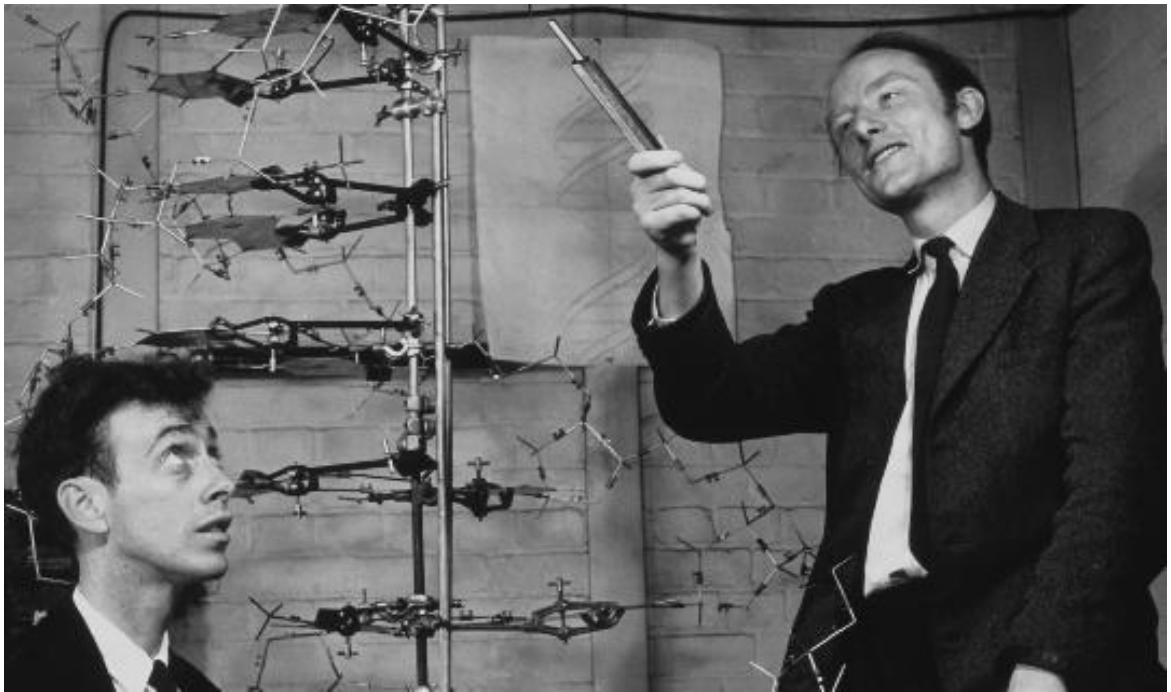
DNA & DNA Replication

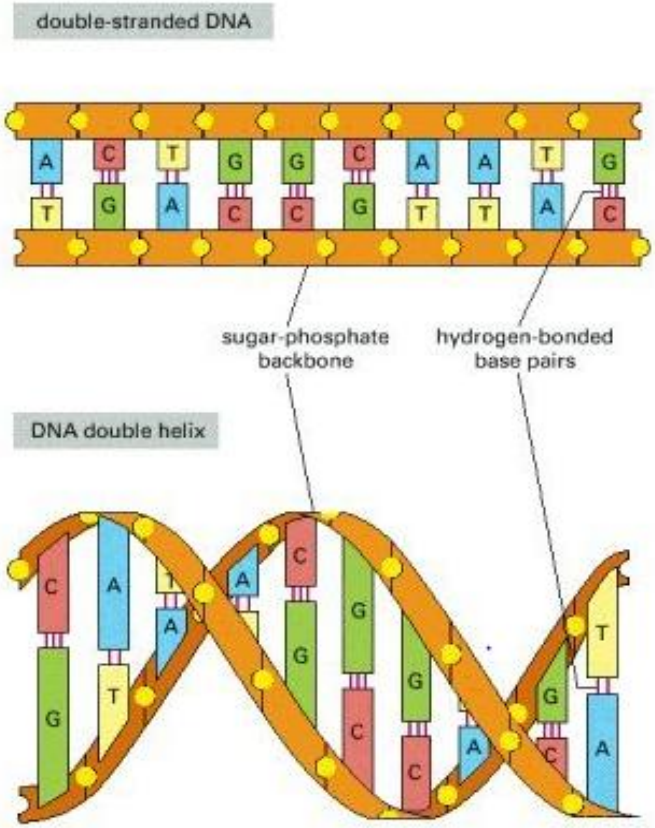
DNA Structure

- **How did Watson and Crick contribute to our understanding of genetics?**
  - Watson and Crick developed the double helix model for DNA



DNA Structure

- **What is a double helix?**
  - the double helix refers to the shape of the DNA molecule



DNA Structure

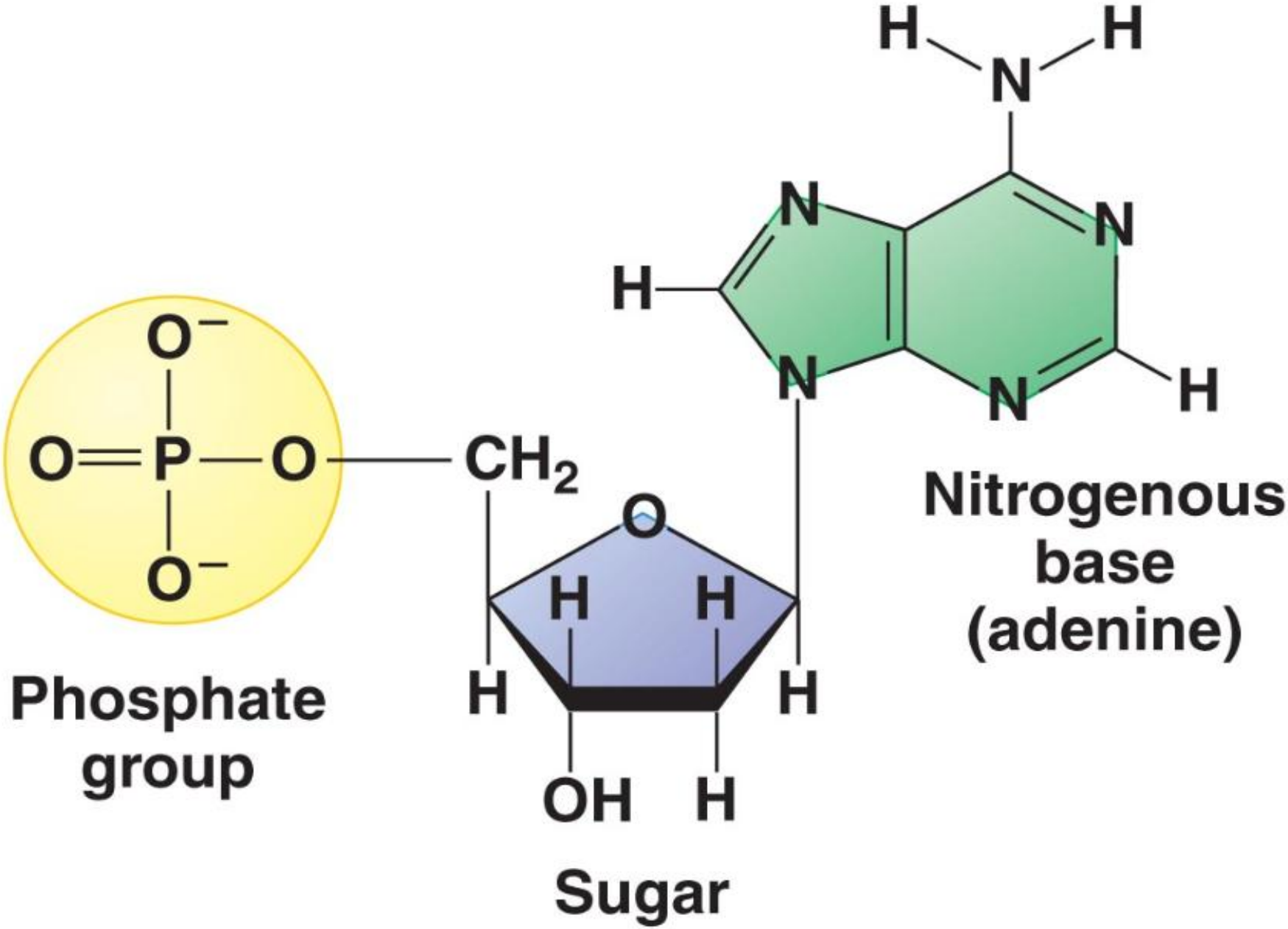
- **DNA is an abbreviation for what term?**
  - DNA is also referred to as Deoxyribonucleic Acid

