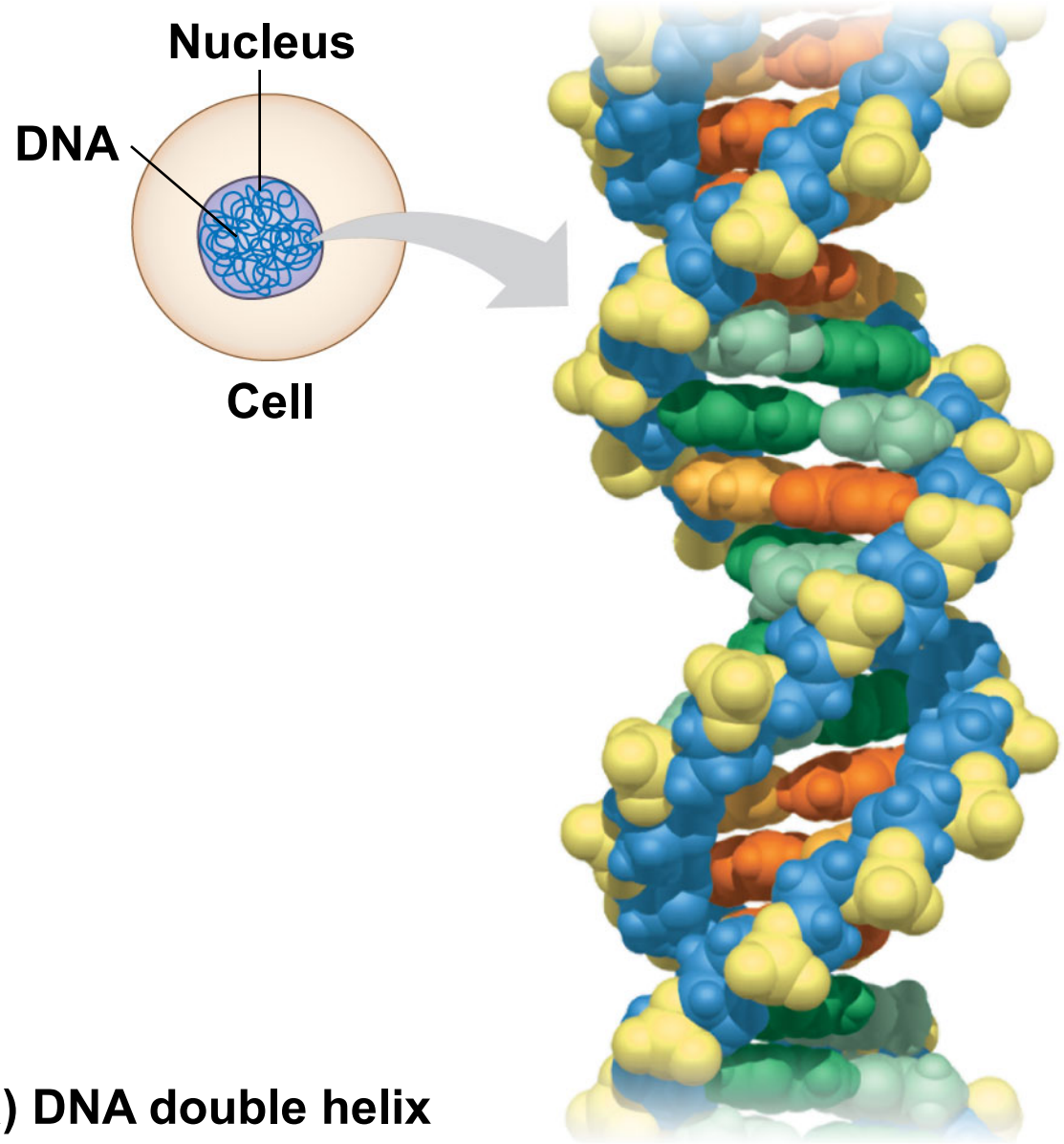
# Overview: Cell Structure and Function

- Videos:
  - https://www.youtube.com/watch?v=rABKB5aS2Zg
  - https://www.youtube.com/watch?v=KzMviiBoRtA
- Questions:
  - What is the function of the (cell) *plasma membrane?*
  - What is the function of the *nucleus*?
  - What is the function of the *mitochondria*?
  - What is the function of the *ribosomes*?
  - What is the function of the *Golgi apparatus*?
  - What is the function of the *endoplasmic reticulum (ER)*?

