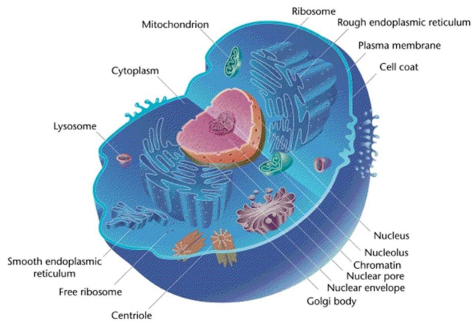
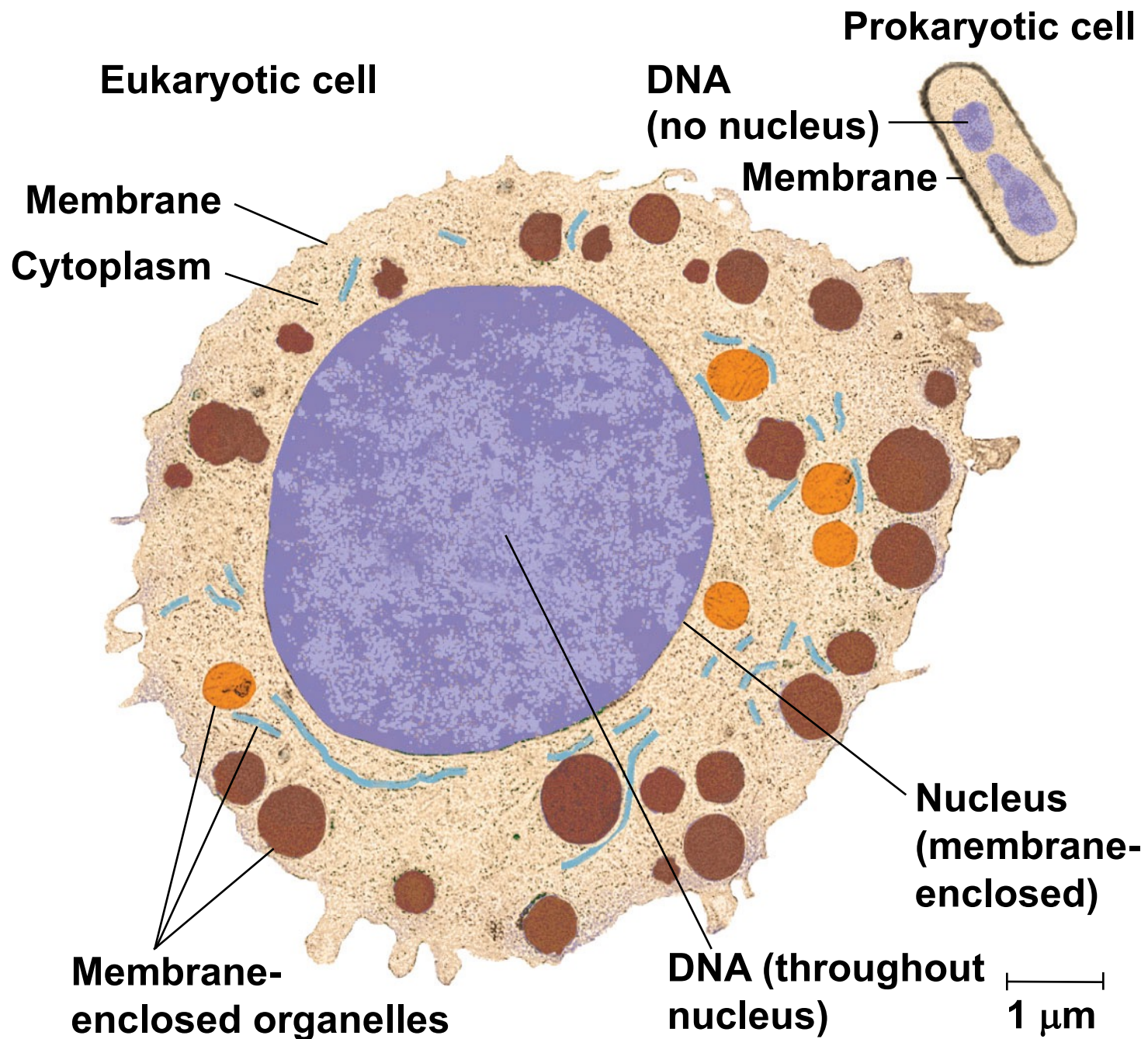


# The cell as the basic unit of life



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)