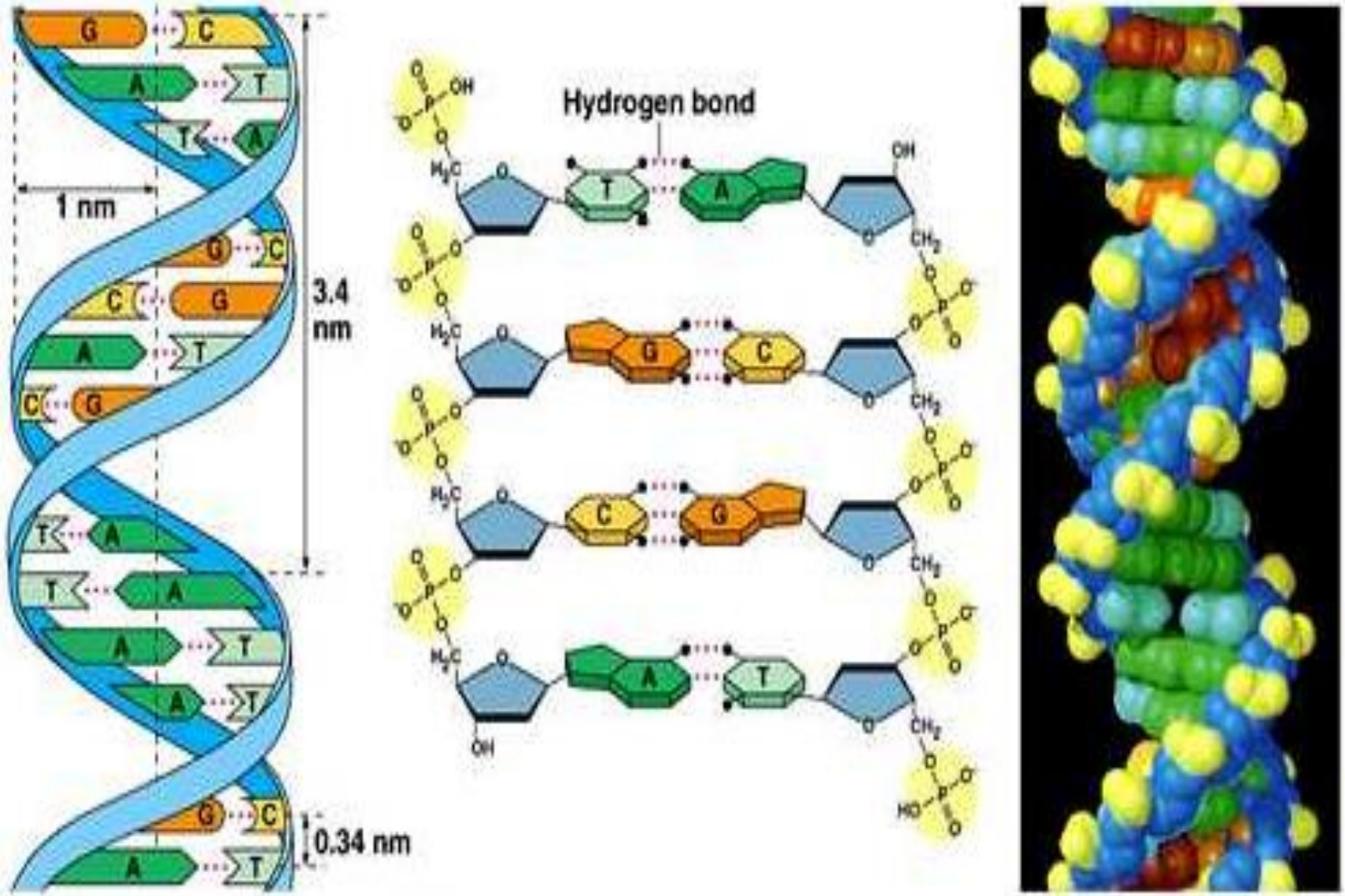
DNA Structure

- **What are nucleotides?**
  - nucleotides are small molecules used to build DNA
  - chromosome 1 has about 263 million nucleotides; chromosome 21 has about 50 million
  - the four different nucleotides in DNA include: Adenine, Thymine, Cytosine, Guanine

DNA Structure

- **What are the three parts found in every nucleotide?**
  - each nucleotide is composed of three parts: sugar, nitrogenous base, phosphate group





(a) (b) (c)

DNA Structure

- **What are the complimentary base pairs found in DNA?**
- A pairs with T; C pairs with G
- therefore, the amount of A = the amount of T; and the amount of C = the amount of G

DNA Replication

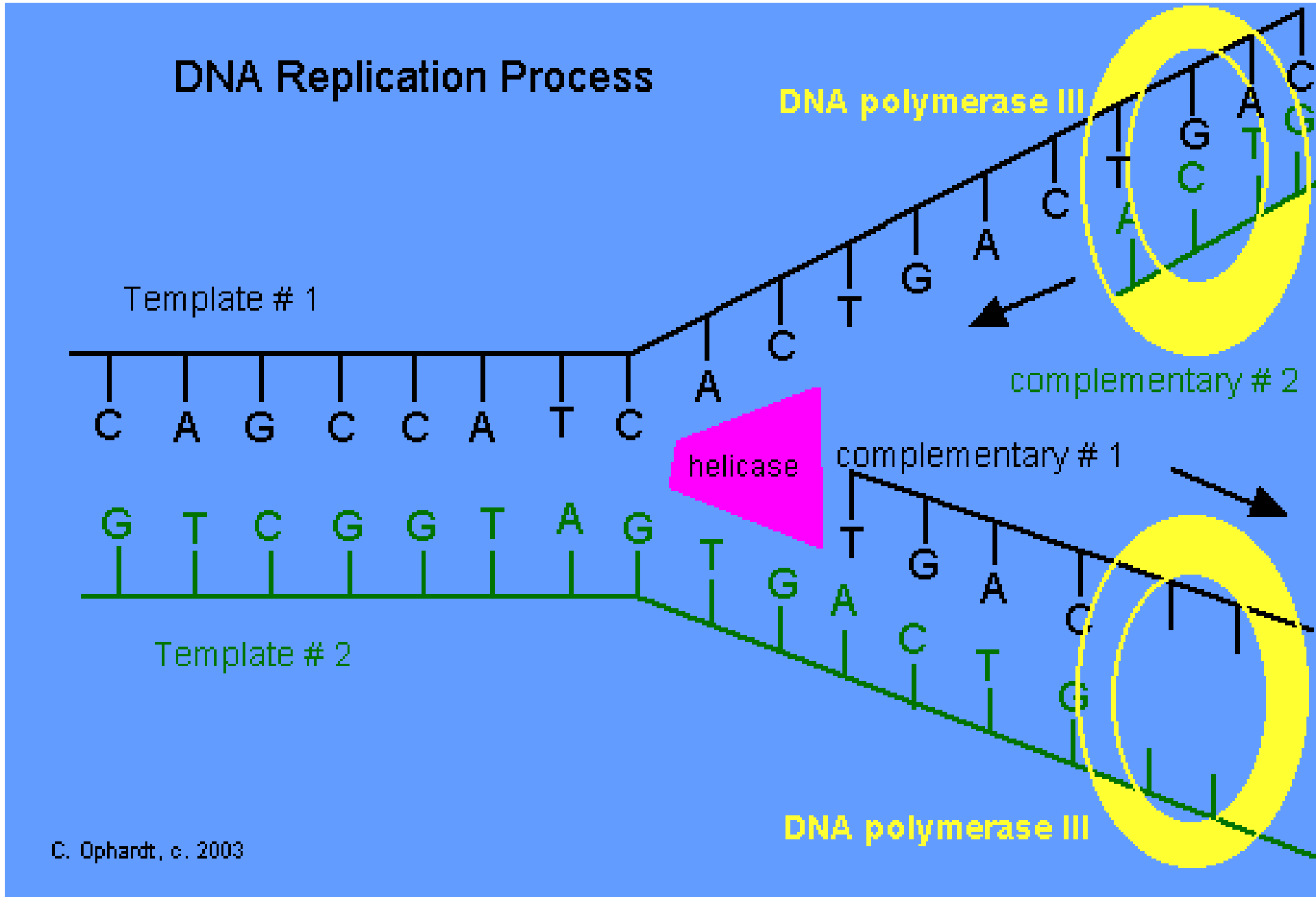
- **When and why does DNA replication occur within cells?**
  - DNA replication occurs during the S phase of interphase; before cell division
  - this ensures each daughter cell will gets complete copy of all the chromosomes

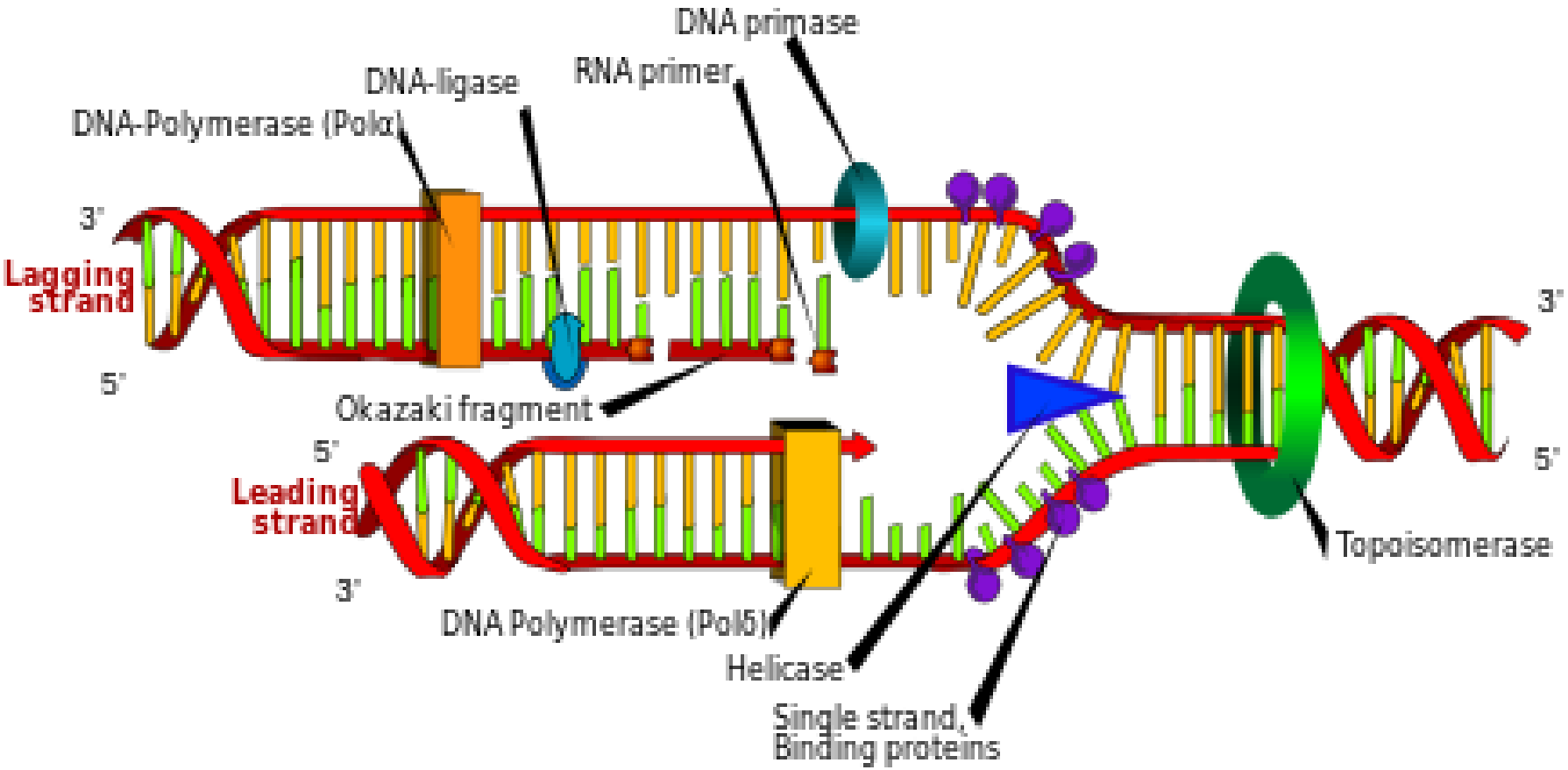
DNA Replication

- **What are the key events of the *template model* for DNA replication?**
  - helicase unwinds the double helix
  - the two exposed strands of DNA act as a template for DNA replication
  - DNA polymerase adds the correct complimentary base pairs to the exposed strands