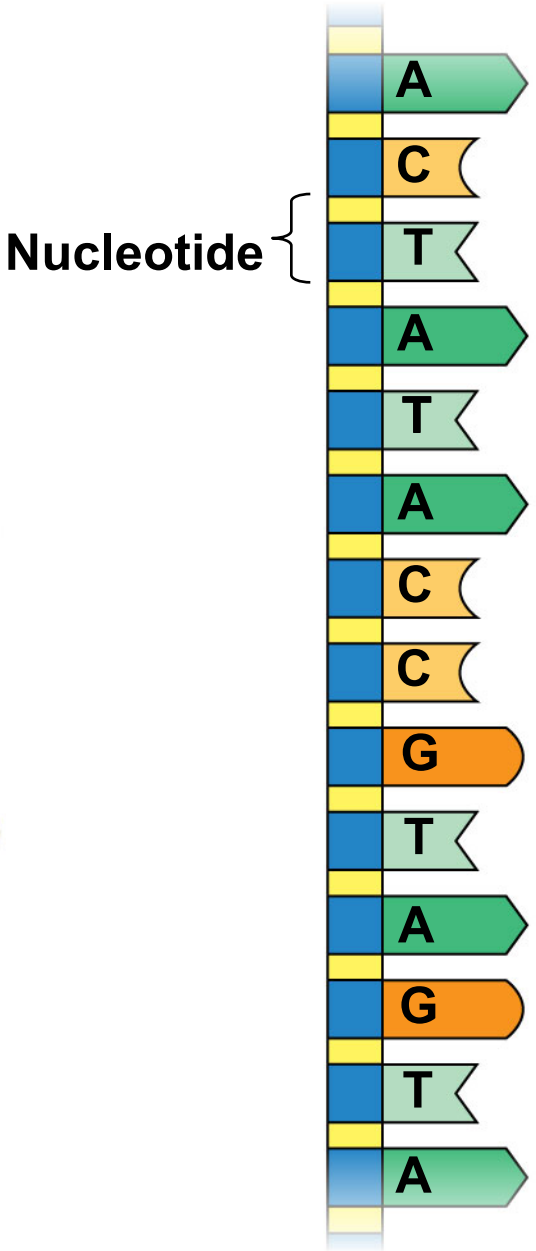
# Eukaryotic cell



# The nucleus contains the DNA

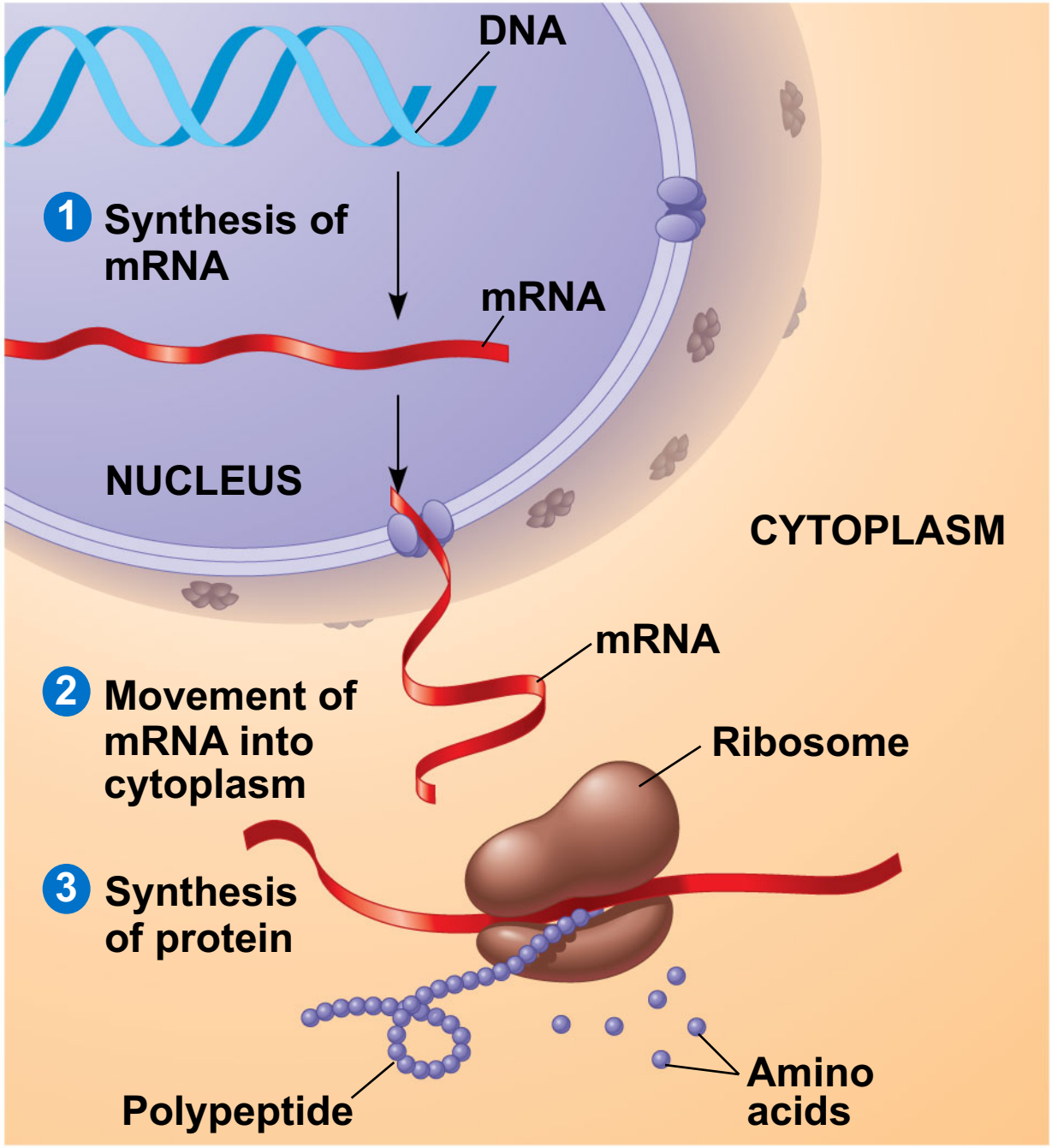



(a) DNA double helix




(b) Single strand of DNA

# Overview of Gene Expression

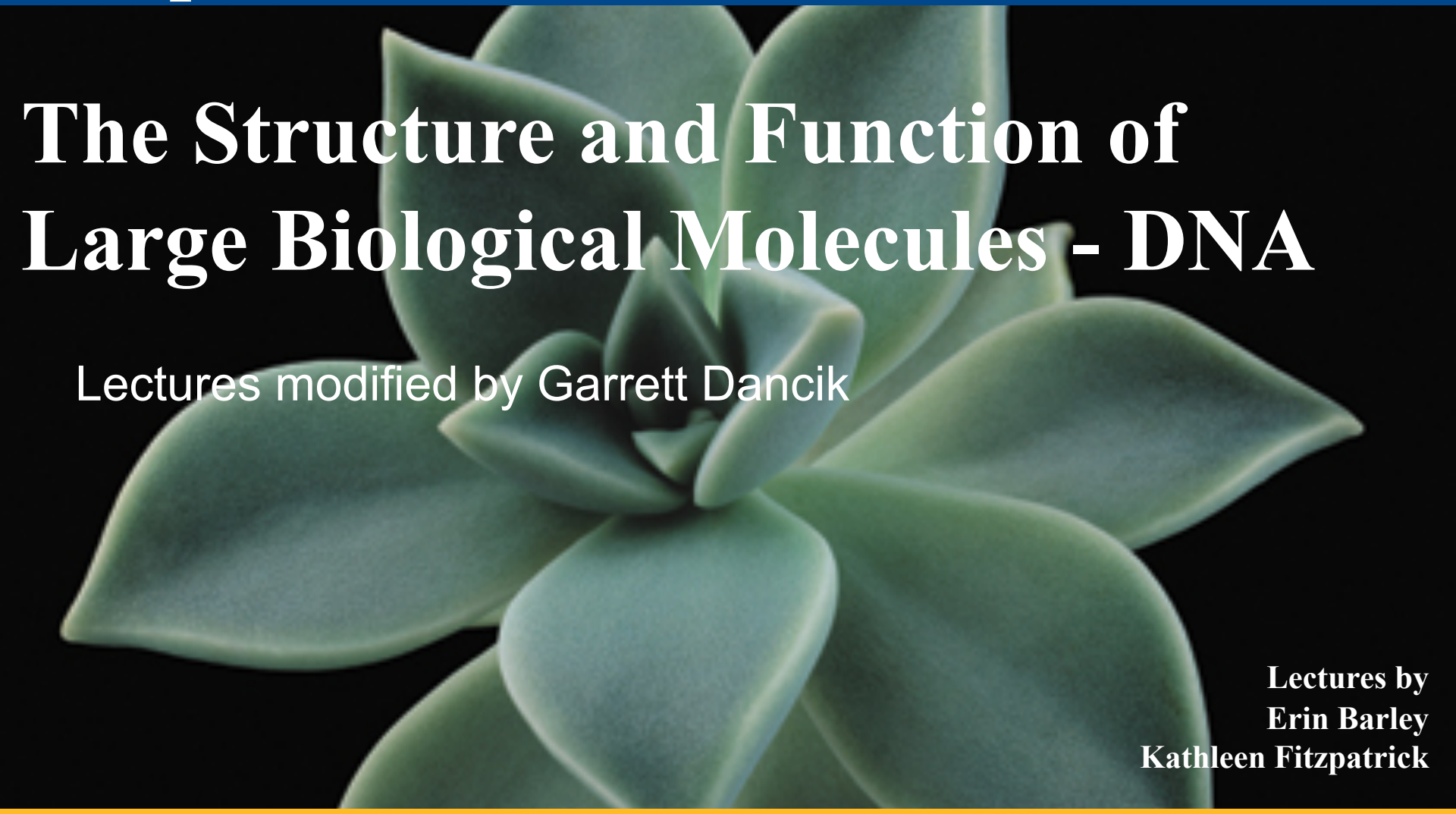


**LECTURE PRESENTATIONS**
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

# Chapter 5

# The Structure and Function of Large Biological Molecules - DNA

Lectures modified by Garrett Dancik



**Lectures by**
**Erin Barley**
**Kathleen Fitzpatrick**

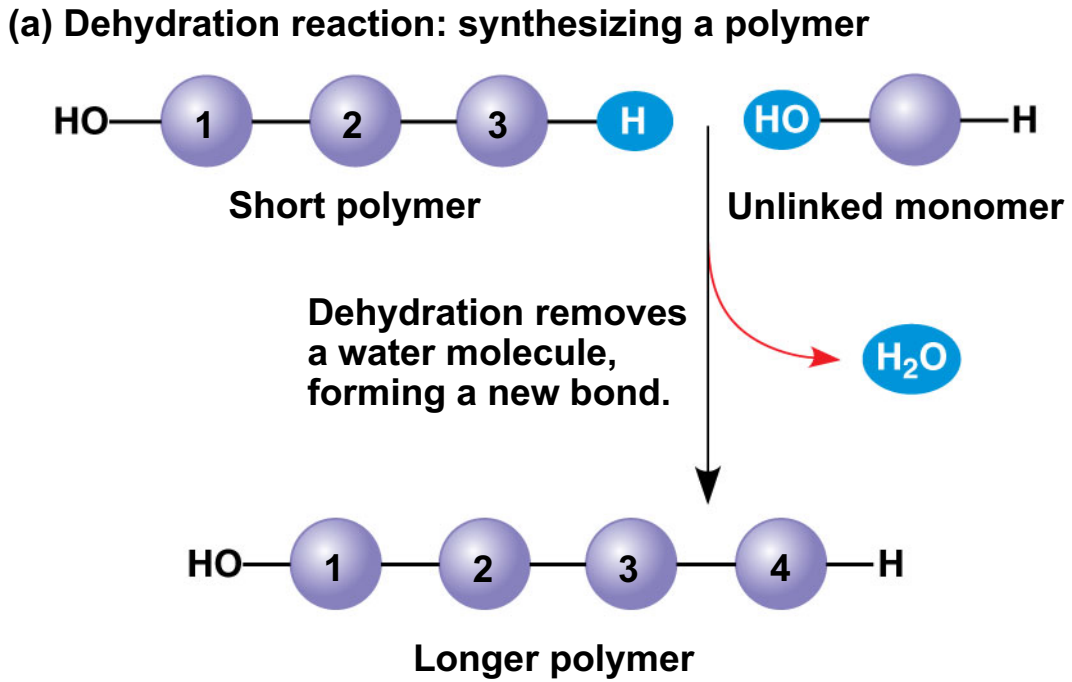