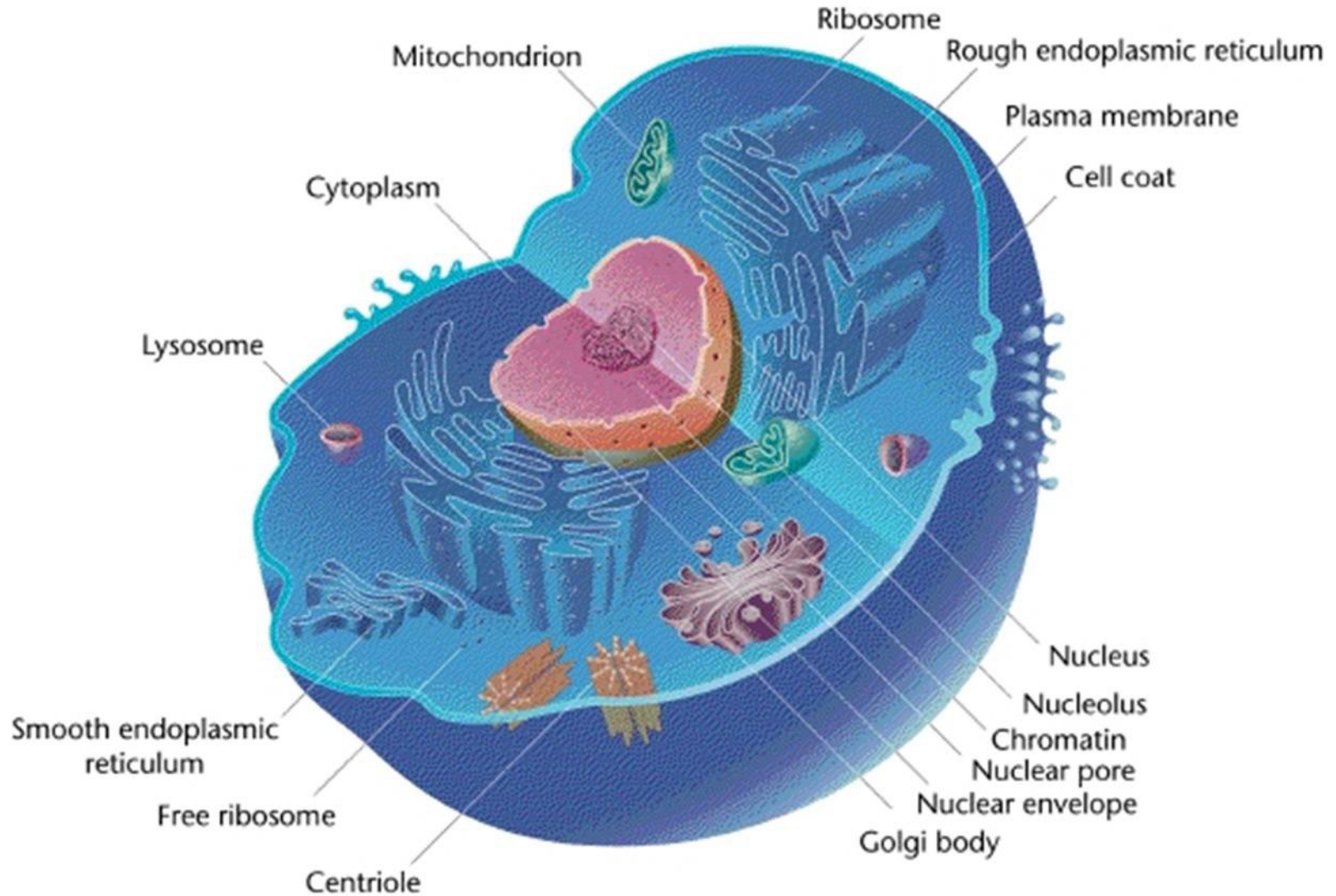
Figure 1.8



# Overview: Cell Structure and Function

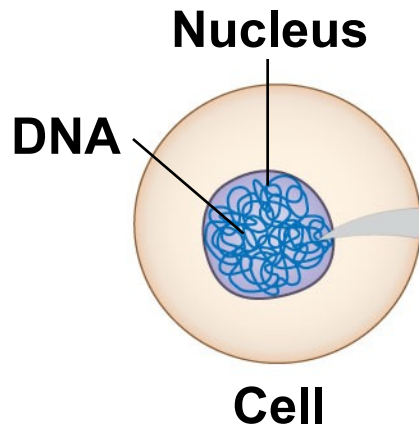
- Videos:
  - <https://www.youtube.com/watch?v=rABKB5aS2Zg>
  - <https://www.youtube.com/watch?v=KzMviiBoRtA>
- Questions:
  - What is the function of the (cell) *plasma membrane*?
  - What is the function of the *nucleus*?
  - What is the function of the *mitochondria*?
  - What is the function of the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