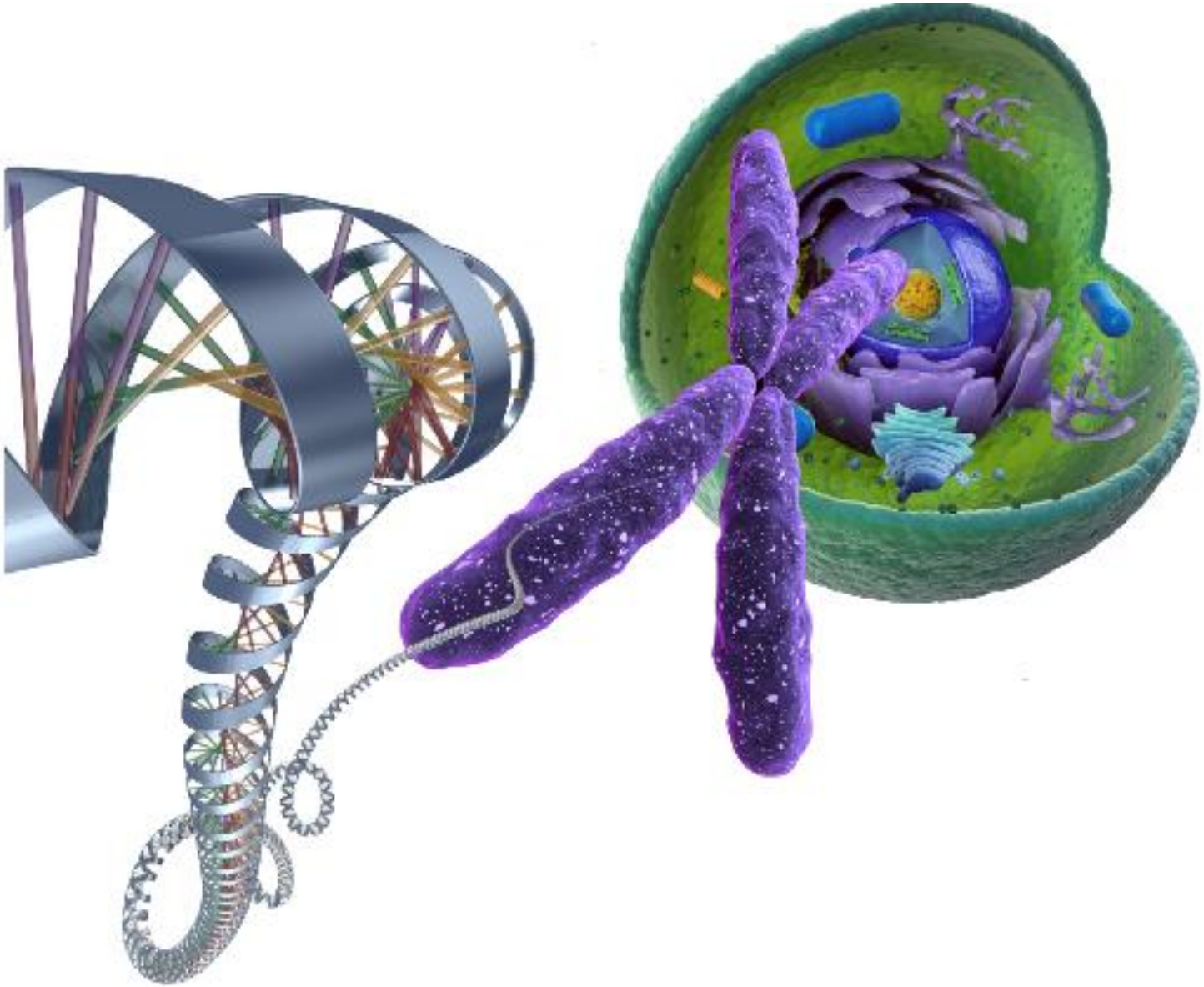
DNA Replication

- **What is the end result of DNA replication?**
  - two identical copies of DNA are produced; one copy for each new daughter


DNA Replication Process
DNA polymerase III
Template # 1
C A G C C A T C
A C T G A C T G A C
complementary # 2
helicase
complementary # 1
T G A C T G
G T C G G T A G T G A C T G
Template # 2
DNA polymerase III
C. Ophardt, c. 2003


DNA primase
RNA primer
DNA-ligase
DNA-Polymerase (Polα)
3'
Lagging strand
5'
Okazaki fragment
5'
Leading strand
3'
DNA Polymerase (Polδ)
Helicase
Single strand Binding proteins
3'
5'
Topoisomerase

Gene Expression



RNA Structure

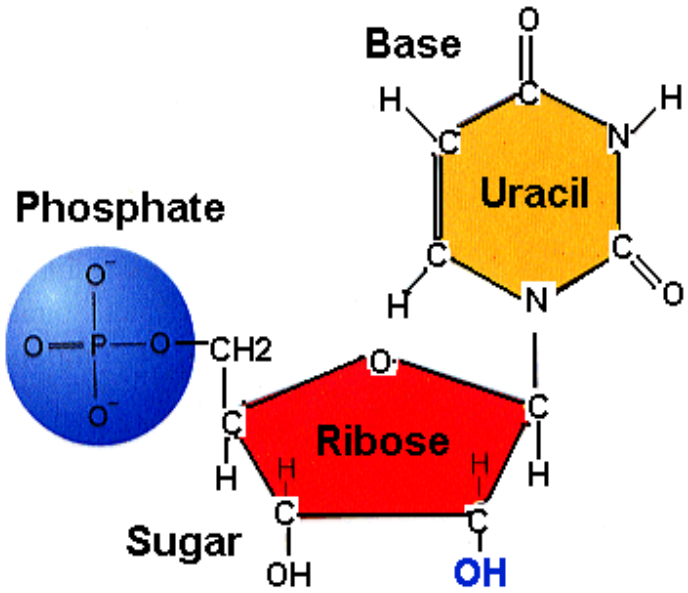
- **RNA is an abbreviation for what term?**
  - RNA is also referred to as Ribonucleic Acid

RNA Structure

- **What are nucleotides?**
  - nucleotides are small molecules used to build DNA
  - the four different nucleotides in RNA include: Adenine, Uracil, Cytosine, Guanine

RNA Structure

- **What are the three parts found in every nucleotide?**
  - each nucleotide is composed of three parts: sugar, nitrogenous base, phosphate group



DNA vs RNA

	DNA	RNA
sugar present	deoxyribose	ribose
structure	double helix	multiple structures exist
# of strands of nucleotides	2	1
nitrogenous bases	A, **T**, C, G	A, **U**, C, G
does its job in the…	nucleus	cytoplasm

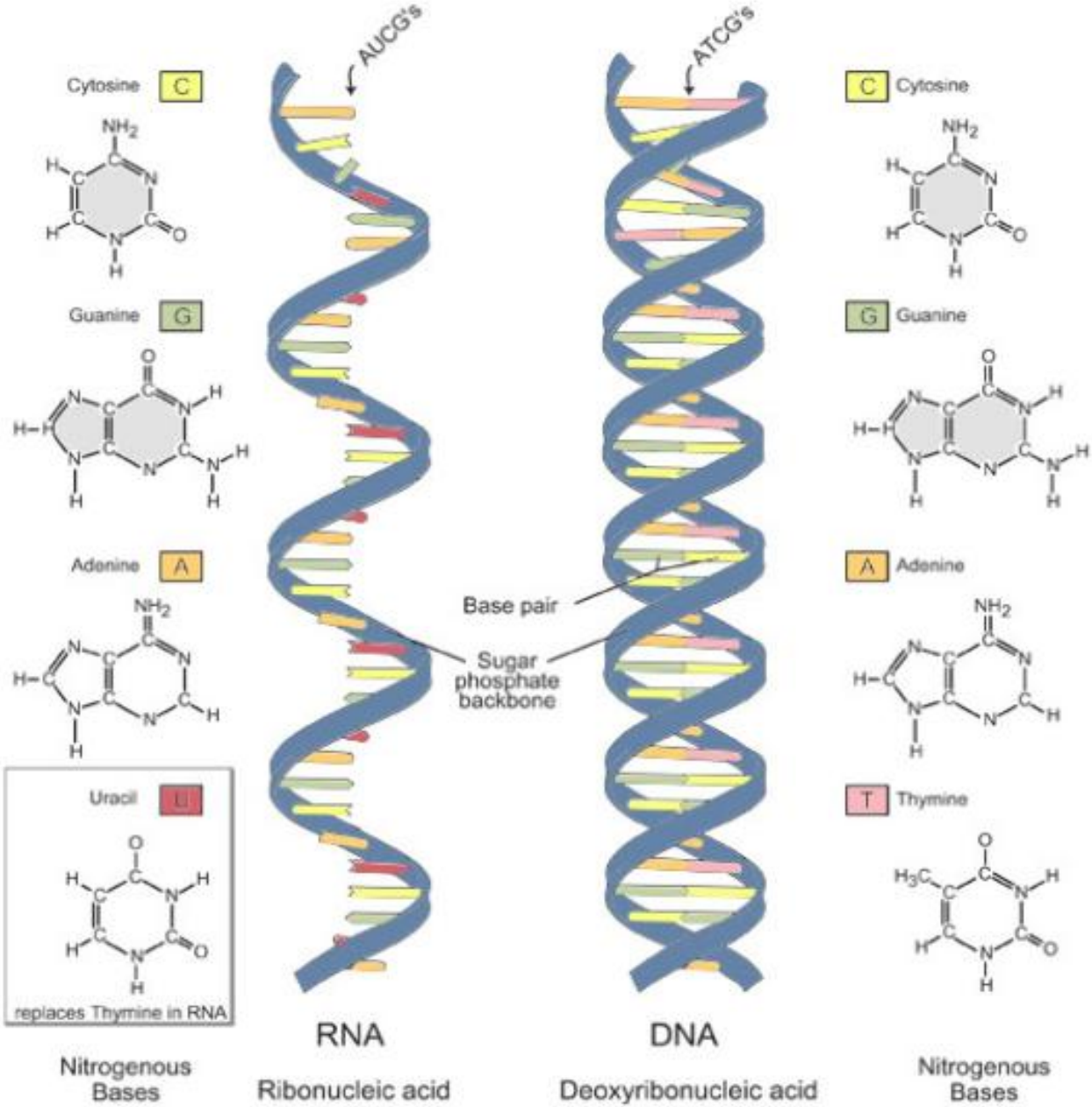
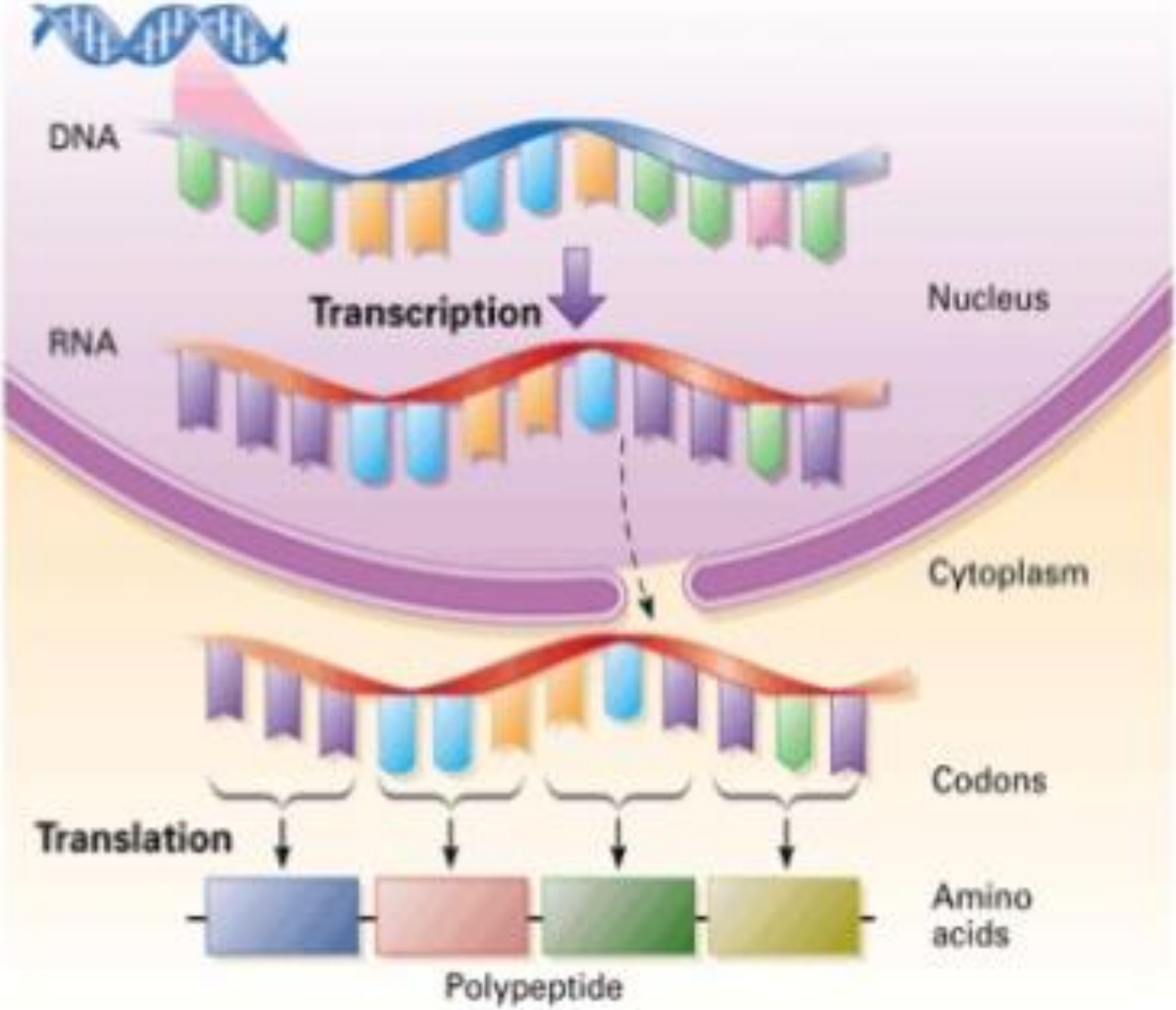