# Overview: The Molecules of Life

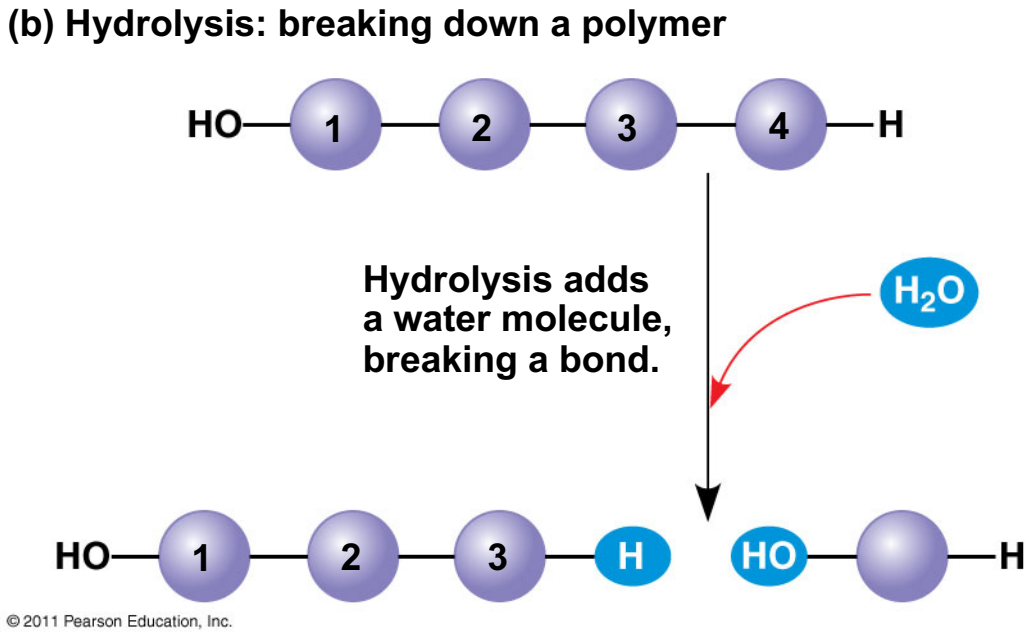
- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids

# The Synthesis and Breakdown of Polymers

- A monomer is a building block of a polymer
  - DNA: the nucleotides (characters) A,C,G, and T
  - RNA: the nucleotides (characters) A,C,G, and U
  - Proteins: twenty kinds of amino acids (characters)
- A **dehydration reaction** occurs when two monomers bond together through the loss of a water molecule
- Polymers are disassembled to monomers by **hydrolysis**, a reaction that is essentially the reverse of the dehydration reaction