# Eukaryotic cell





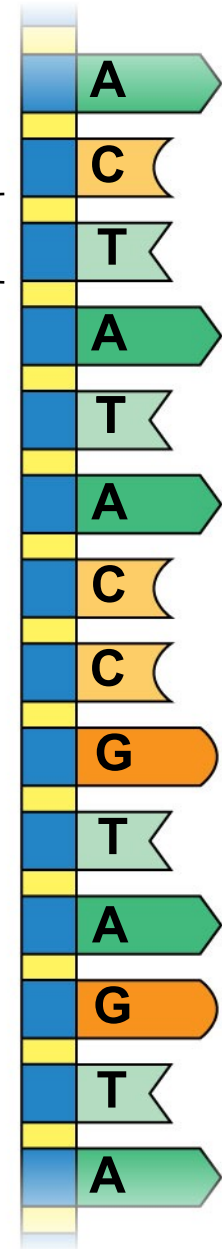
# The nucleus contains the DNA



(a) DNA double helix

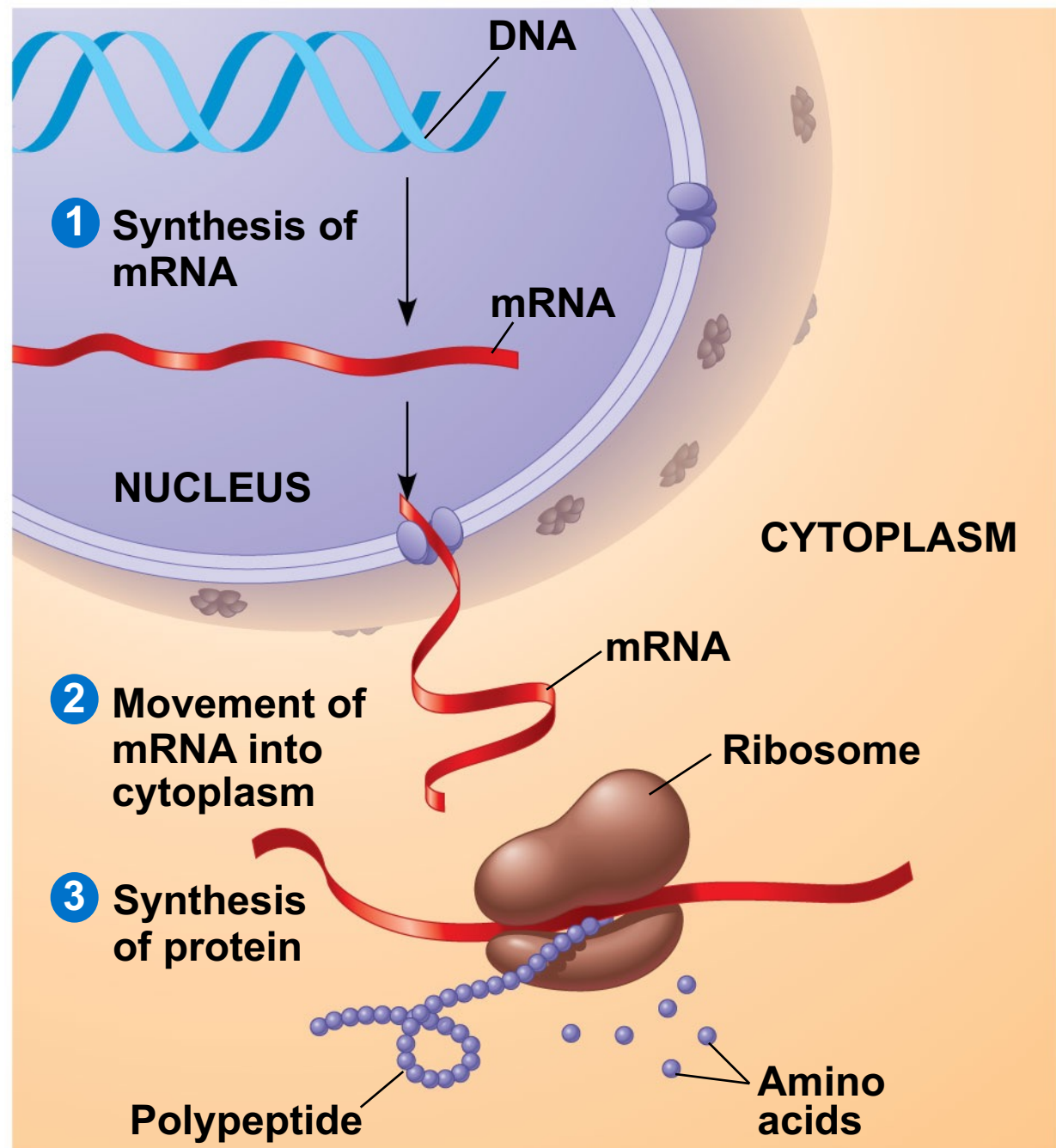


Nucleotide



(b) Single strand of DNA

# Overview of Gene Expression



# **Chapter 5**

# **The Structure and Function of Large Biological Molecules - DNA**

Lectures modified by Garrett Dancik

**Lectures by  
Erin Barley  
Kathleen Fitzpatrick**

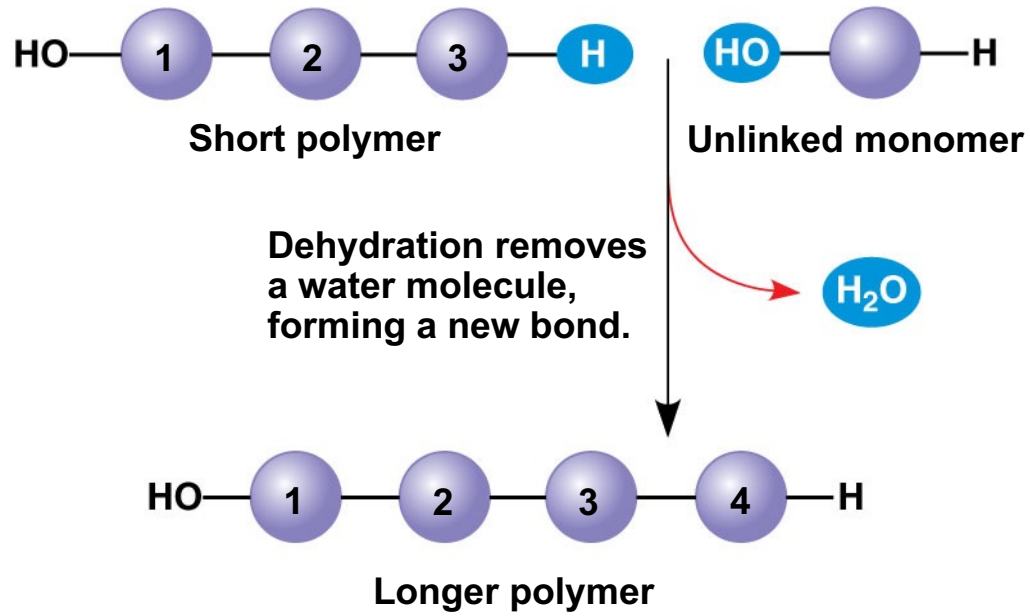
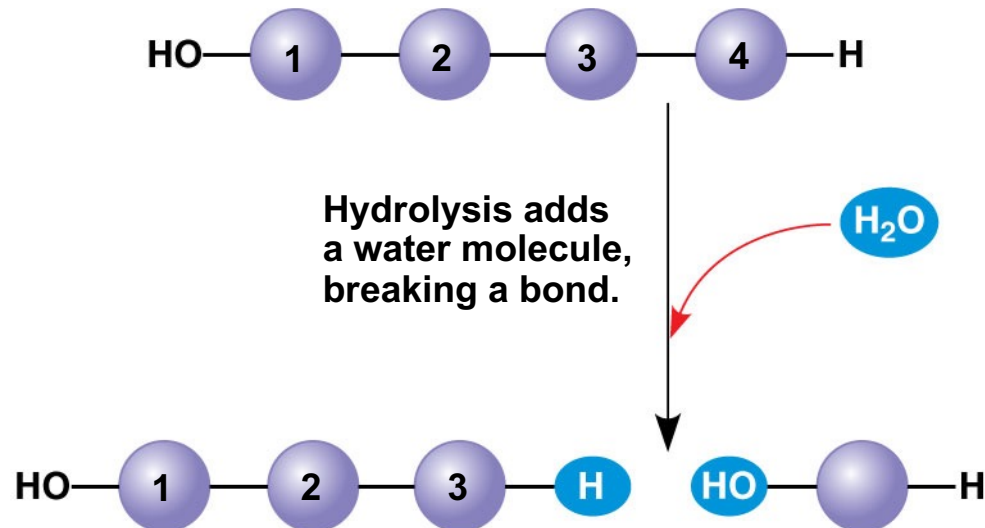
# Overview: The Molecules of Life