Image adapted from: National Human Genome Research Institute. Talking Glossary of Genetic Terms. Available at: www.genome.gov/Pages/Hyperion//DIR/VIP/Glossary/Illustration/rna.shtml.

The Flow of Genetic Information

- **What is "the flow of genetic information"?**
  - the genetic information in DNA is a guide to making RNA, and the genetic information
  - in RNA is used as a guide to make proteins; or DNA → RNA → Protein


DNA
Transcription
Nucleus
RNA
Cytoplasm
Codons
Translation
Amino acids
Polypeptide

Transcription

– Before we can discuss how transcription occurs, we must be familiar with base pairing rules between DNA and RNA.

DNA base	A	T	C	G	C	T	G	A
RNA base	U	A	G	C	G	A	C	U

Transcription

- **When and where does transcription occur within a cell?**
  - transcription occurs at all times inside the nucleus

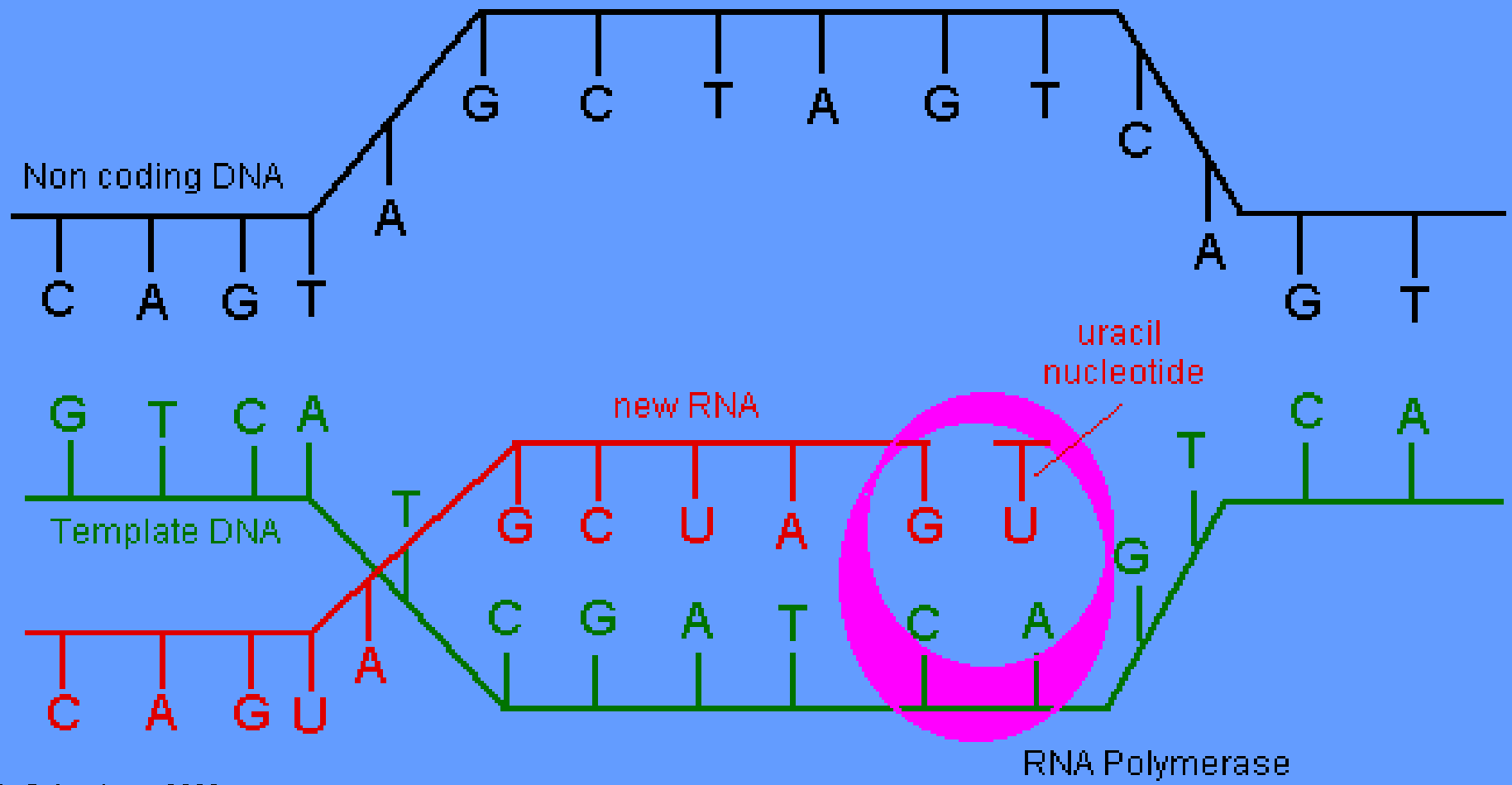
Transcription

- **What are the key events of transcription?**
  - RNA polymerase unwinds the double helix
  - the template strand of DNA acts as a guide for mRNA production
  - RNA polymerase adds the correct complimentary base pairs to the exposed strands

Transcription

- **What is the end result of transcription?**
  - messenger RNA, transfer RNA, and ribosomal RNA are produced
  - all three types of RNA are needed in translation

RNA Transcription



Translation

- Before we can discuss how translation occurs, we must be familiar with *the genetic code*.
  - a chart containing mRNA codons contains the genetic code
  - a mRNA codons contain 3 bases, which code for one amino acid
  - 64 mRNA codons exist
  - AUG refers to the start codon, which signals the start of translation
  - UAA, UAG, or UGA refer to stop codons, which signals translation to stop

Second nucleotide

First nucleotide	U	C	A	G	Third nucleotide
U	UUU Phe UUC UUA Leu UUG	UCU UCC Ser UCA UCG	UAU Tyr UAC UAA STOP UAG STOP	UGU Cys UGC UGA STOP UGG Trp	U C A G
C	CUU CUC Leu CUA CUG	CCU CCC Pro CCA CCG	CAU His CAC CAA Gln CAG	CGU CGC Arg CGA CGG	U C A G
A	AUU Ile AUC AUA AUG Met	ACU ACC Thr ACA ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC Val GUA GUG	GCU GCC Ala GCA GCG	GAU Asp GAC GAA Glu GAG	GGU GGC Gly GGA GGG	U C A G

Translation

- **When and where does translation occur within a cell?**
  - translation occurs at all times inside the cytoplasm, at the ribosomes
  - ribosomes, composed of rRNA, are needed
  - mRNA and tRNA are also needed

Translation

- **What are the key events of translation?**
  - tRNA, transfer RNA – carries amino acids from the cytoplasm to the ribosomes
  - mRNA, messenger RNA – determines what order the amino acids should be placed in
  - ribosomes – forms peptide bonds between the amino acids

Translation

- **What is the end result of translation?**
  - proteins are produced
  - some of the proteins made include: enzymes, structural proteins, antibodies, transport proteins, contracting proteins