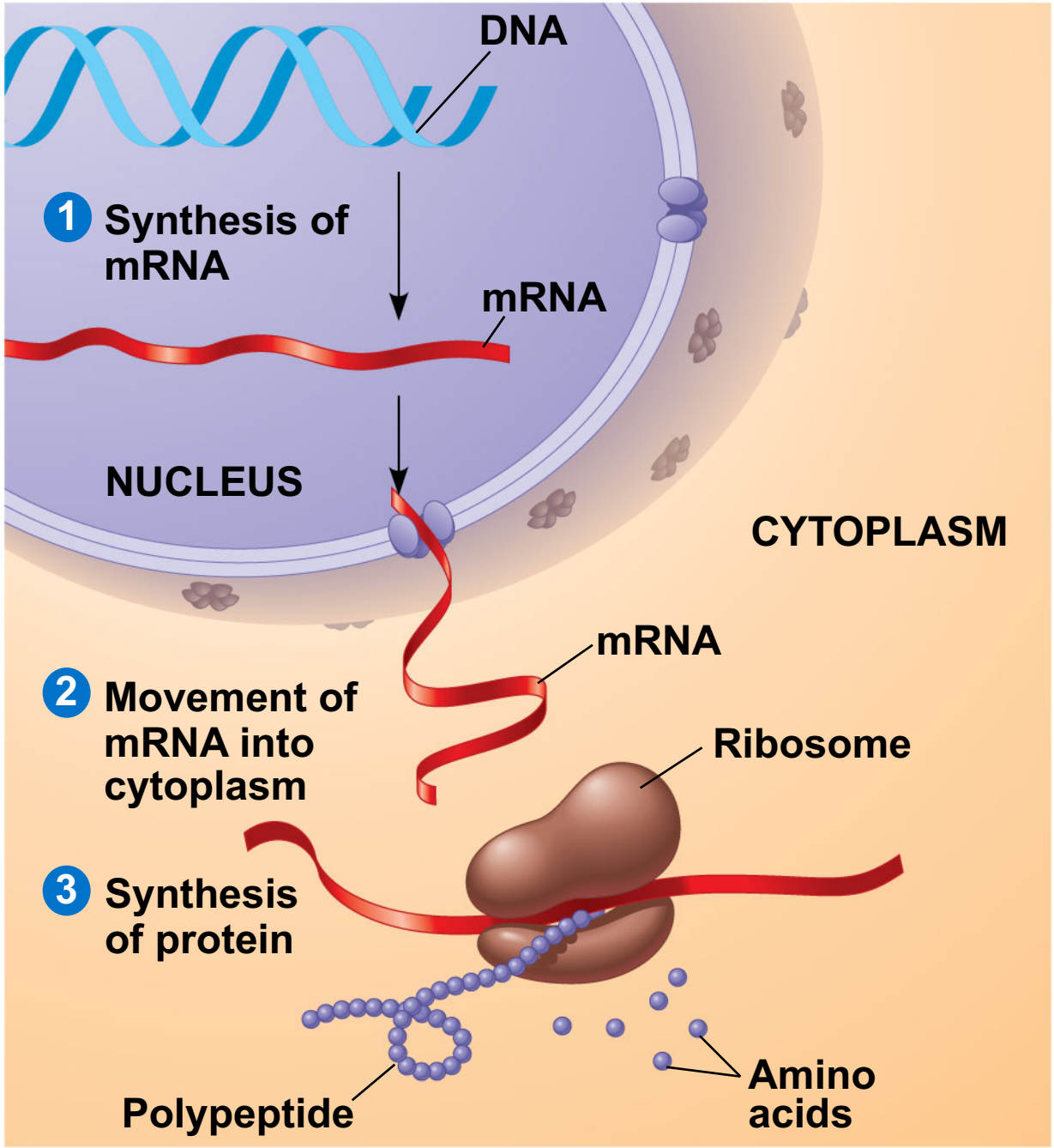
Figure 5.2



# Relationship between DNA, RNA, and protein

- Genes are made of DNA, a **nucleic acid** made of monomers called nucleotides
- A gene is a unit of inheritance that codes for the amino acid sequence of a polypeptide (shown) or a functional RNA product (not shown)



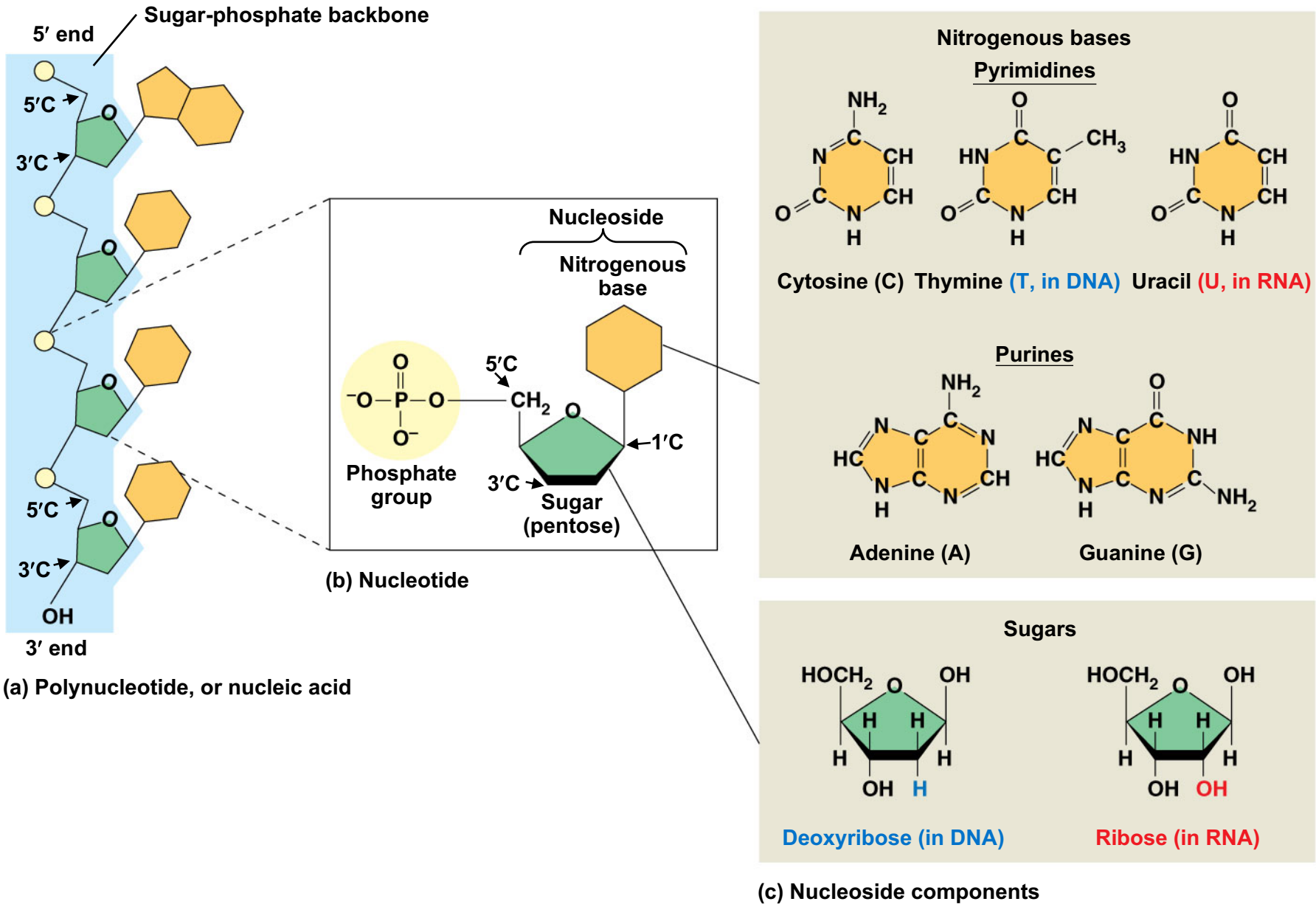
# Role of Nucleic Acids

- Nucleic acids store, transmit, and help express hereditary information
- There are two types of nucleic acids
  - **Deoxyribonucleic acid (DNA)**
  - **Ribonucleic acid (RNA)**
- DNA provides directions for its own replication
- DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls protein synthesis

# The Components of Nucleic Acids

- Nucleic acids are polymers called **polynucleotides**
- Each polynucleotide is made of monomers called **nucleotides**
- Each nucleotide consists of a nitrogenous base, a pentose sugar, and one or more phosphate groups
- The portion of a nucleotide without the phosphate group is called a nucleoside