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



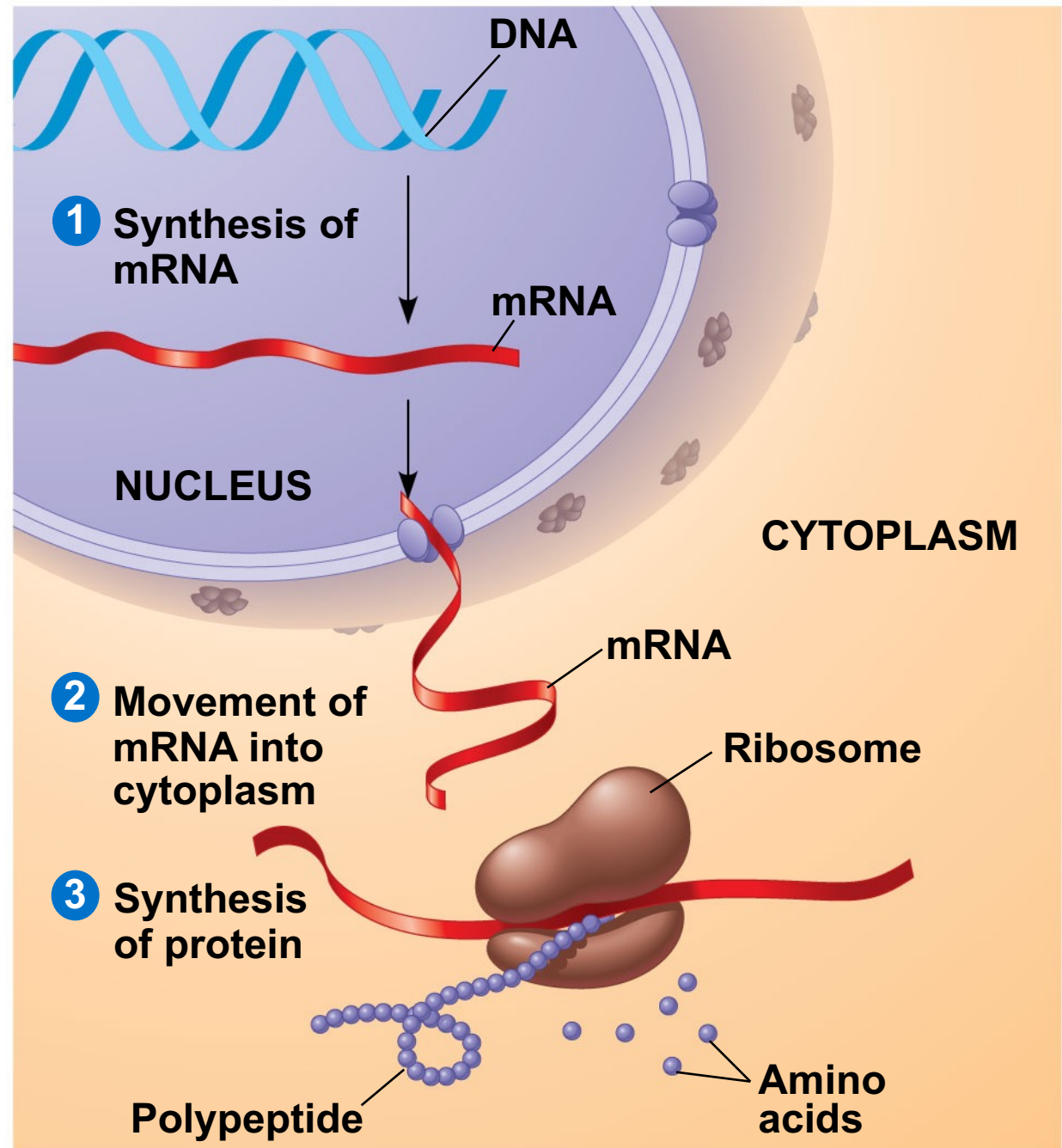
# The Synthesis and Breakdown of Polymers

- 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

**(a) Dehydration reaction: synthesizing a polymer****(b) Hydrolysis: breaking down a polymer**

# 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

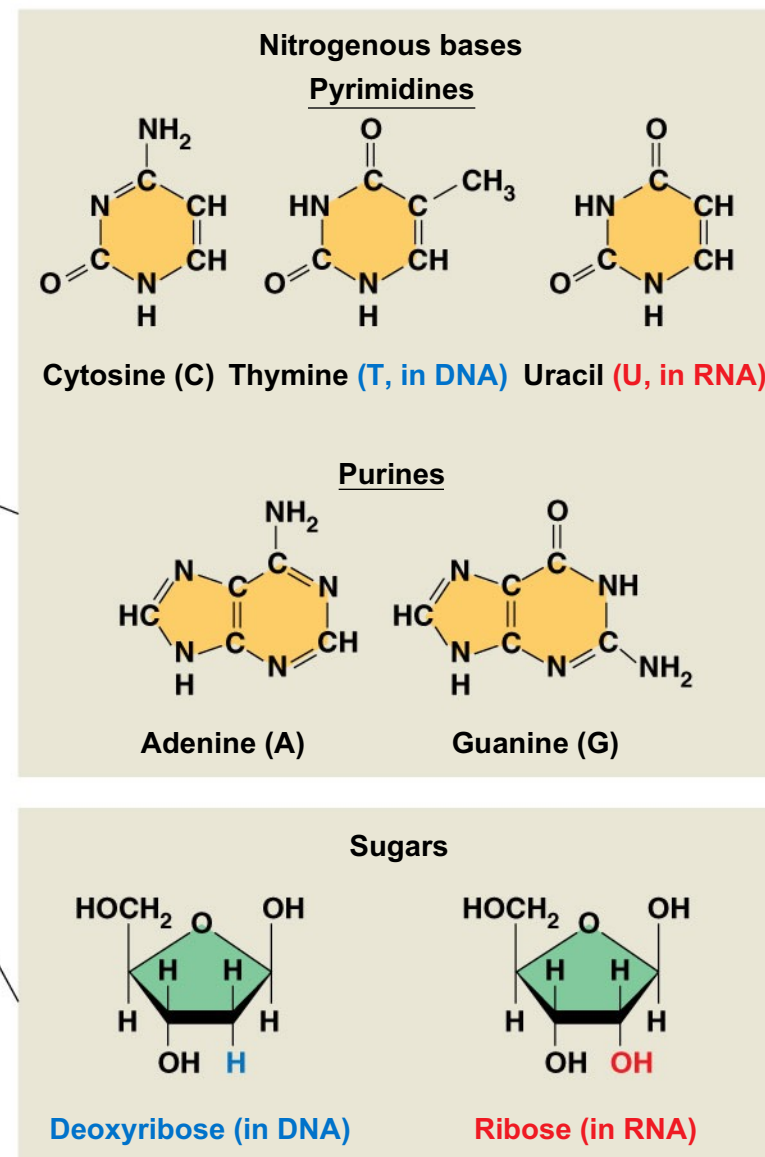
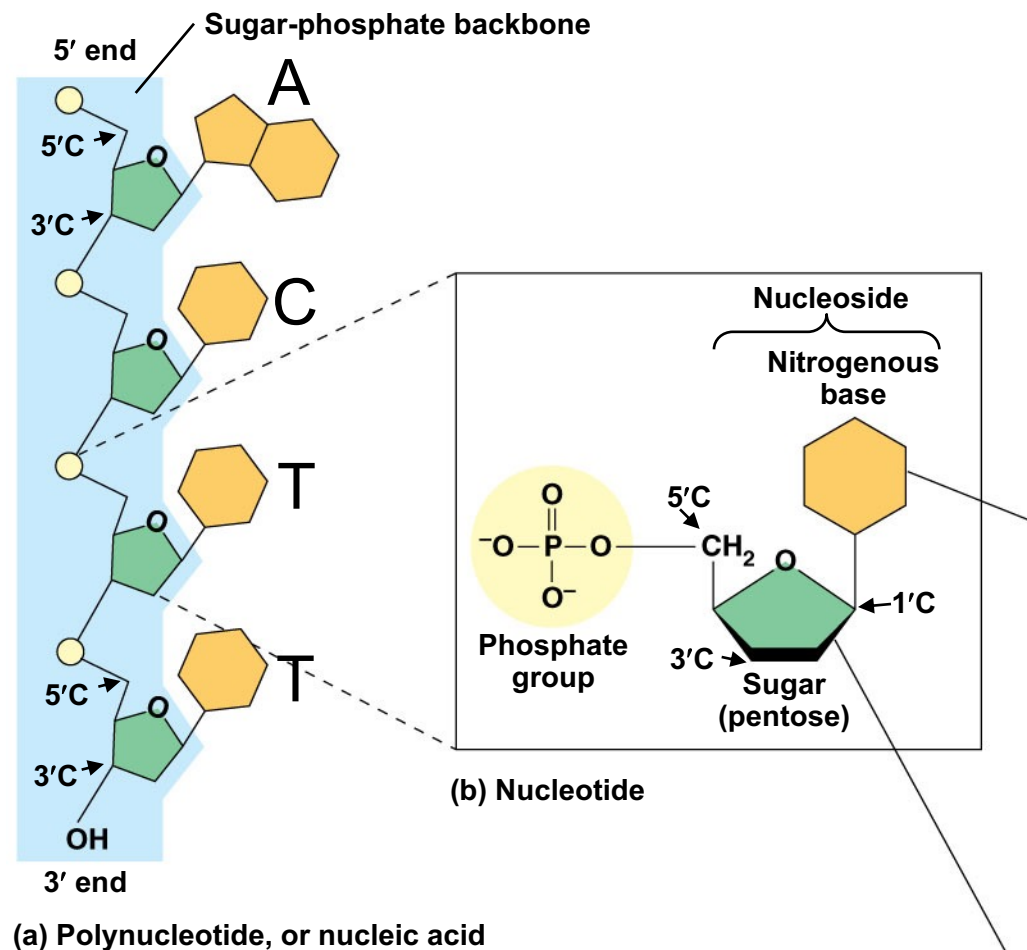
- Nucleic acids store, transmit, and help express hereditary information
- There are two types of nucleic acids
  - **Deoxyribonucleic acid (DNA)**
  - **Ribonucleic acid (RNA)**
- DNA provides directions for its own replication
- DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls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