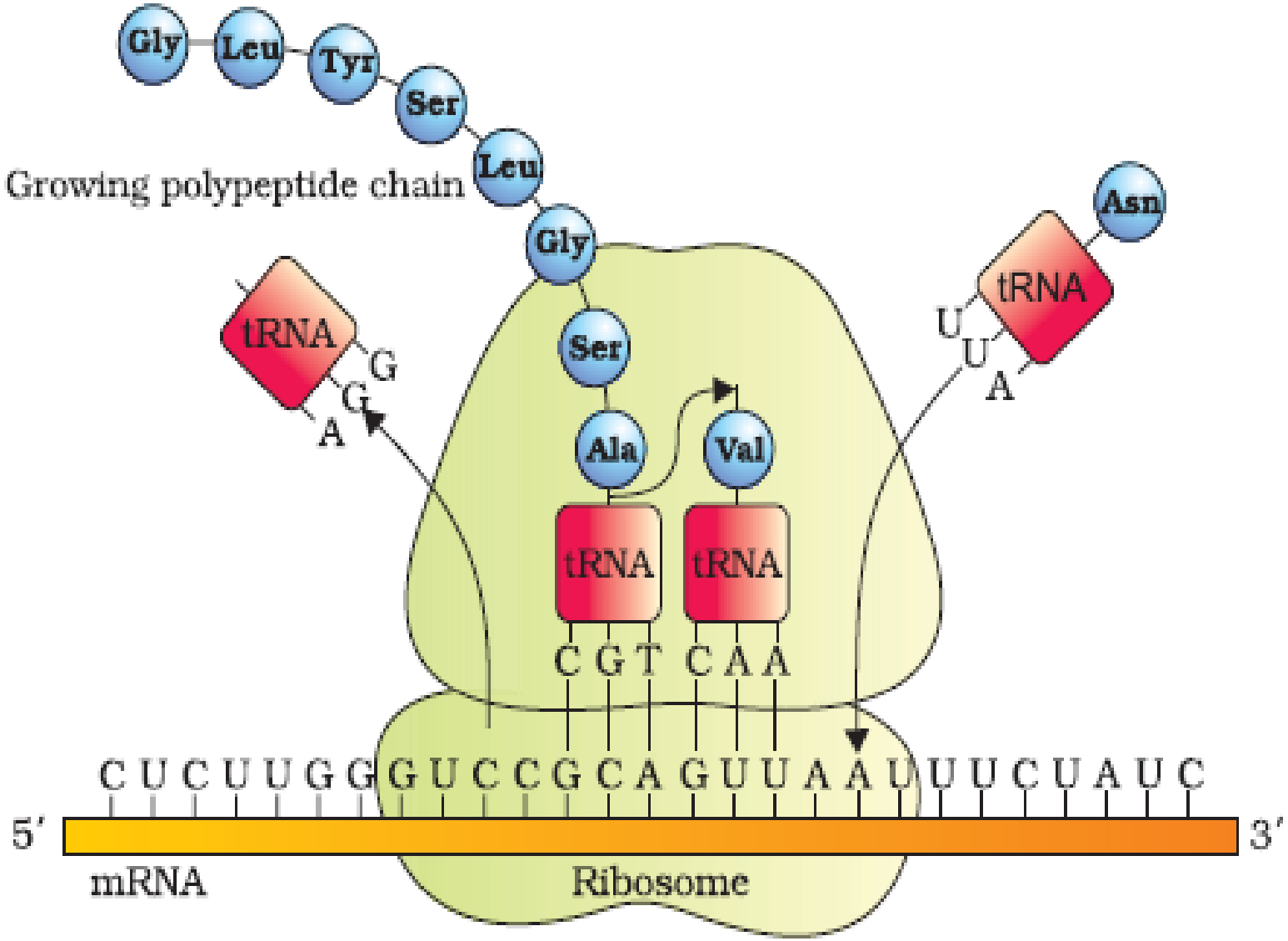


Figure 6.13 Translation

Mutations

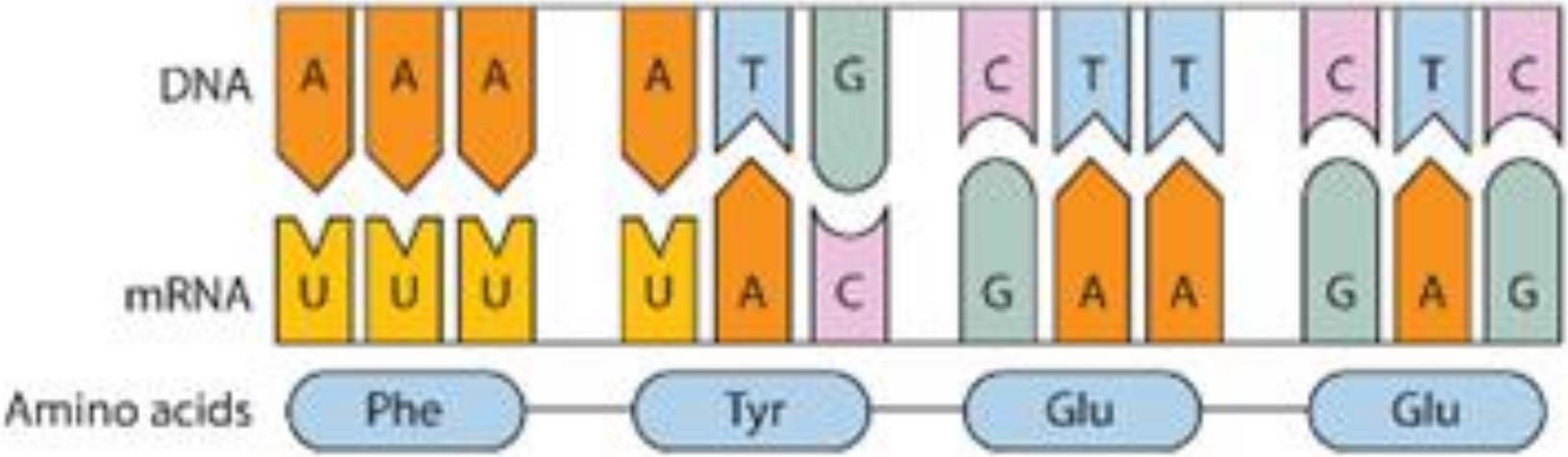
- **What is a mutation?**
  - a mutation is a change in the sequence of bases in DNA
  - mutations may result in the production of defective proteins

Mutations

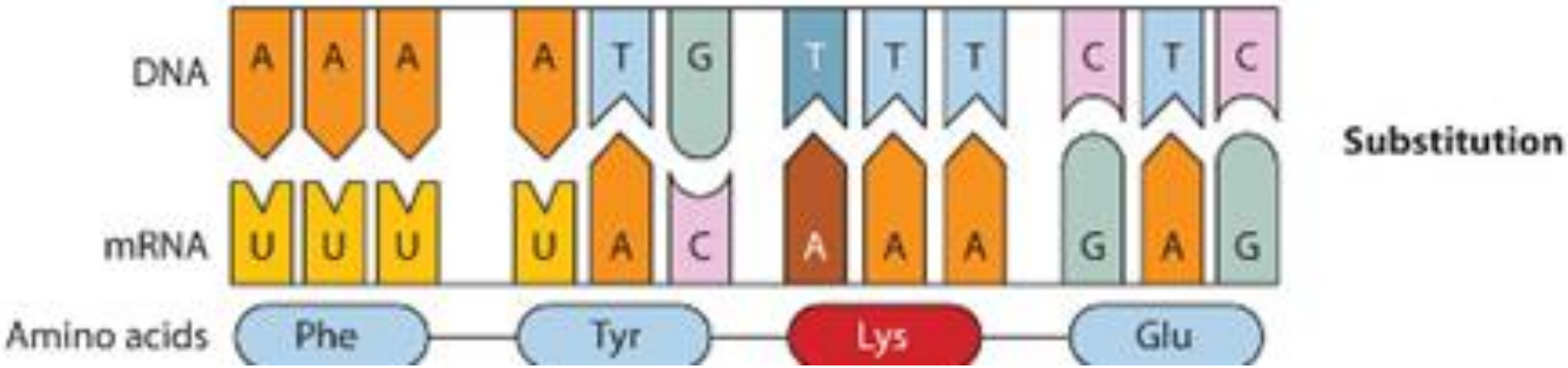
- **What environmental factors may cause mutations to occur?**
  - mutations may be caused by: UV radiation, viruses, cigarette smoking, dietary fat

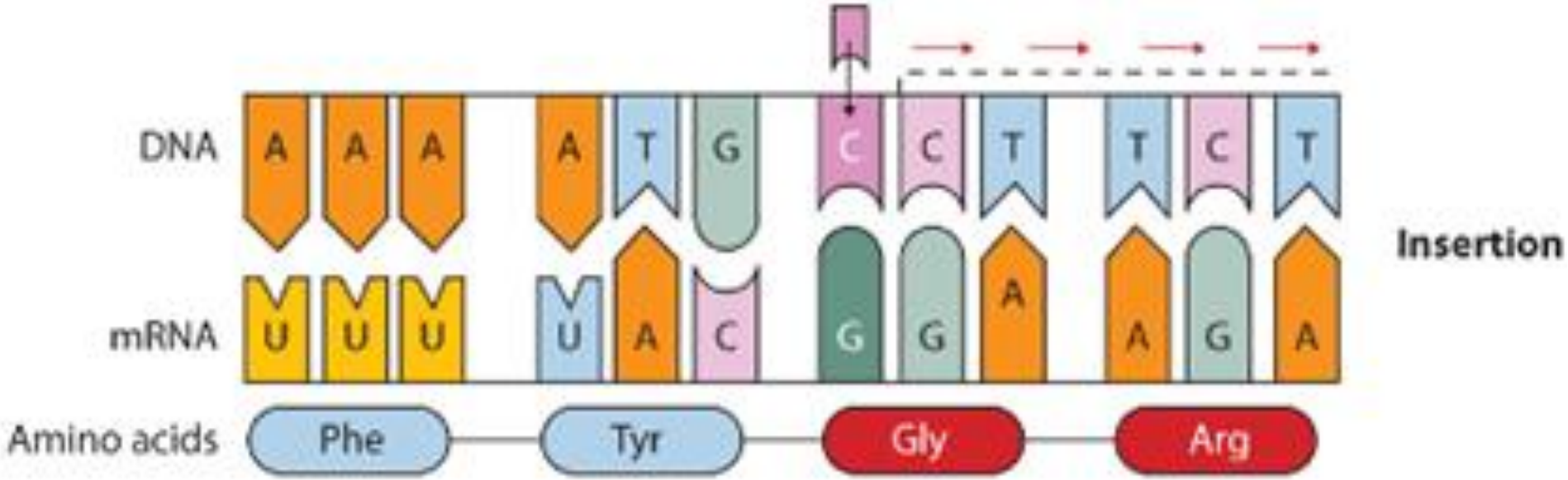
Mutations

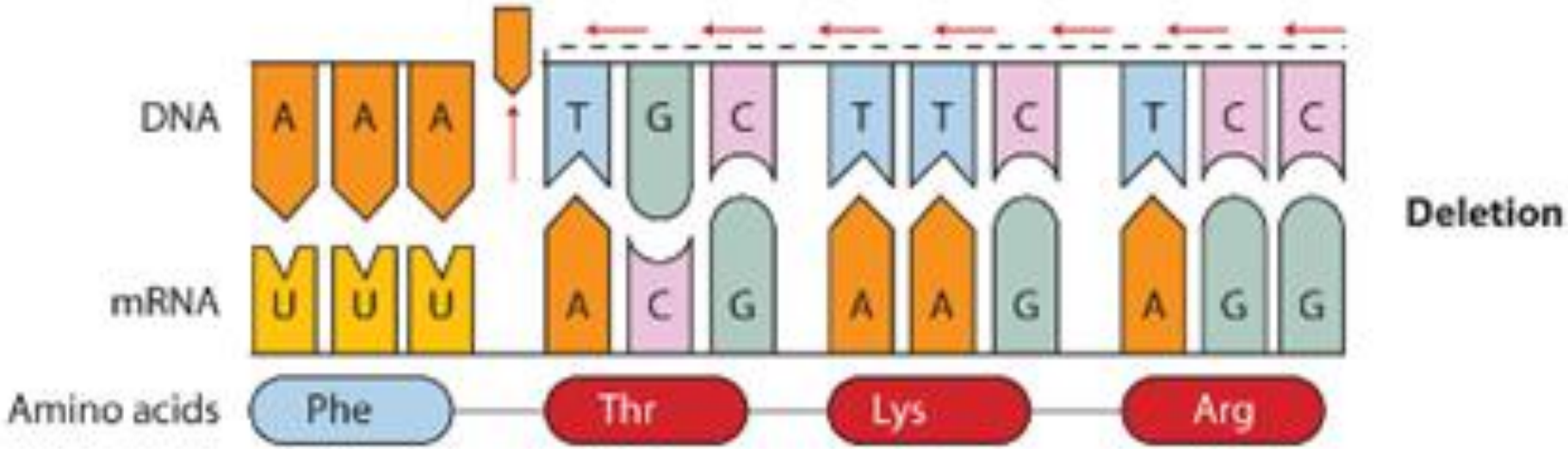
- **Are mutations beneficial to organisms?**
  - yes: mutations may result in genetic variation
  - no: mutations may disrupt metabolism, resulting in a genetic disorder, disease, or death


