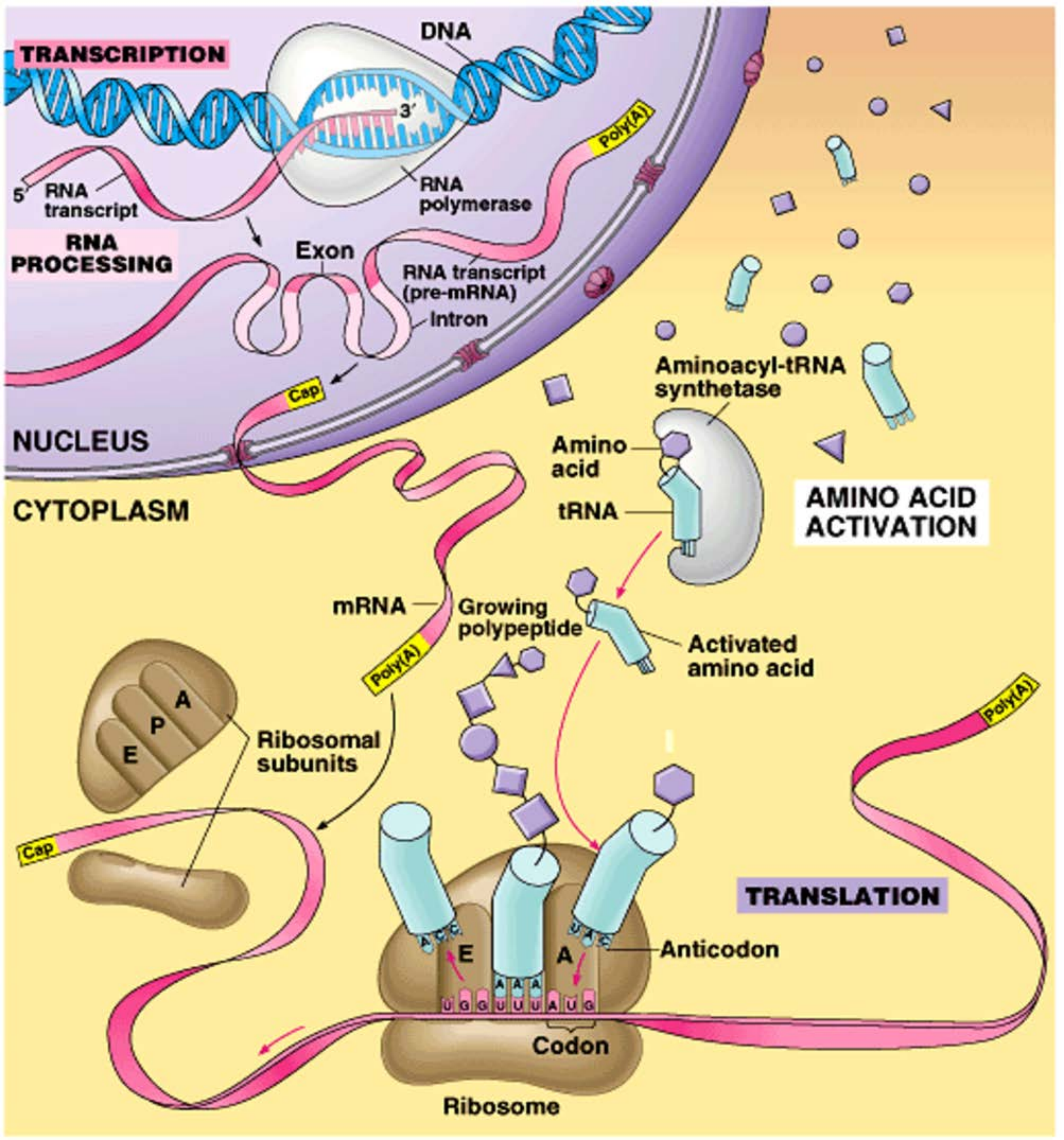
TRANSCRIPTION
DNA
3′
5′
RNA transcript
RNA polymerase
Poly(A)
RNA PROCESSING
Exon
RNA transcript (pre-mRNA)
Intron
Cap
NUCLEUS
CYTOPLASM
Aminoacyl-tRNA synthetase
Amino acid
tRNA
AMINO ACID ACTIVATION
mRNA
Growing polypeptide
Activated amino acid
Poly(A)
A
P
E
Ribosomal subunits
Cap
Poly(A)
TRANSLATION
E
A
Anticodon
U G G U U U A U G
Codon
Ribosome