**(c) Nucleoside components**

- 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

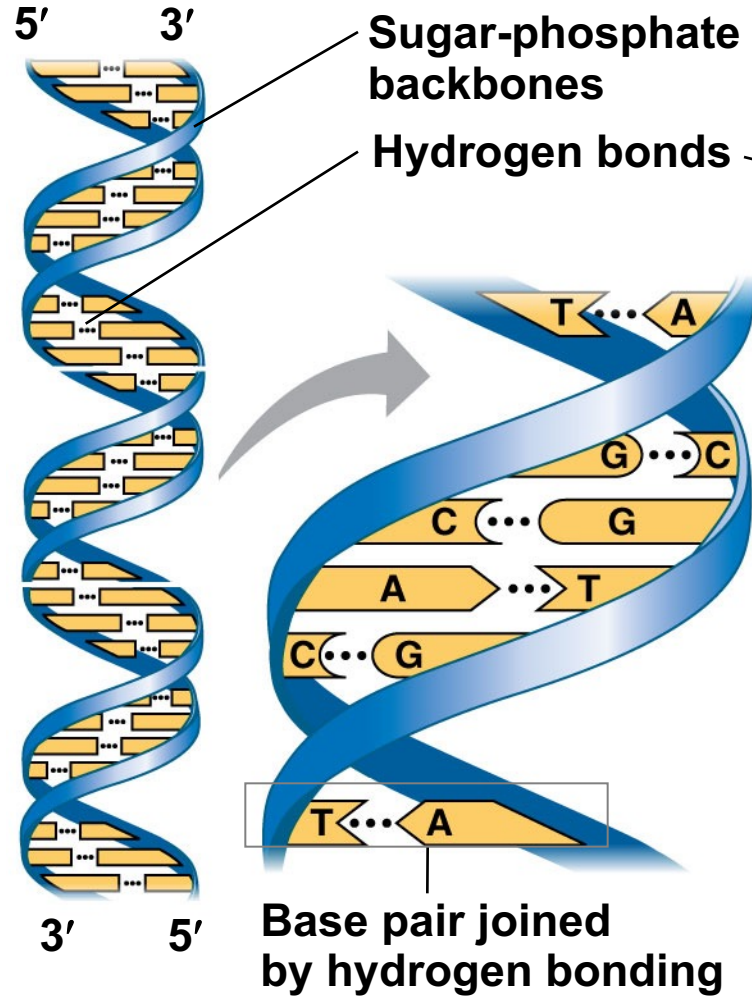
# The Structures of DNA and RNA Molecules