DNA
A A A A T G C T T C T C
mRNA
U U U U A C G A A G A G
Amino acids
Phe
Tyr
Glu
Glu

Normal


DNA
A A A A T G T T T C T C
mRNA
U U U U A C A A A G A G
Amino acids
Phe
Tyr
Lys
Glu
Substitution

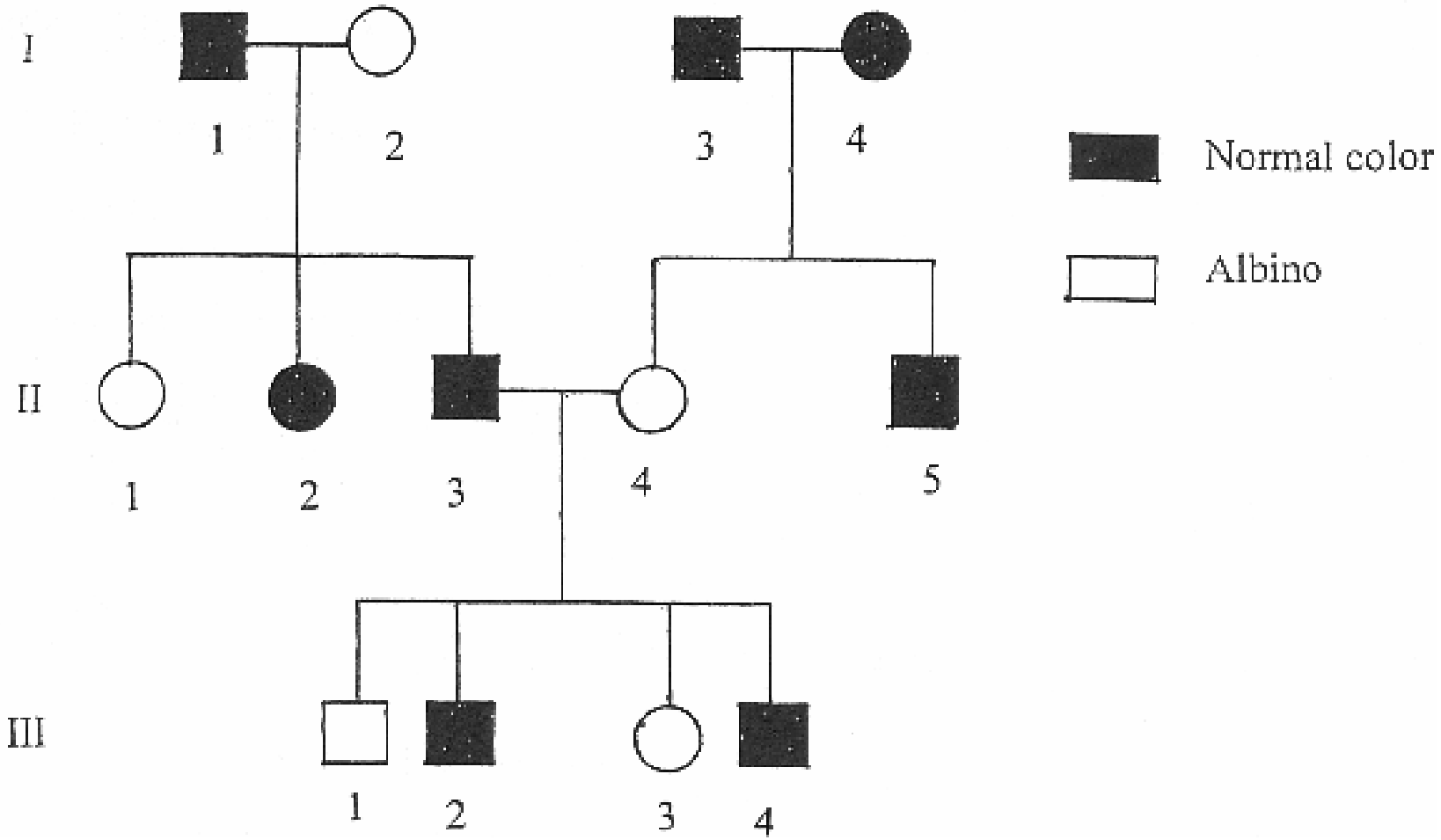

DNA
A A A A T G C C T T C T
mRNA
U U U U A C G G A A G A
Amino acids
Phe
Tyr
Gly
Arg
Insertion

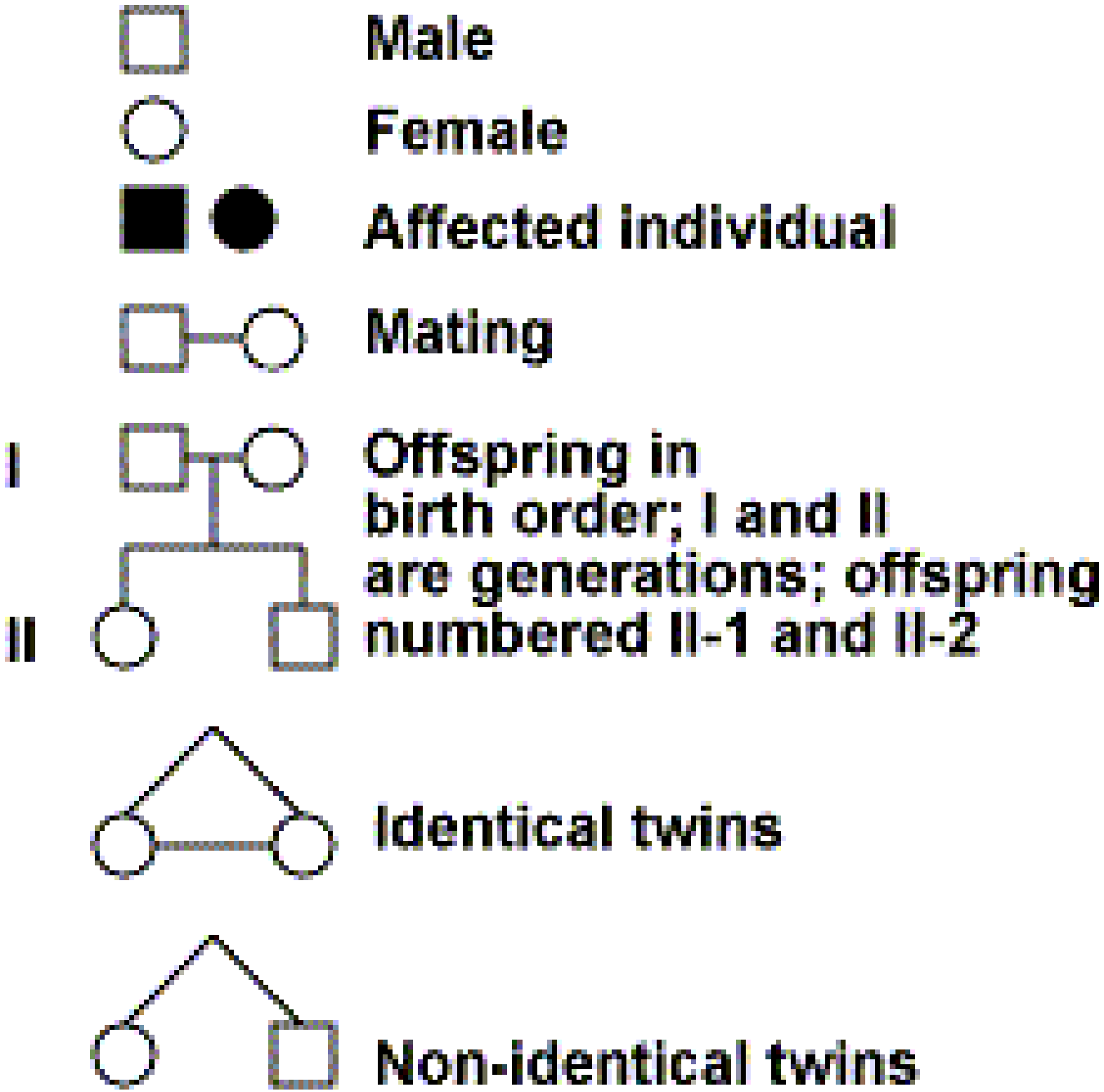

DNA
A A A
T G C T T C T C C
mRNA
U U U
A C G A A G A G G
Amino acids
Phe
Thr
Lys
Arg
Deletion

Genetic Disorders

- **What is a pedigree?**
  - a diagram that shows the occurrence of a genetic trait over several generations of a family
  - helps determine whether a genetic disorder is Autosomal (dominant or recessive) or sex linked
  - With the help of a genetic counselor, a pedigree can help parents determine if there is a chance of passing a genetic disorder to their children

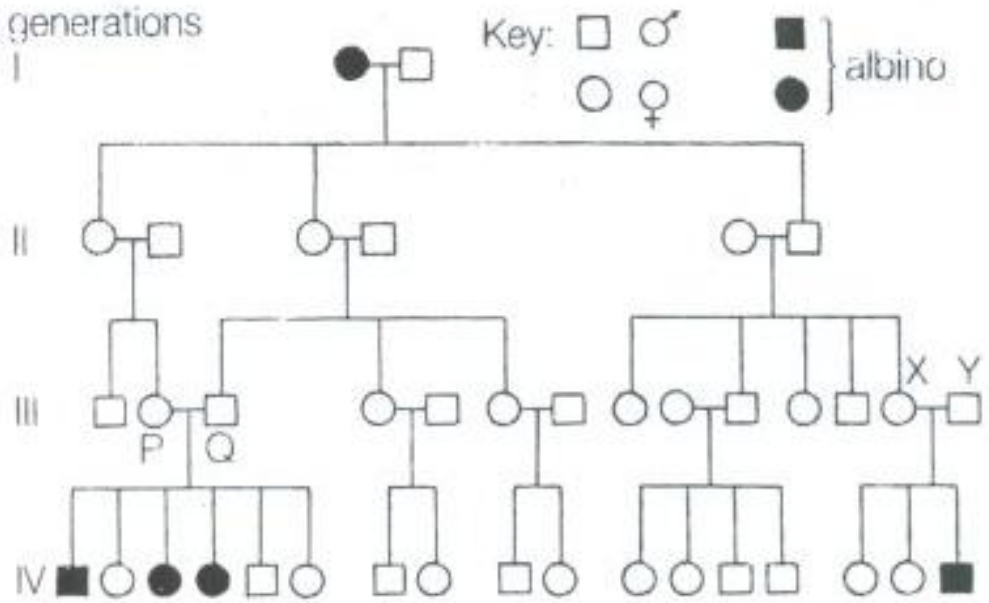
Figure 14.3-5 Pedigree for skin color




Male
Female
Affected individual
Mating
I
II
Offspring in birth order; I and II are generations; offspring numbered II-1 and II-2
Identical twins
Non-identical twins