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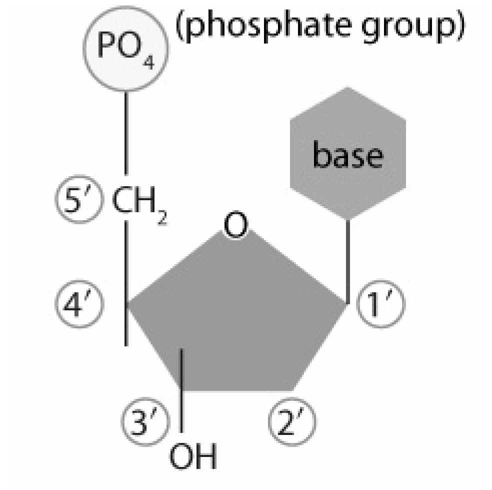
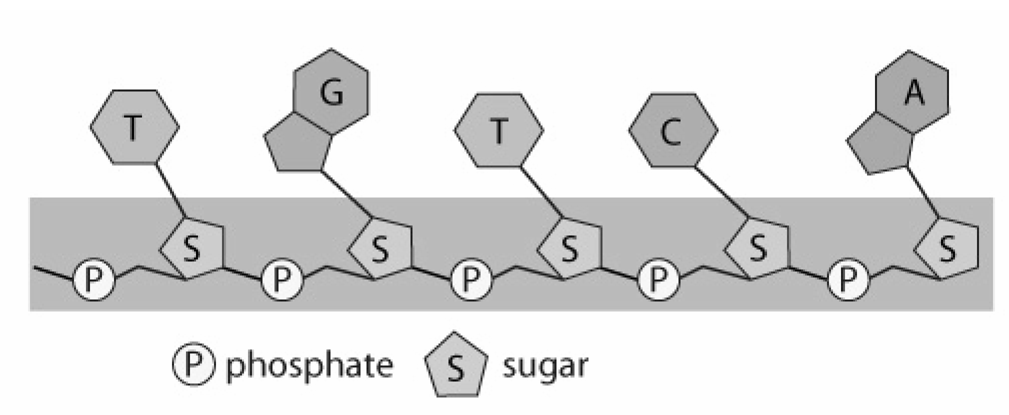
CHAPTER 18 OVERHEAD	DNA Nucleotide and Sugar-Phosphate Backbone	BLM 18.1.4