- 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

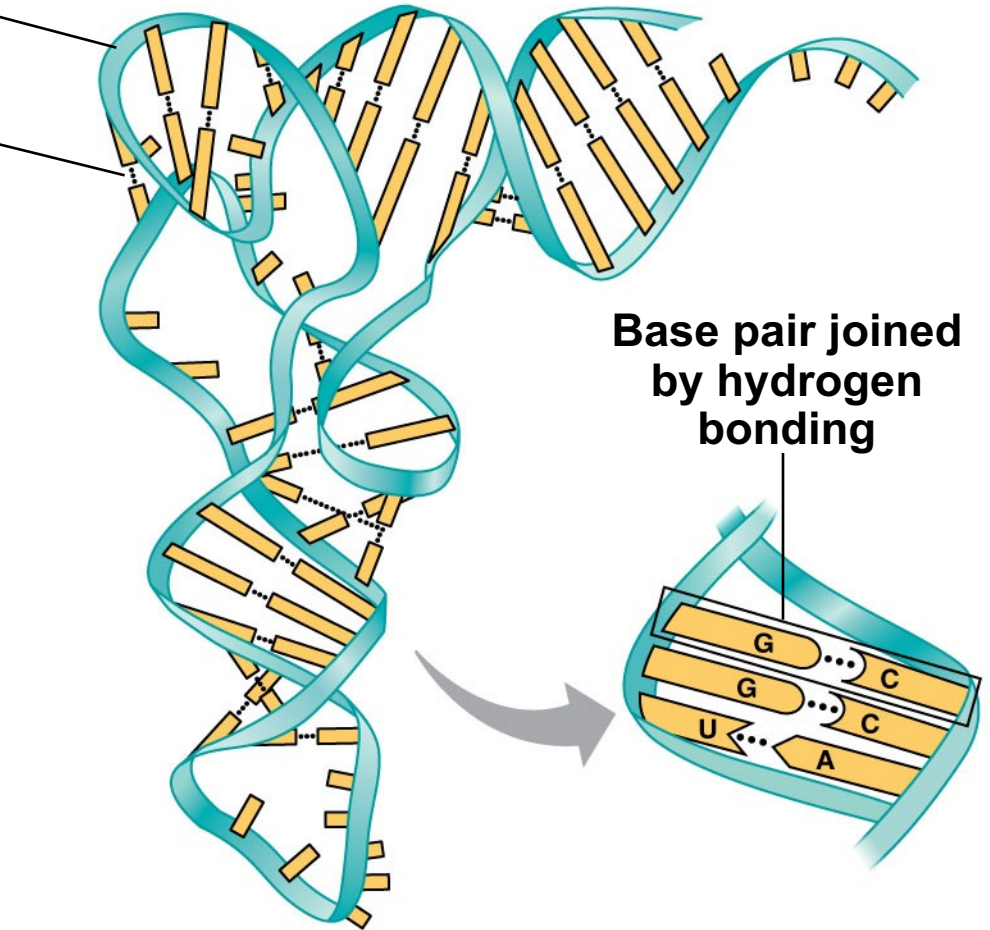


Figure 5.27



(a) DNA

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(b) Transfer RNA

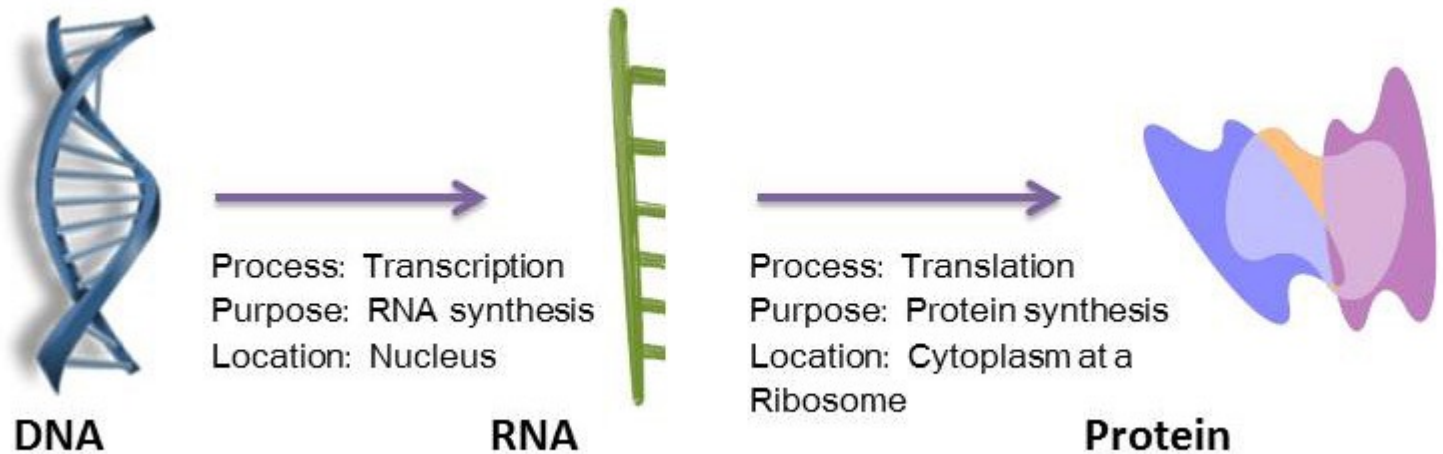
# Genome sequencing

- 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

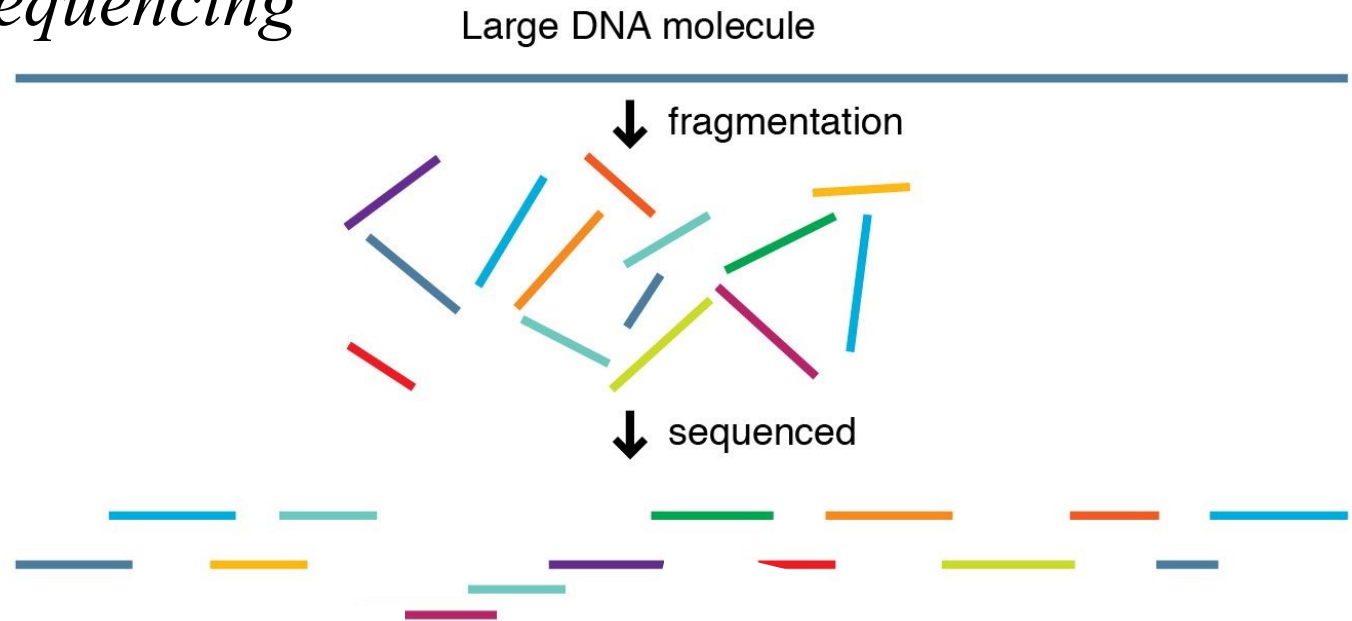
## The genomic revolution

- 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](http://www.ted.com/talks/richard_resnick_welcome_to_the_genomic_revolution)
  - What are they????

# Gene Expression



## *Genomic sequencing*



TAGACGTAGC

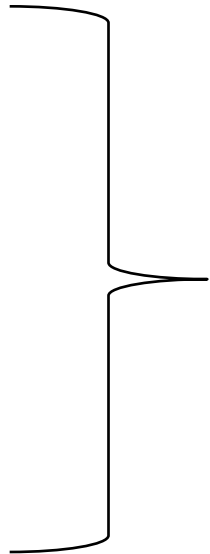
GAATAGCTAG

GTCGAGCGTA

CCTCATAAGA

CGAGAATAGC

.....