Figure 5.26



- Nucleoside = nitrogenous base + sugar
- There are two families of nitrogenous bases
  - **Pyrimidines** (cytosine, thymine, and uracil) have a single six-membered ring
  - **Purines** (adenine and guanine) have a six-membered ring fused to a five-membered ring
- In DNA, the sugar is **deoxyribose**; in RNA, the sugar is **ribose**
- Nucleotide = nucleoside + phosphate group

# Nucleotide Polymers

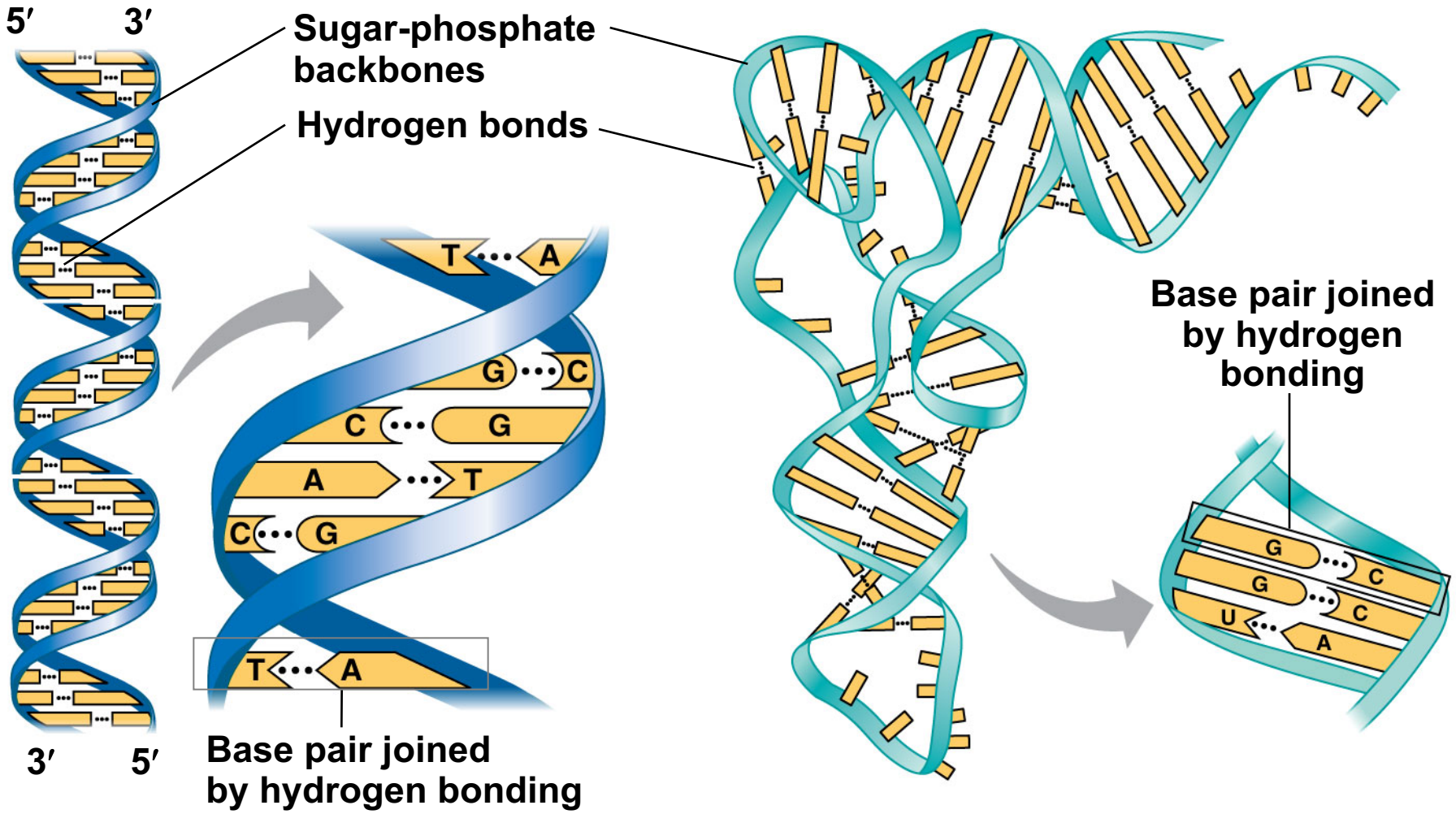
- Nucleotide polymers are linked together to build a polynucleotide
- Adjacent nucleotides are joined by covalent bonds that form between the —OH group on the 3′ carbon of one nucleotide and the phosphate on the 5′ carbon on the next
- These links create a backbone of sugar-phosphate units with nitrogenous bases as appendages
- The sequence of bases along a DNA or mRNA polymer is unique for each gene

# The Structures of DNA and RNA Molecules

- RNA molecules usually exist as single polypeptide chains
- DNA molecules have two polynucleotides spiraling around an imaginary axis, forming a **double helix**
- In the DNA double helix, the two backbones run in opposite 5′→ 3′ directions from each other, an arrangement referred to as **antiparallel**
- One DNA molecule includes many genes

- **Complementary base pairing**
  - The nitrogenous bases in DNA pair up and form hydrogen bonds: adenine (A) always with thymine (T), and guanine (G) always with cytosine (C)
  - Complementary pairing can also occur between two RNA molecules or between parts of the same molecule
- In RNA, thymine is replaced by uracil (U) so A and U pair

Figure 5.27



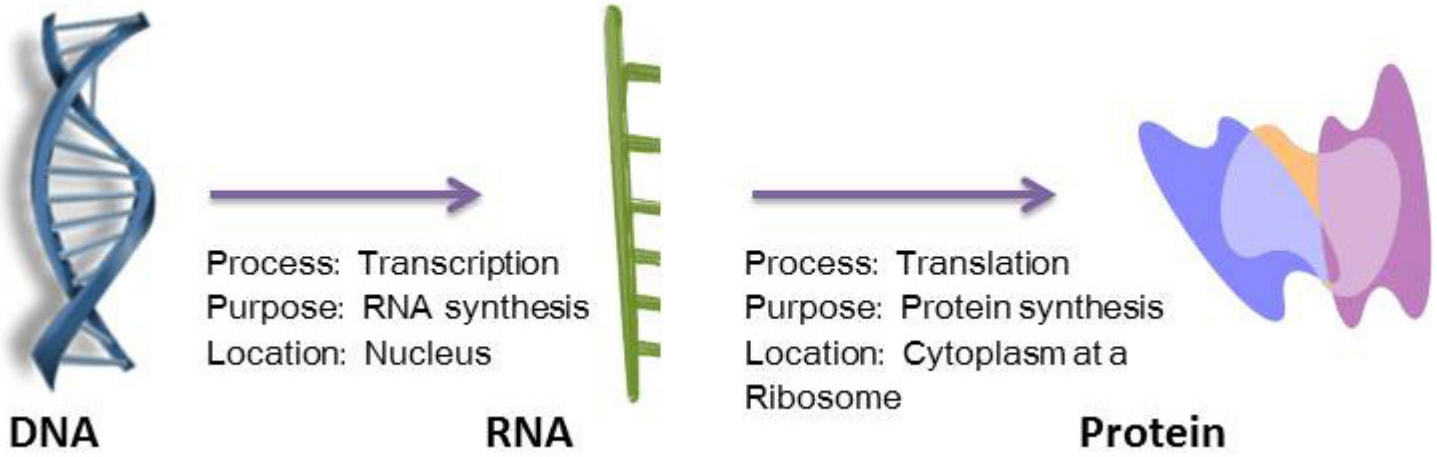
# Genome sequencing

- The human genome project took over 13 years to complete and cost ~$3 billion (~$1 / base pair sequenced)
  - Sequence assembly was one of the first bioinformatics challenges