DNA Nucleotide and Sugar-Phosphate Backbone

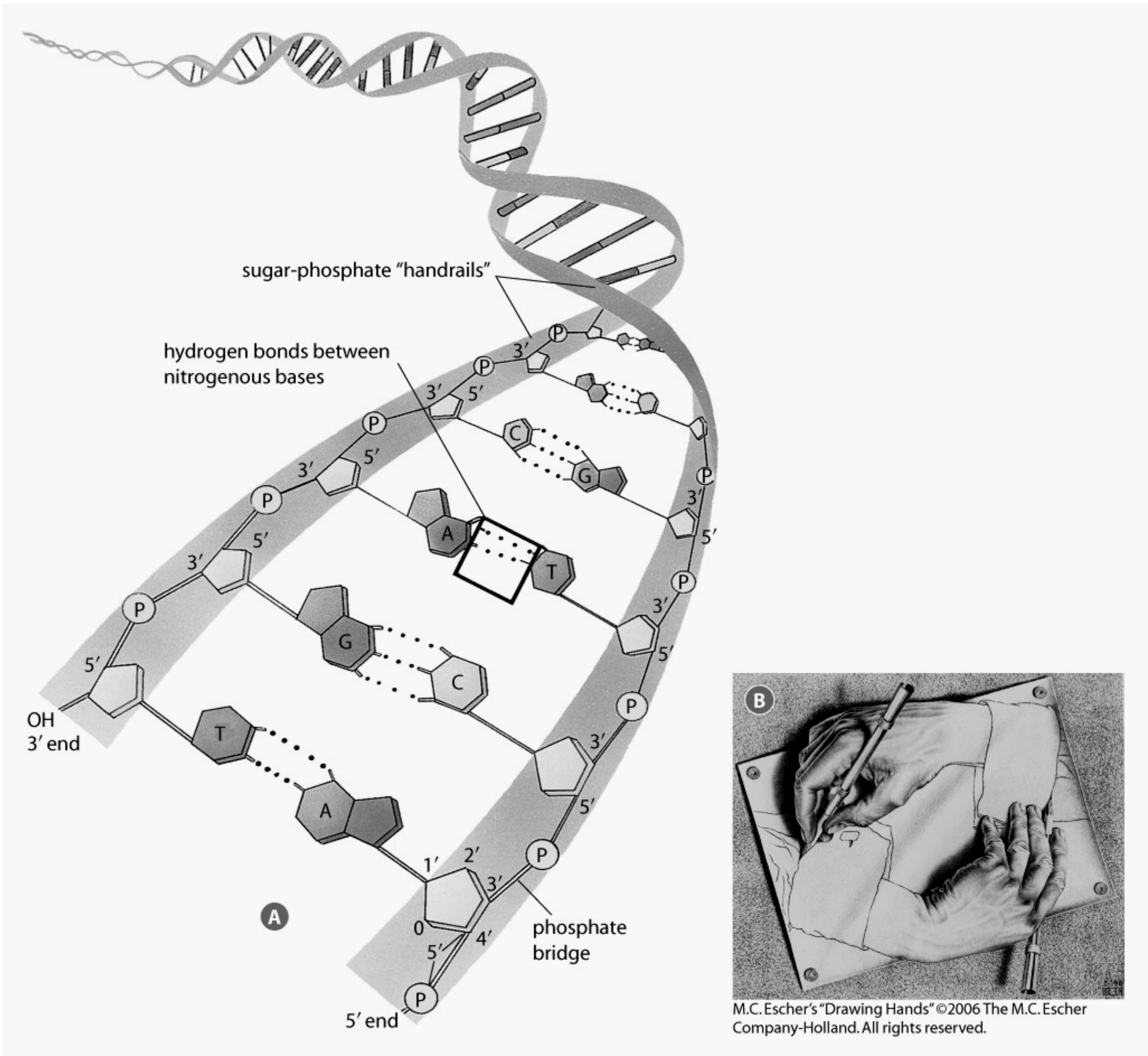


The general structure of a DNA nucleotide. An RNA nucleotide has an additional oxygen molecule in the five-carbon sugar ring. Notice the numbering of the carbon atoms on the sugar molecule. The five carbon atoms of the sugar of the nucleotide are numbered 1' to 5', and they proceed clockwise from the oxygen atom. The prime symbol (') indicates that the carbon belongs to the sugar rather than to the base.



Nucleotides are joined together in a long chain. The "backbone" of the chain is made up of alternating sugar and phosphate groups that are joined by chemical bonds. The nitrogenous bases project out from the sugar-phosphate backbone.

The Double Helix



M.C. Escher's "Drawing Hands" ©2006 The M.C. Escher Company-Holland. All rights reserved.

A DNA molecule is made up of two strands of nucleotides that are wound around each other **(A)**. The two strands are held together by hydrogen bonds between complementary base pairs. C-G pairs are held together by three hydrogen bonds, and A-T pairs are held together by two hydrogen bonds. Notice that the chains are antiparallel—the 5' to 3' orientation runs in the opposite direction on each strand. Another example of antiparallelism is represented by M.C. Escher's sketch, "Drawing Hands" **(B)**.