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

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

-----ACGTCGAGCGTAGACGTAGCGAGAATAGCTAGCTATAAAGGCCTCGTAAGA-----

TAGACGTAGC  
GAATAGCTAG  
GTCGAGCGTA  
CCTCATAAGA  
CGAGAATAGC

.....

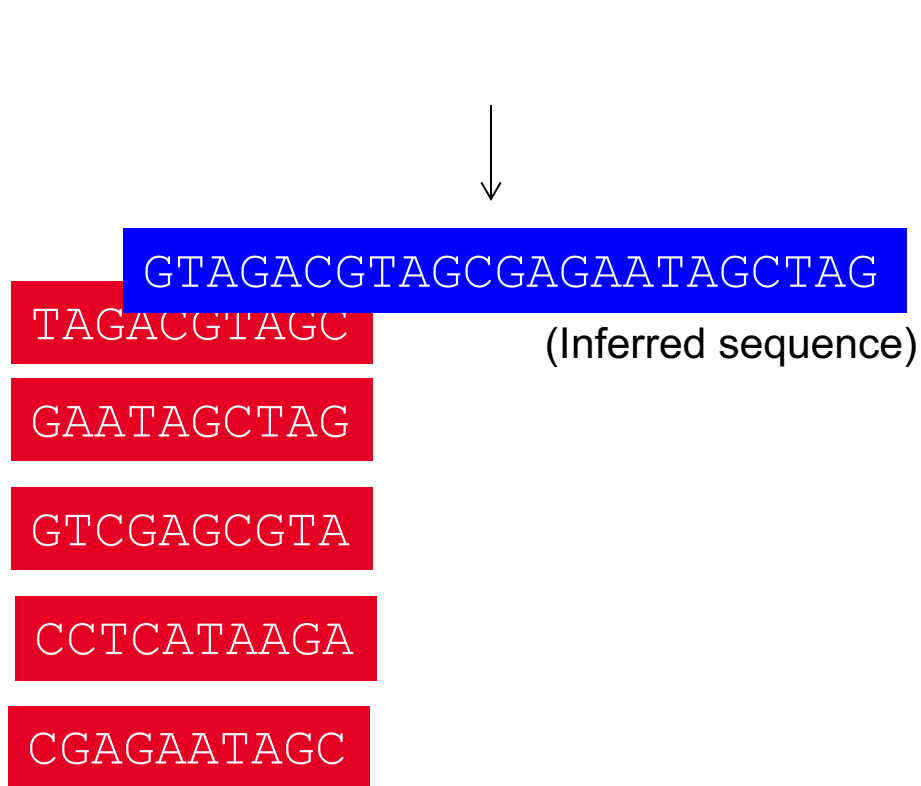
Align fragments to  
reference genome;  
must allow for  
variation

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



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

-----ACGTCGAGCGTAGACGTAGCGAGAATAGCTAGCTATAAAGGCCTCGTAAGA-----



Align fragments to  
reference genome;  
must allow for  
variation

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

---ACGTCGAGCGTAGACGTAGCGAGAATAGCTAGCTATAAAGGCCTCGTAAGA---

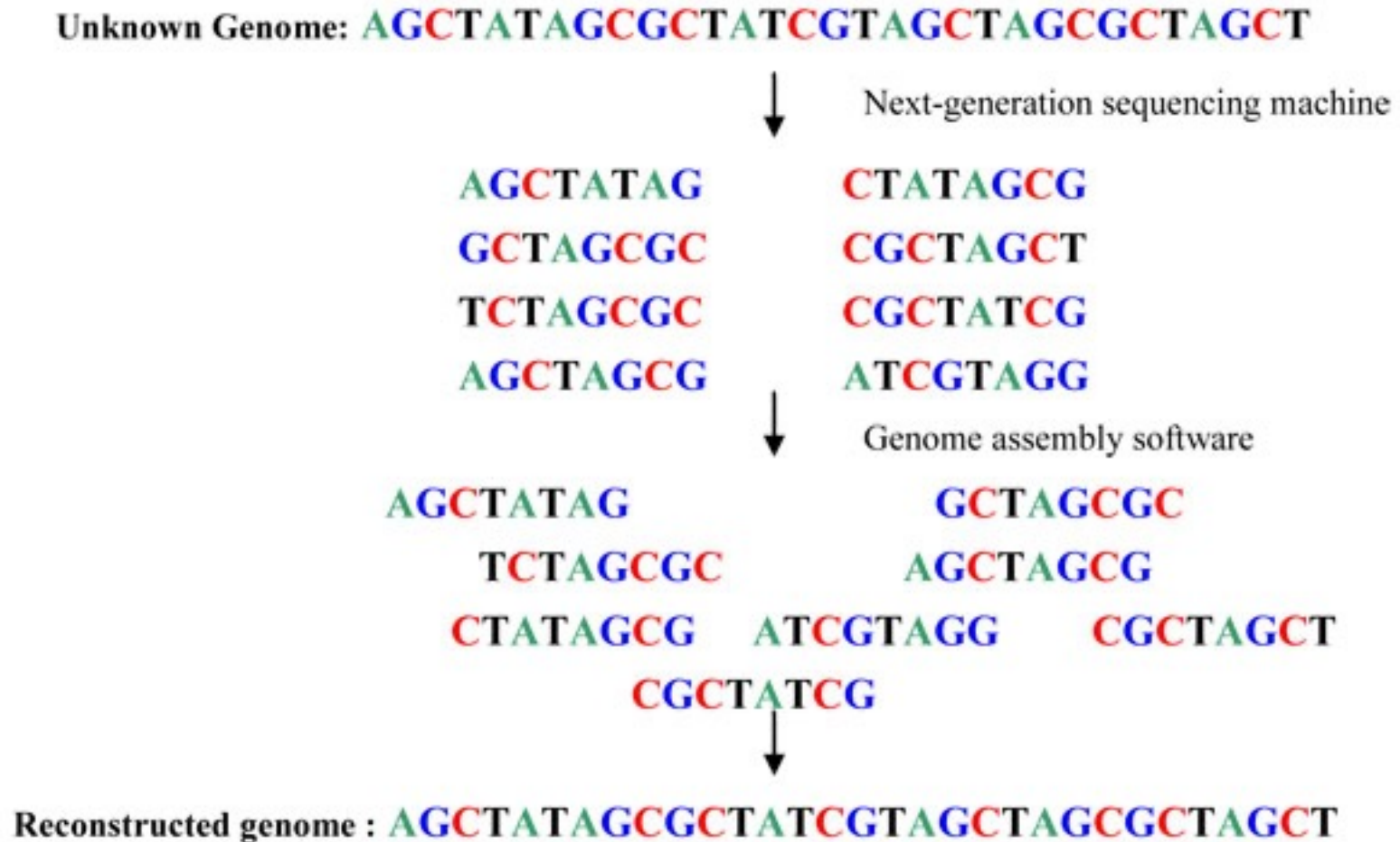


GTAGACGTAGCGAGAATAGCTAG

(Inferred sequence)