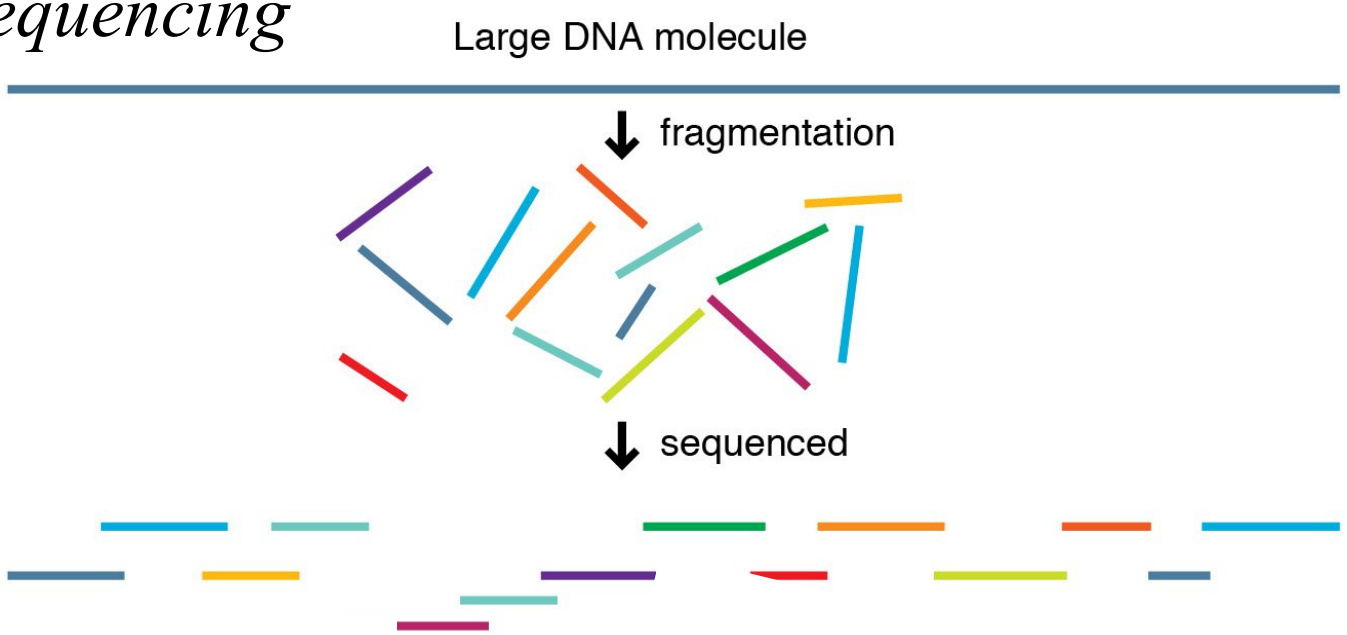
# The genomic revolution

- The $1000 genome arrived in 2014
- https://www.forbes.com/sites/matthewherper/2014/01/14/the-1000-genome-arrives-for-real-this-time/
  - Sequencing machines cost $10 million
    - Can sequence 18,000 genomes / year
- Implications of cheap genomic sequencing
  - http://www.ted.com/talks/richard_resnick_welcome_to_the_genomic_revolution.html
  - What are they????