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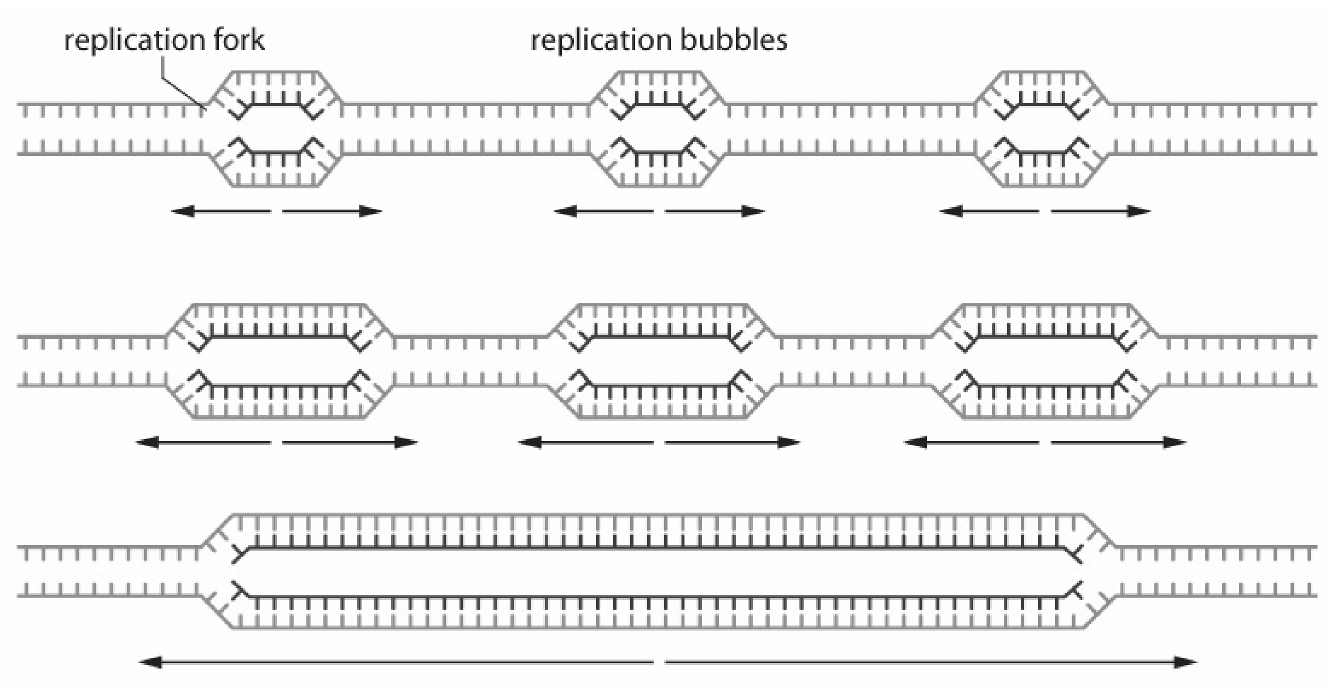
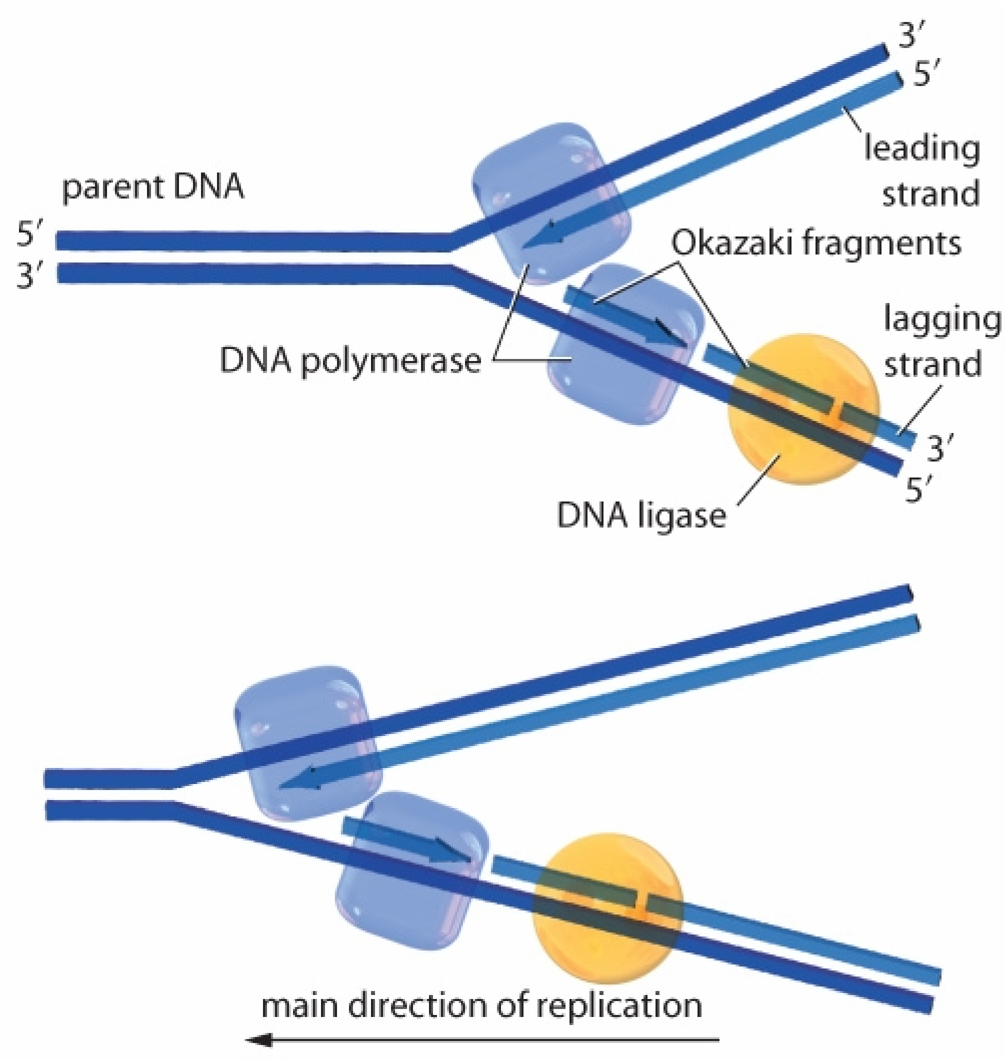
CHAPTER 18 OVERHEAD	DNA Replication	BLM 18.1.7