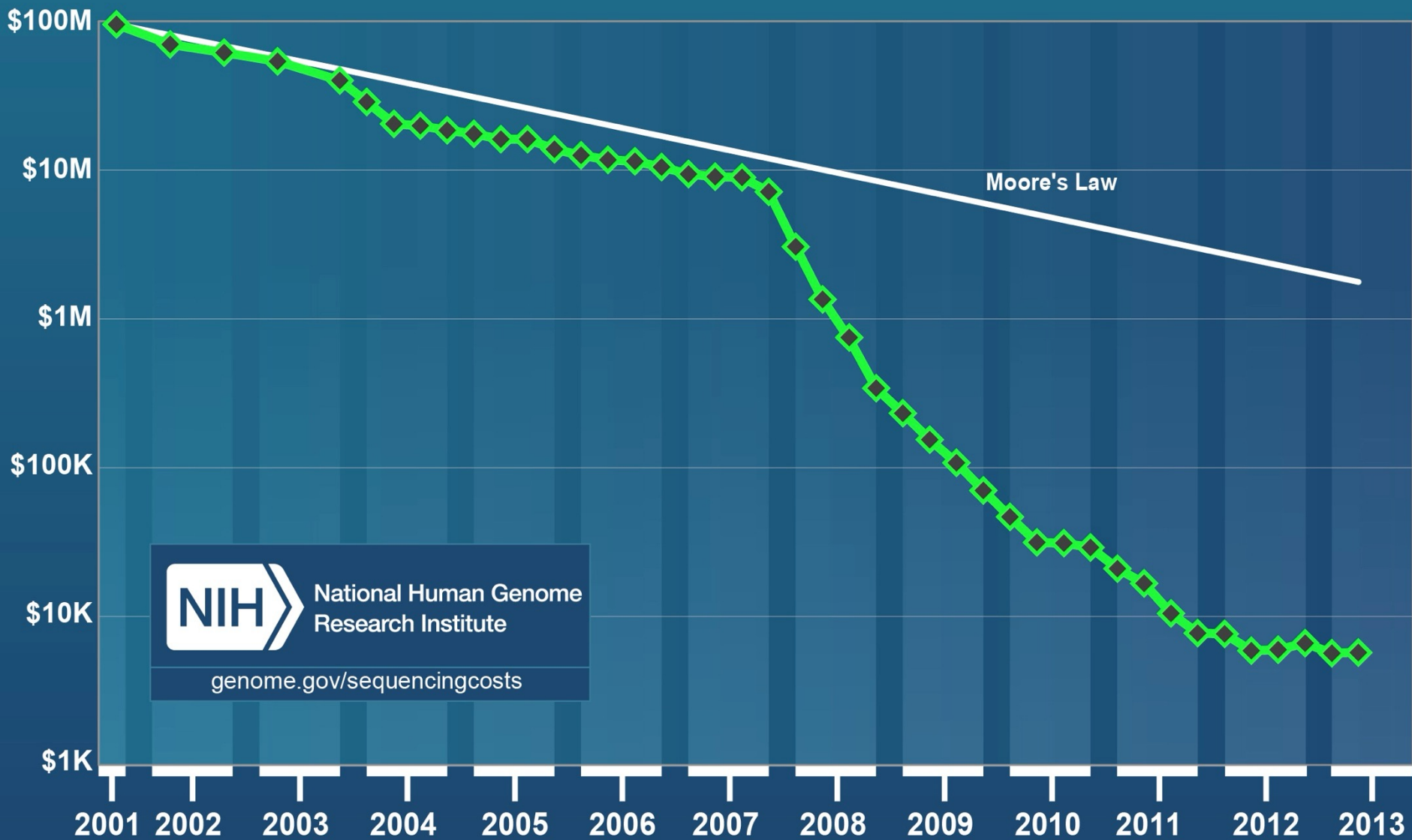
Align fragments to  
reference genome;  
must allow for  
variation

# *De novo sequence assembly*



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

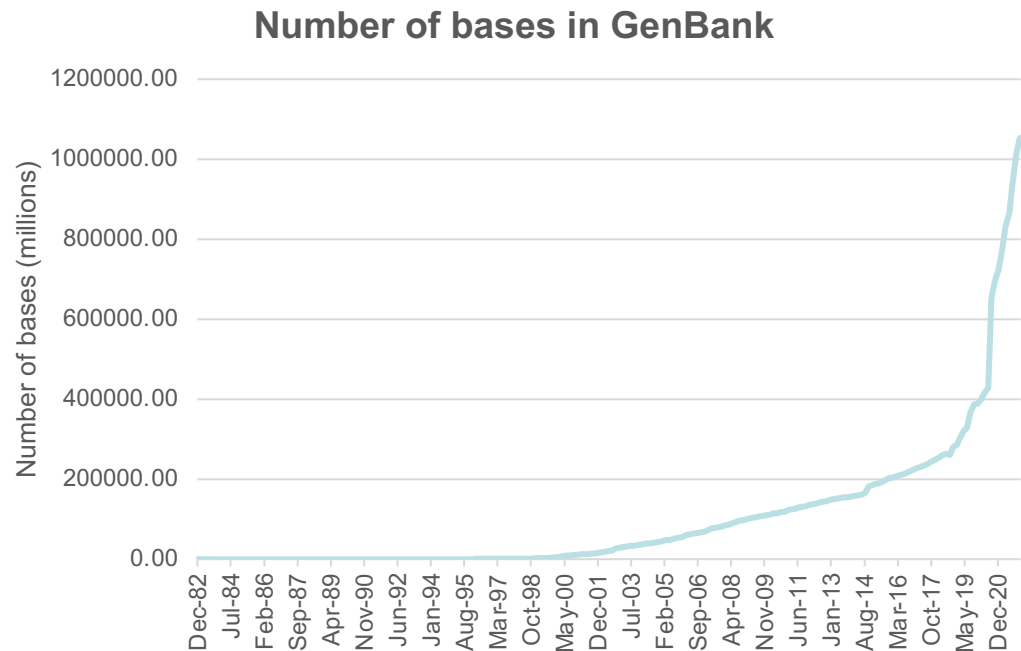
# Cost per Genome



# The number of DNA nucleotides sequenced has grown exponentially

Genbank statistics  
(December 2021)

- 1+ trillion bases in nucleotide database
- 14+ trillion additional bases processed for whole genome shotgun sequencing projects



<https://www.ncbi.nlm.nih.gov/genbank/statistics/>