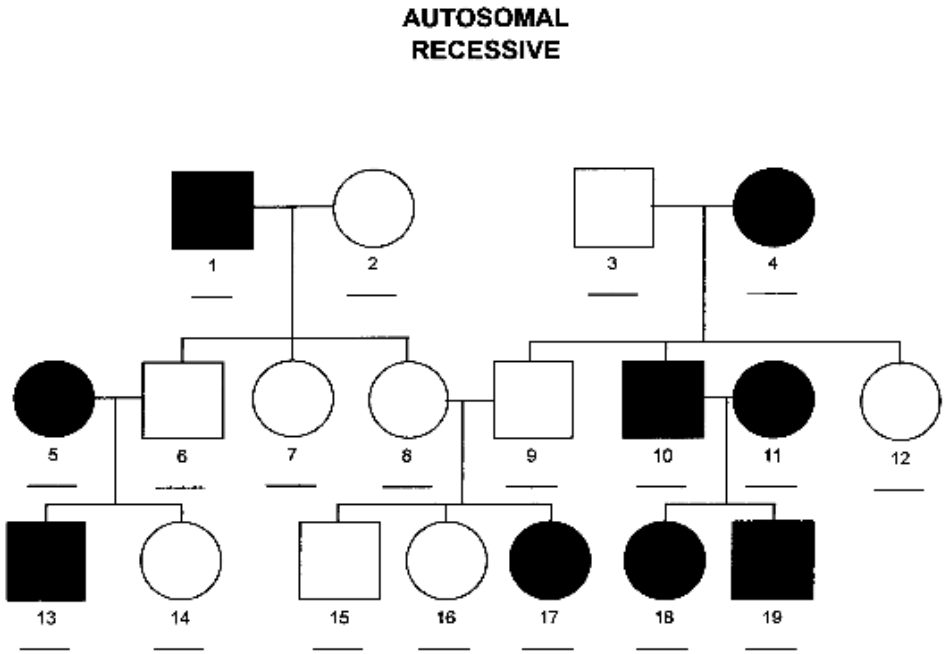
Genetic Disorders

- **Autosomal Recessive Disorders**
  - Albinism: lack of pigments
  - cystic fibrosis: thick mucus in lungs
  - phenylketonuria
  - sickle cell disease
  - tay - sachs disease



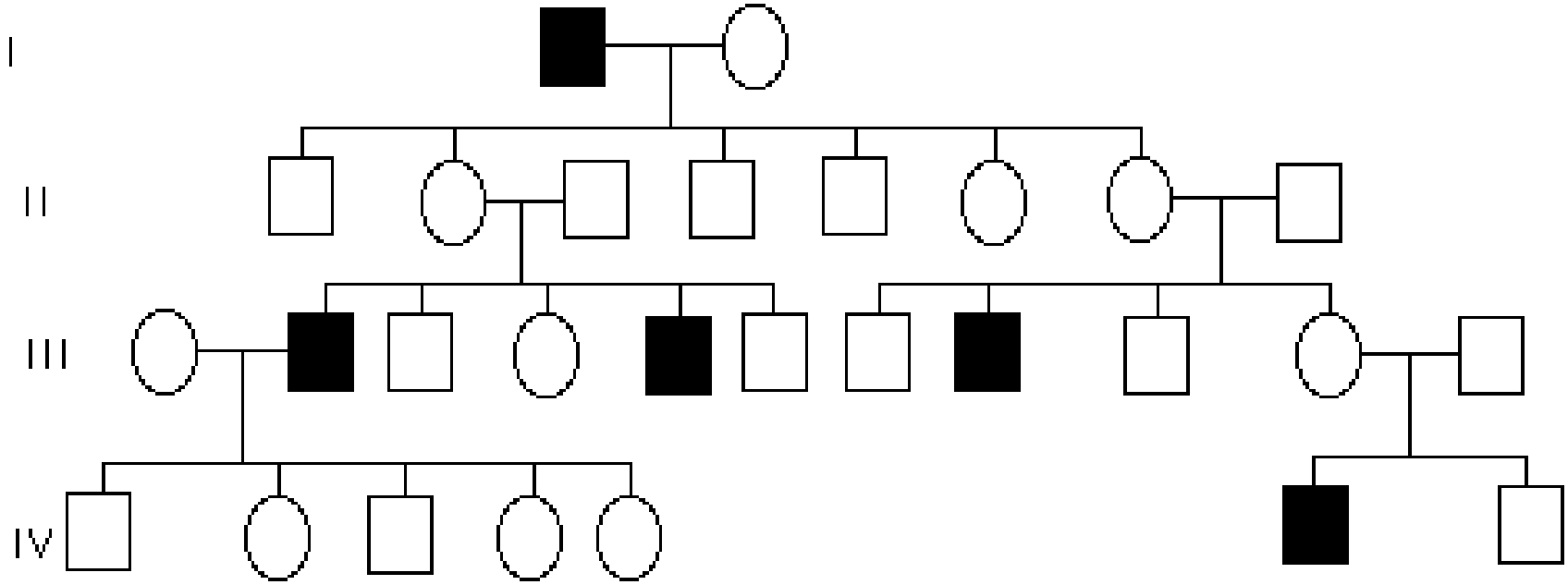
Genetic Disorders

- Autosomal Dominant Disorders
  - Achondroplasia: a form of dwarfism
  - Alzheimer's disease: mental deterioration
  - Huntington's disease
  - hypercholesterolemia



Genetic Disorders

- **Sex-Linked Disorders**
  - red - green color blindness
  - Hemophilia: blood does not clot properly
  - Duchenne muscular dystrophy



Biotechnology

- **What is a clone?**
  - a clone is an exact copy of an organism
  - if two organisms are considered clones, they should be genetically identical
- **Can cloning occur among organisms in nature?**
  - yes
  - bacteria, some algae, some fungus, some plants, and some animals can clone themselves

Biotechnology

- **When did humans start cloning organisms?**
  - 1950's – scientists demonstrate cloning is possible in plants
  - 1997 – scientists demonstrate cloning is possible in a mammal, Dolly the sheep

Biotechnology

- **What are the potential benefits of cloning organisms?**
  - in agriculture: development of animals with desired traits
    - tomatoes that resist bruising and spoiling
    - pigs with lean meat
    - bacteria make cellulase to digest cellulose for animal feed
  - in the pharmaceutical industry: production of medications for human use
    - mammals produce factor viii to help clot blood
    - bacteria produce insulin to treat diabetes
    - bacteria produce human growth hormone to treat growth defects

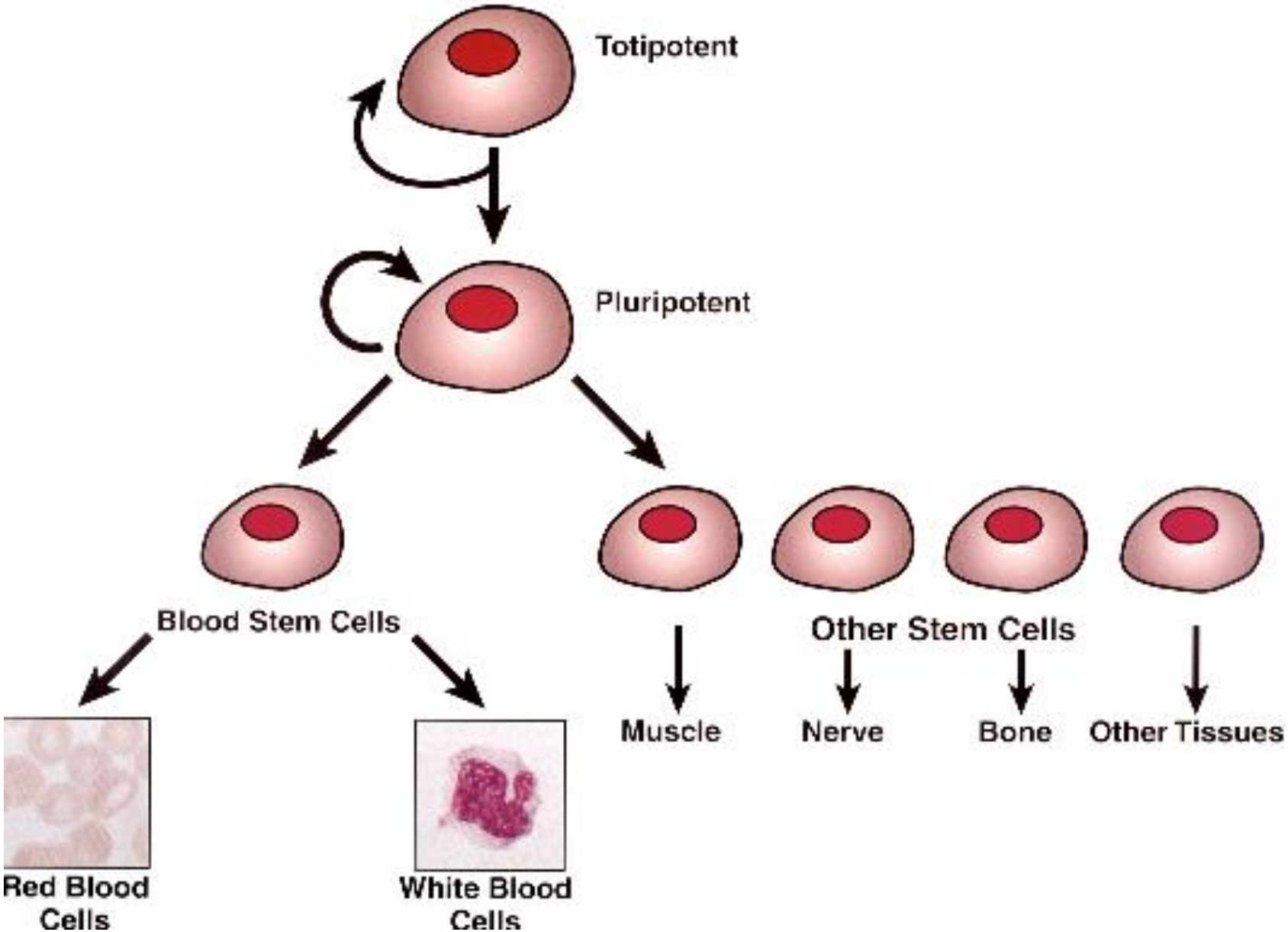
Biotechnology

- **What are the potential benefits of cloning organisms?**
  - for the environment
    - bacteria that remove toxic metals such as lead from the soil
    - bacteria that can break down chemicals released during an oil spill
    - bacteria that can remove harmful chemicals at waste water treatment plants

Biotechnology

- **What are stem cells?**
  - stem cells are unspecialized
  - stem cells can divide indefinitely
  - stem cells can develop into many other cell types