Replication takes place at several locations simultaneously. Each replication bubble represents two replication forks moving in opposite directions along the length of the chromosome. As replication proceeds along the strand, the bubbles grow until they meet. The parent strand of DNA is shown in grey. The new complementary strand is shown in black.

DNA Replication



During DNA synthesis, the overall direction of elongation is the same along both strands, but elongation occurs differently. On the leading strand, DNA synthesis takes place along the DNA molecule in the same direction as the movement of the replication fork. On the lagging strand, DNA synthesis proceeds in the opposite direction to the movement of the replication fork. As well, the lagging strand is synthesized in short fragments.

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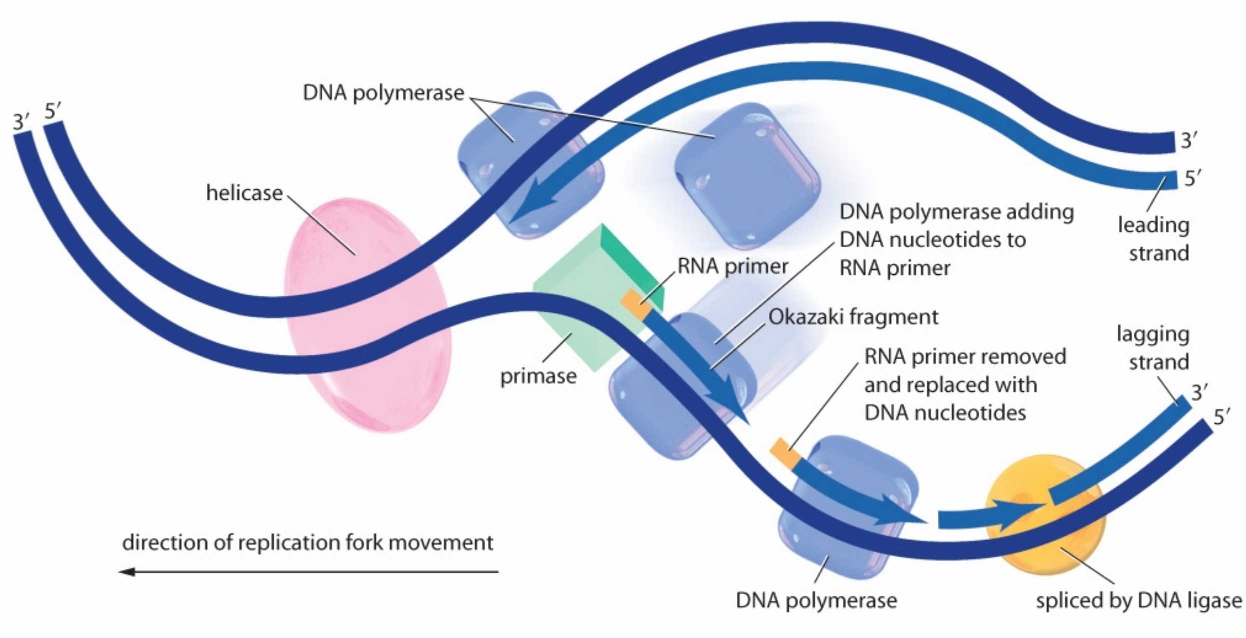
OVERHEAD