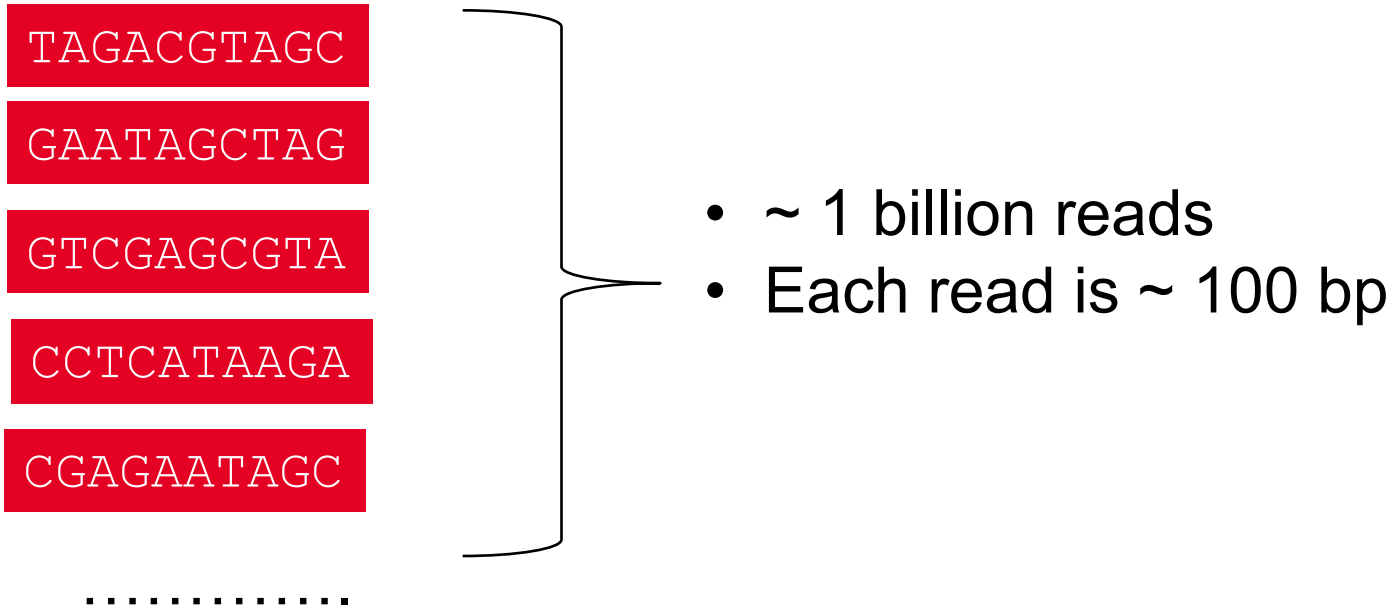
# Gene Expression




*Genomic sequencing*




http://knowgenetics.org




Genome assembly when a reference genome is available

# Reference Genome Sequence (~3 billion bp for humans)

----ACGTCGAGCGTAGACGTAGCGAGAATAGCTAGCTATAAAGGCCTCGTAAGA---

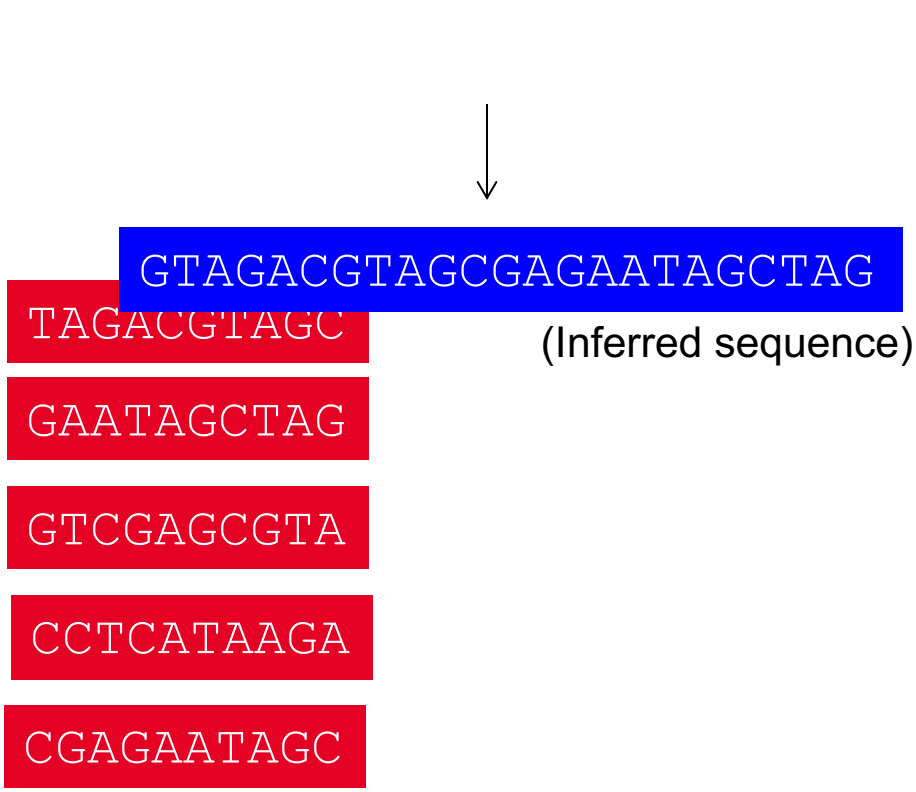

Align fragments to reference genome; must allow for variation

- ~ 1 billion reads
- Each read is ~ 100 bp

Genome assembly when a reference genome is available

# Reference Genome Sequence (~3 billion bp for humans)

----ACGTCGAGCGTAGACGTAGCGAGAATAGCTAGCTATAAAGGCCTCGTAAGA---




Genome assembly when a reference genome is available

# *De novo sequence assembly*

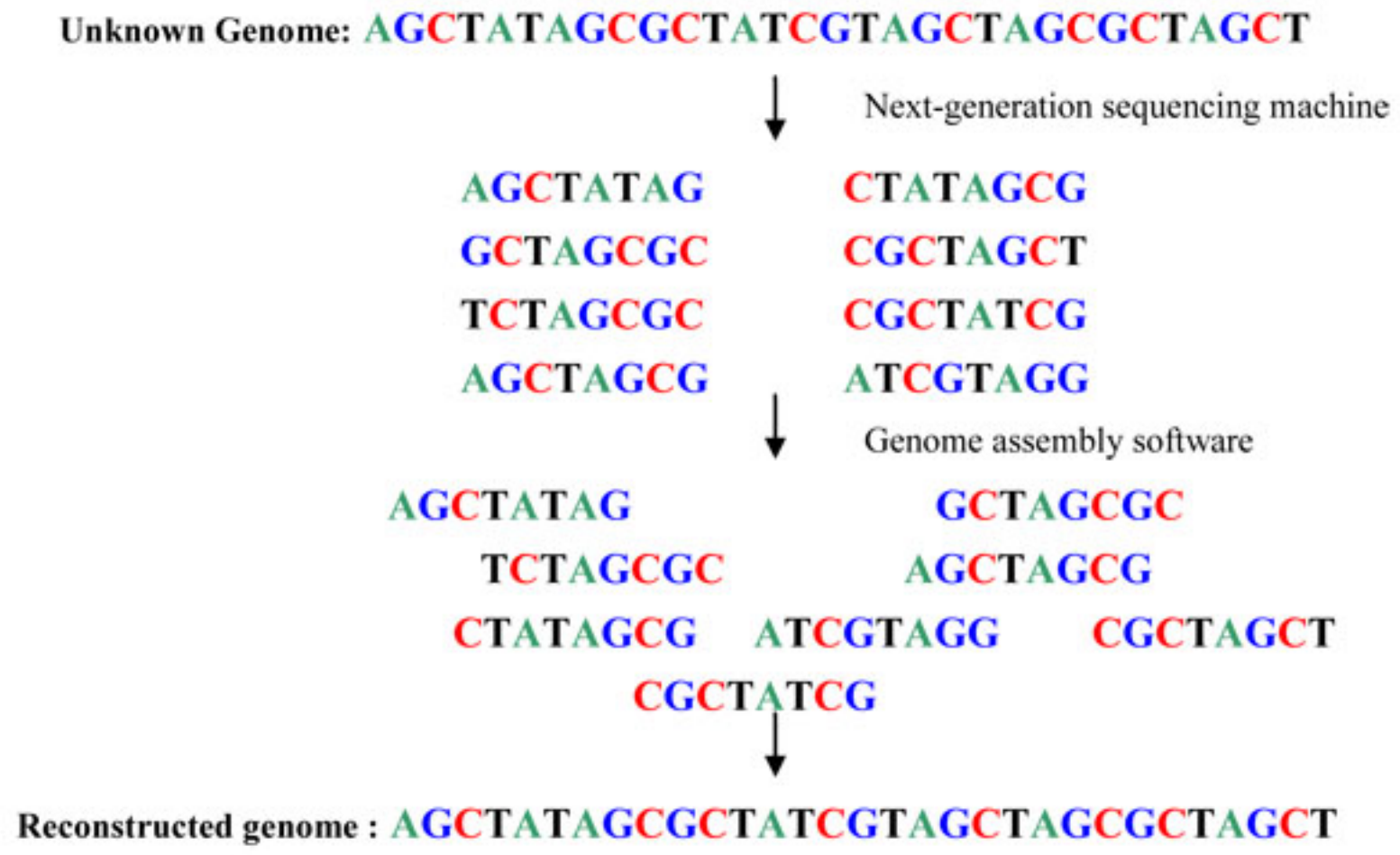
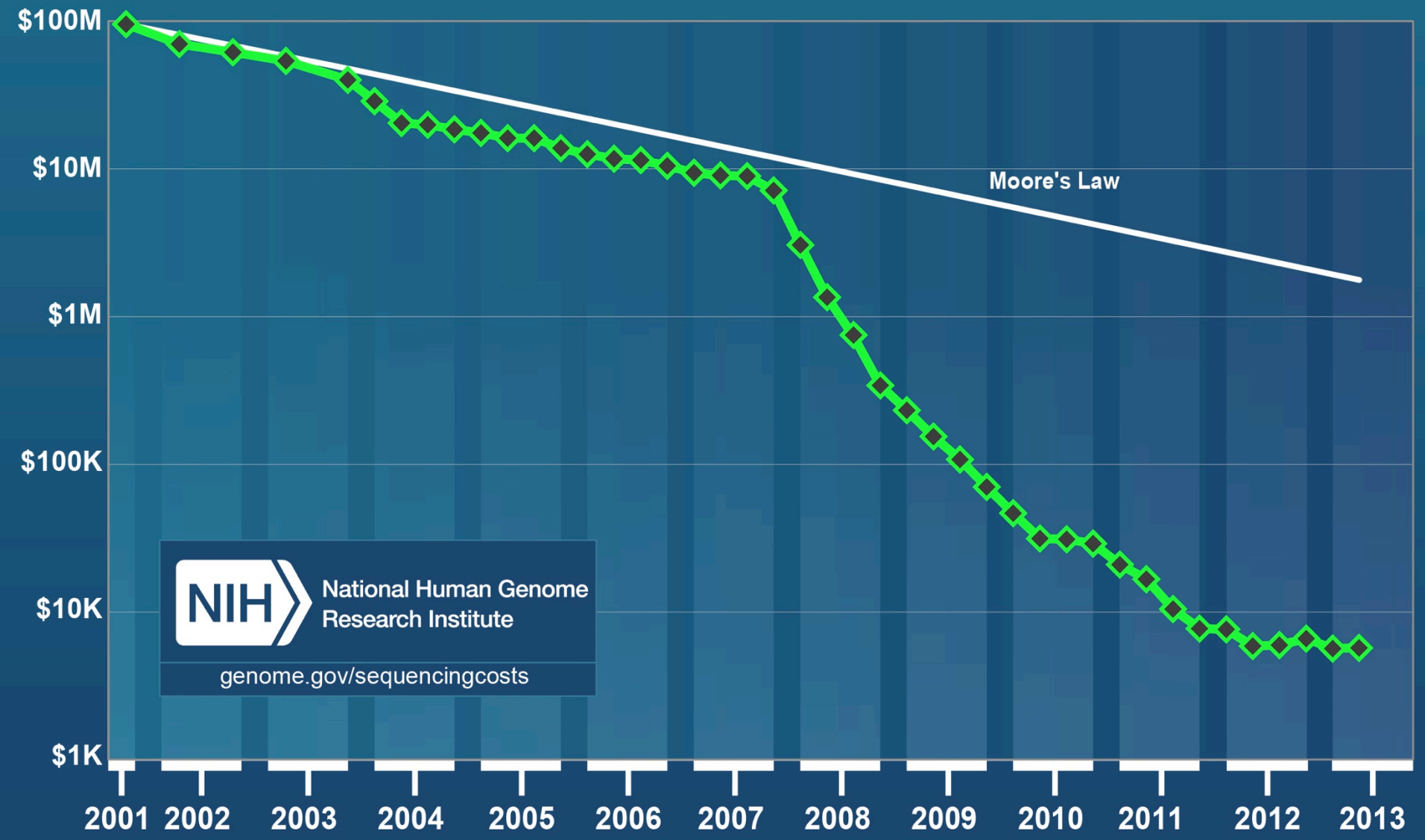