Hierarchy of Stem Cells

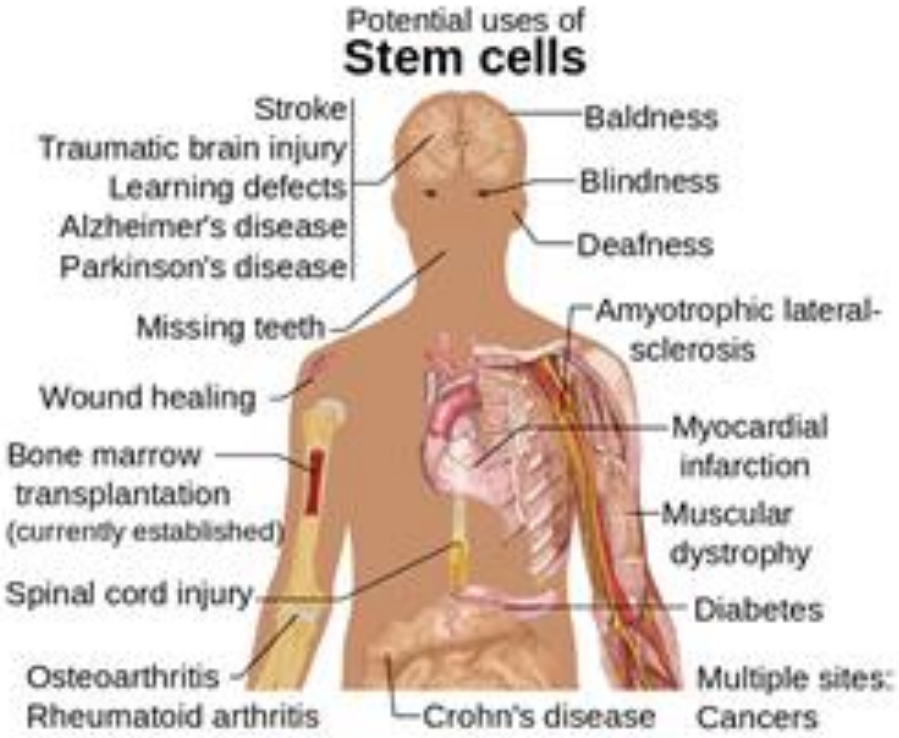


Biotechnology

- **How are embryonic stem cells different from adult stem cells?**
  - embryonic stem cells can develop into all cell types
  - adult stem cells can develop into a limited number of cell types

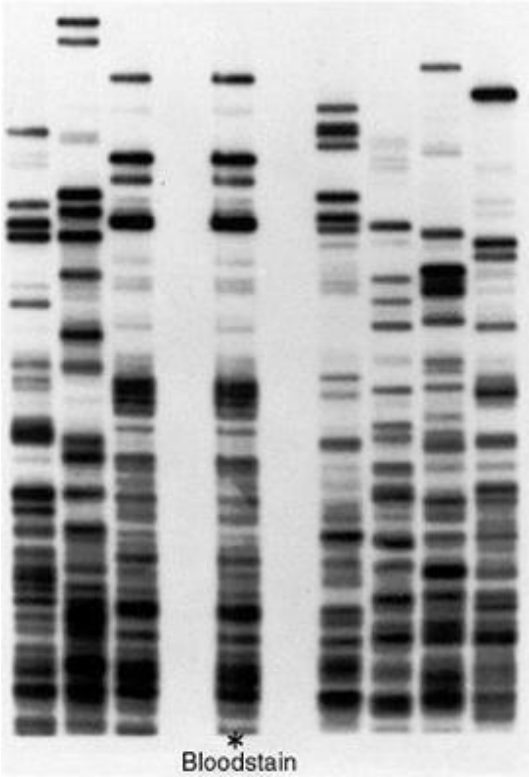
Biotechnology

- **Why conduct stem cell research?**
  - stem cell research may result in treatment for many medical conditions



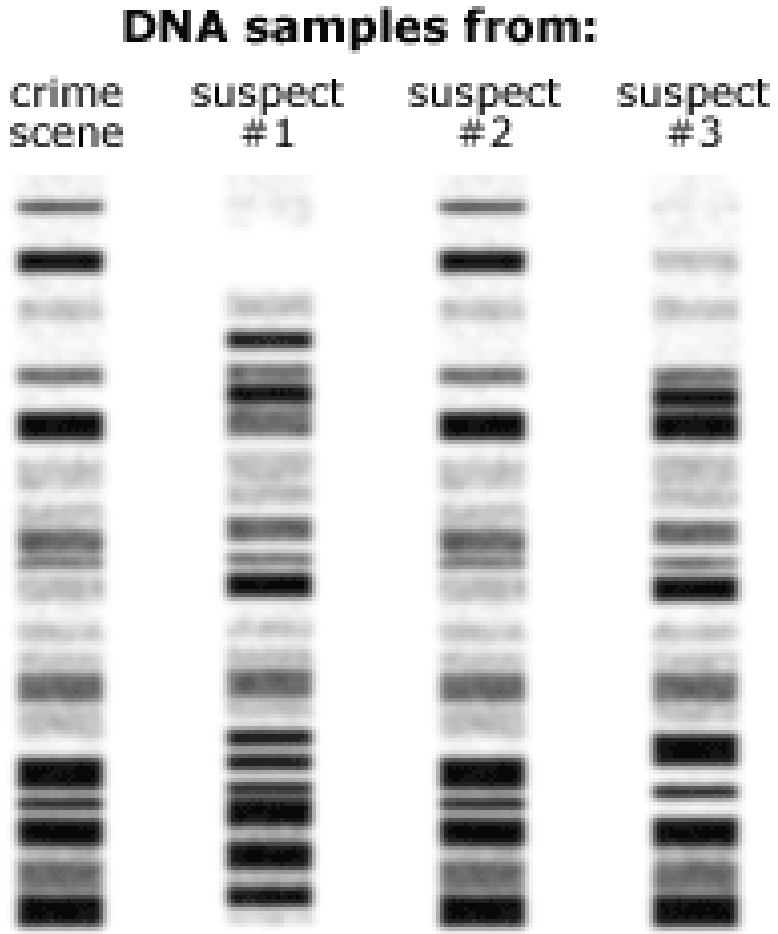
Biotechnology

- **What is a DNA fingerprint?**
  - a DNA fingerprint refers to a specific banding pattern seen in a DNA sample taken from an individual



Biotechnology

- **How are DNA fingerprints useful?**
  - Crime scene investigation
  - Missing person identification
  - Paternity testing
  - Diagnosing genetic disorders
  - Species identification



When forensic scientists examine DNA in the lab, each sample appears as a unique sequence of dark bars. Patterns of bars are compared to find a match. In the hypothetical example shown here, it looks like suspect #2 left some DNA at the crime scene.

Biotechnology

- **What is gene therapy?**
  - this procedure involves altering an individual's genes
  - genes that cause genetic disorders are replaced with normal genes

Biotechnology

- **Why conduct gene therapy?**
  - it may be possible to cure individuals that have genetic disorders

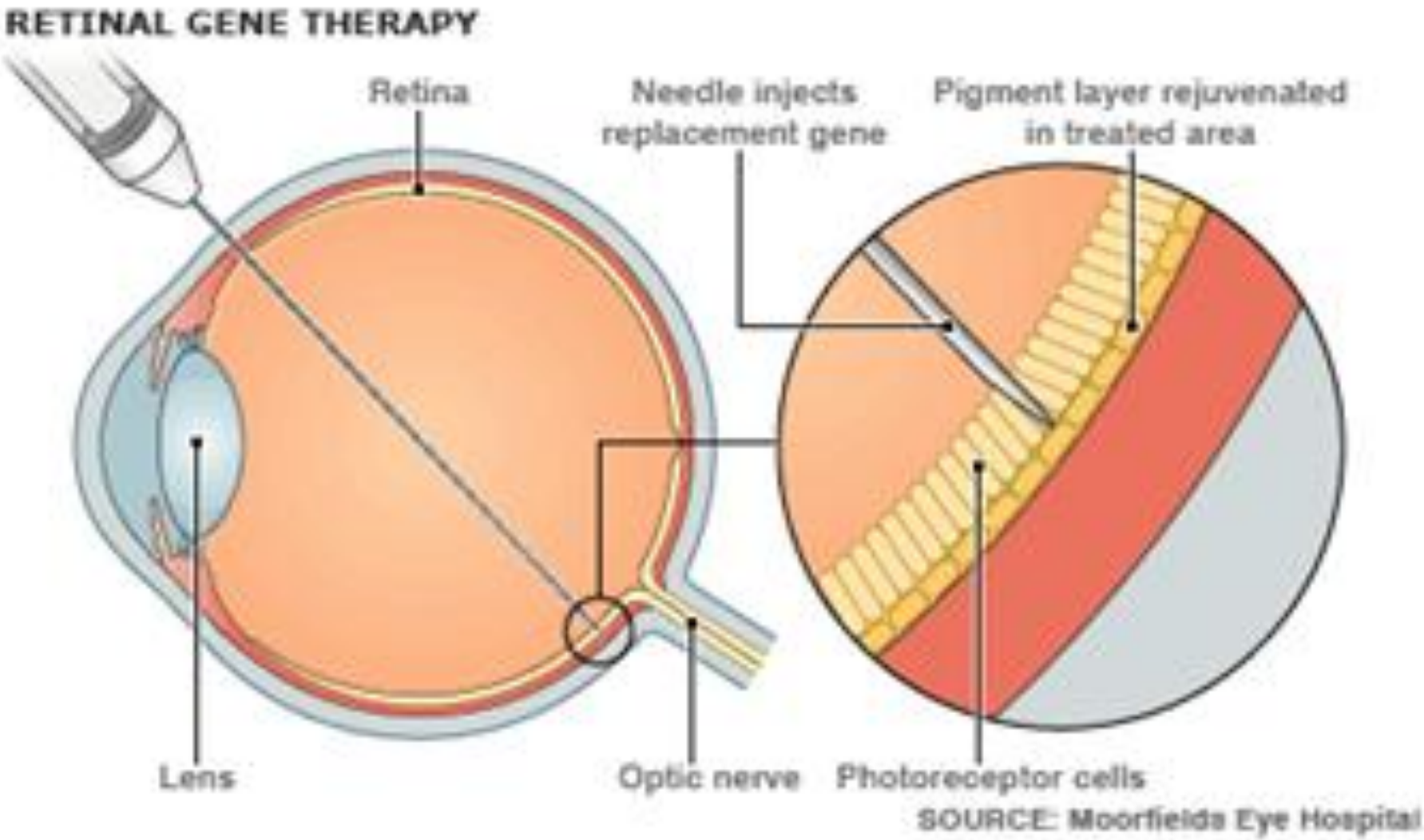
How It Works | The procedure the SCID-X1 trial will use

Stem cells are isolated from bone marrow harvested from a baby's hip

The normal gene is inserted into the stem cells in the lab.

The corrected cells are then transfused back into the baby and populate over time, repairing the baby's faulty immune system.

Source: Children's Hospital Boston
Photo: Getty Images


RETINAL GENE THERAPY
Retina
Needle injects replacement gene
Pigment layer rejuvenated in treated area
Lens
Optic nerve
Photoreceptor cells
SOURCE: Moorfields Eye Hospital