DNA Replication

BLM 18.1.7

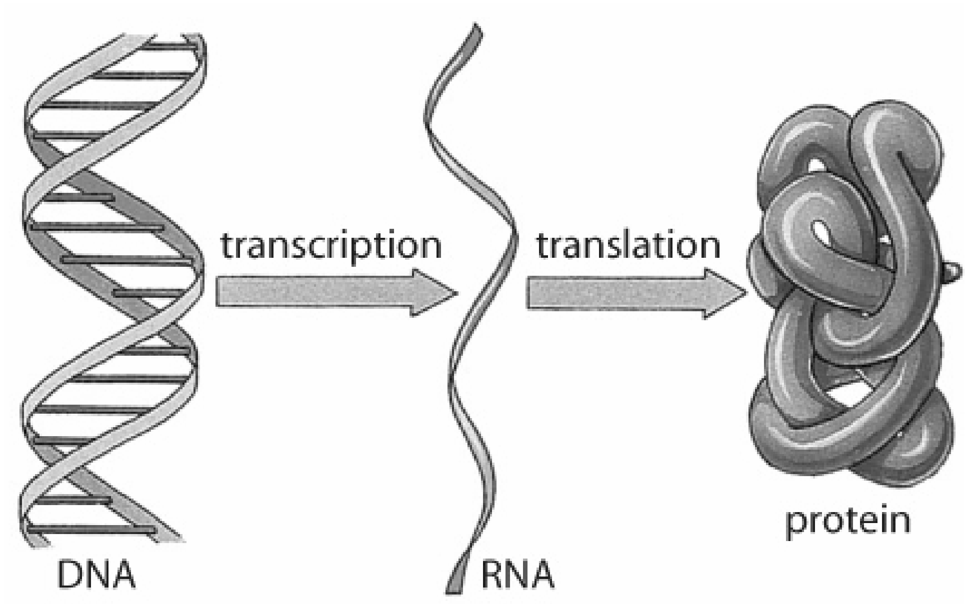


This simplified illustration of the replication machine shows how a loop in the lagging strand allows a single polymerase complex to replicate both DNA strands simultaneously.

CHAPTER 18
OVERHEAD

The Central Dogma

BLM 18.2.1



The path of gene expression. The “central dogma” proposes that genetic information passes (via transcription) from the genes (DNA) to an RNA copy of the gene, and the RNA copy directs the sequential assembly of a chain of amino acids to produce a protein (via translation).

mRNA

mRNA

- **Ribonucleic acid**
- **Sugar component is ribose**
- **Single stranded; may fold in on itself to form regions of complementary base pairs**
- **Nitrogenous bases are A, U, C, and G**
- **One of three forms of RNA: mRNA, tRNA, and rRNA**
- **Carries genetic information from DNA to ribosomes for translation**
- **In eukaryotes, mRNA is found in the mitochondria, nucleus, and cytoplasm**

DNA

- **Deoxyribonucleic acid**
- **Sugar component is deoxyribose**
- **Double stranded; double helix**
- **Nitrogenous bases are A, T, C, and G**
- **Only one form of DNA**
- **Stores genetic information that is replicated during cell division and copied into mRNA during transcription**
- **In eukaryotes, DNA is found in the nucleus and mitochondria**