**Figure 1.** Workflow of discovering the genome of a species



De novo assembly when a reference genome is not available

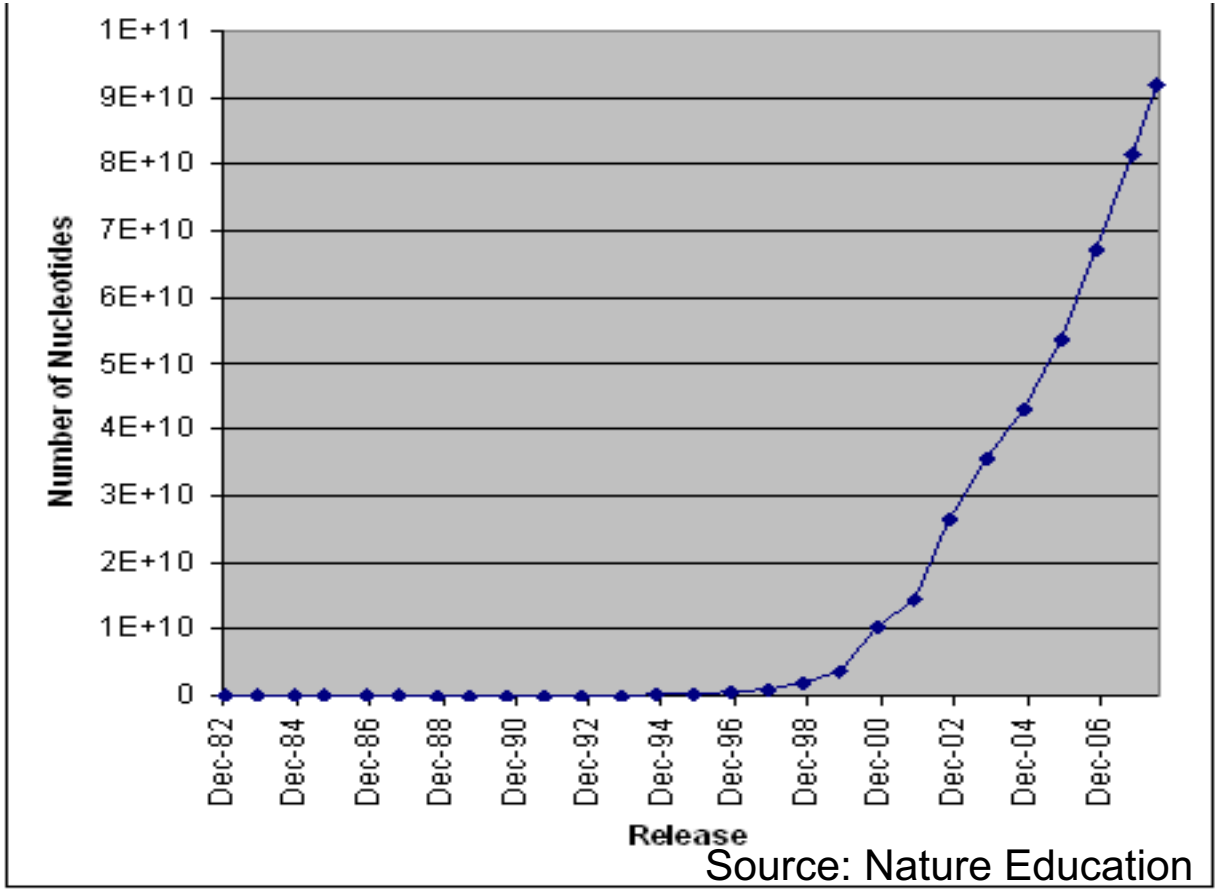
# Cost per Genome



# The number of DNA nucleotides sequenced has grown exponentially

Genbank statistics (December 2018)

- 285+ billion bases in nucleotide database
- 3.6+ trillion additional bases processed for whole genome shotgun sequencing projects




Source: Nature Education