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OVERHEAD

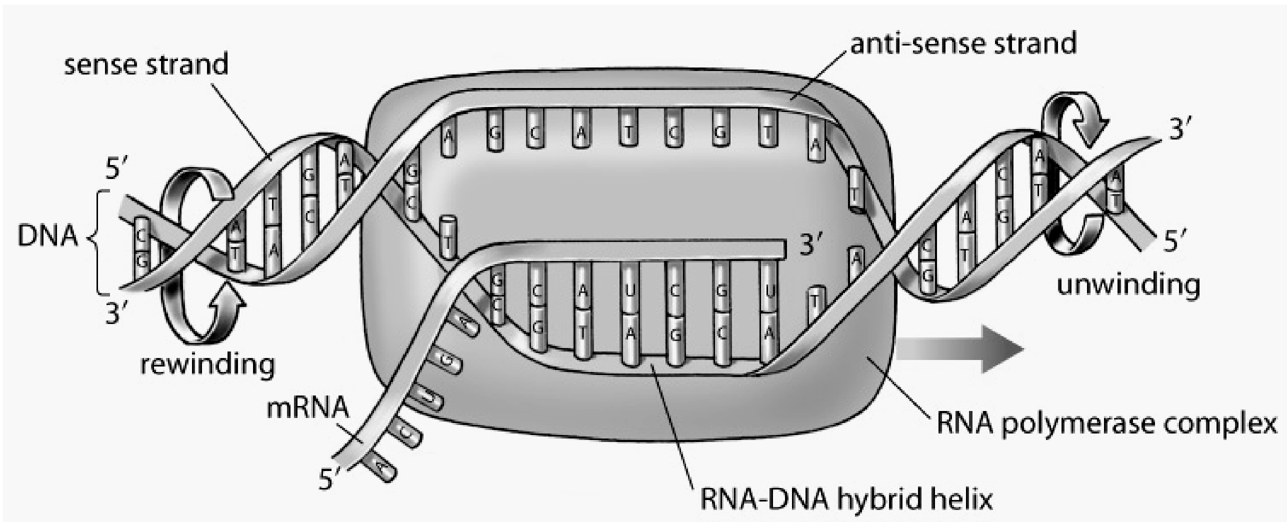
Table: Messenger RNA Codons and Their Corresponding Amino Acids

BLM 18.2.3

First base	Second base				Third base
	U	C	A	G	
U	UUU phenylalanine UUC phenylalanine UUA leucine UUG leucine	UCU serine UCC serine UCA serine UCG serine	UAU tyrosine UAC tyrosine UAA stop** UAG stop**	UGU cysteine UGC cysteine UGA stop** UGG tryptophan	U C A G
C	CUU leucine CUC leucine CUA leucine CUG leucine	CCU proline CCC proline CCA proline CCG proline	CAU histidine CAC histidine CAA glutamine CAG glutamine	CGU arginine CGC arginine CGA arginine CGG arginine	U C A G
A	AUU isoleucine AUC isoleucine AUA isoleucine AUG methionine*	ACU threonine ACC threonine ACA threonine ACG threonine	AAU asparagine AAC asparagine AAA lysine AAG lysine	AGU serine AGC serine AGA arginine AGG arginine	U C A G
G	GUU valine GUC valine GUA valine GUG valine	GCU alanine GCC alanine GCA alanine GCG alanine	GAU aspartate GAC aspartate GAA glutamate GAG glutamate	GGU glycine GGC glycine GGA glycine GGG glycine	U C A G

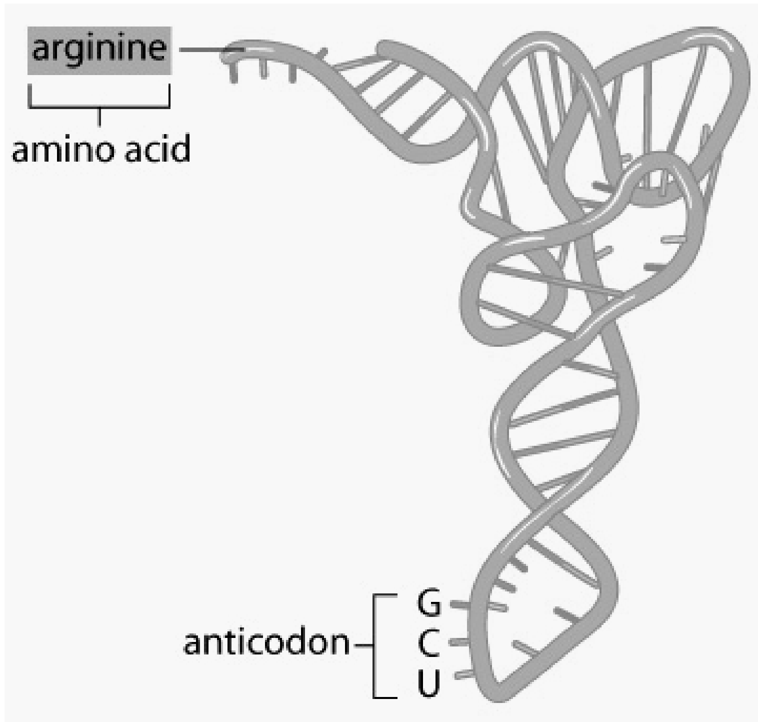
* AUG is an initiator codon. It also codes for the amino acid methionine.
** UAA, UAG, and UGA are terminator codons.

Transcription



During transcription, a complex of RNA polymerases track along the DNA molecule, synthesizing a single-stranded mRNA molecule that is complementary to the sense strand of DNA. The DNA helix reforms behind the RNA polymerase complex.

CHAPTER 18	tRNA	BLM 18.2.5
OVERHEAD		



Each tRNA molecule is about 80 nucleotides long. The tRNA molecule shown here has the anticodon GCU, which pairs with the mRNA sequence CGA. This tRNA molecule carries the amino acid arginine.

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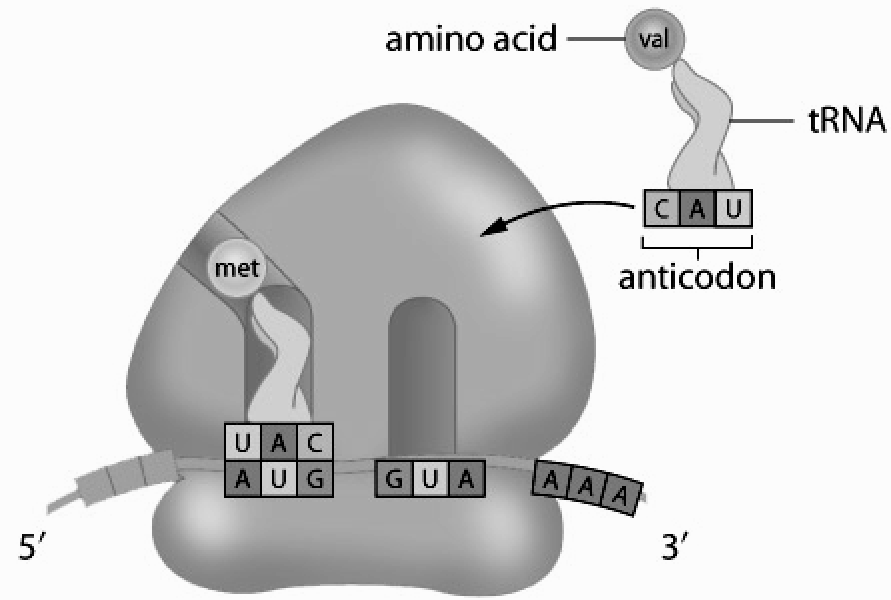
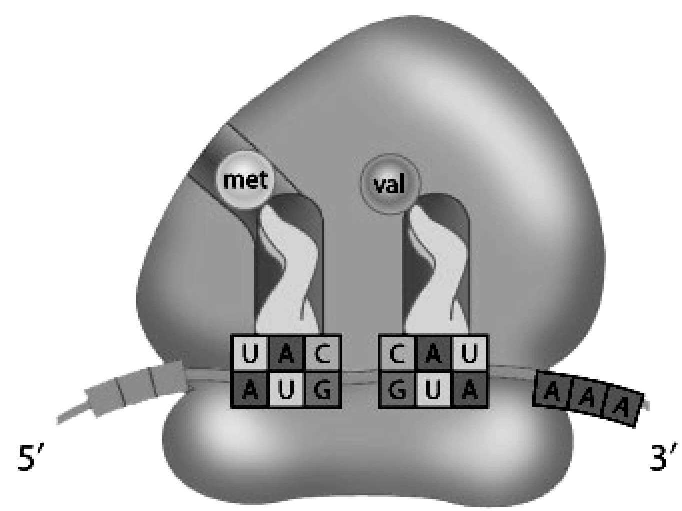
The Translation Cycle

The translation cycle involves the base pairing of a new tRNA, the transfer of a growing polypeptide chain, and the movement of the ribosome along the mRNA molecule. The complete cycle occurs about 15 times per second in a prokaryotic cell.



A When translation is initiated, a single tRNA molecule carrying the amino acid methionine sits on the first exposed codon, the start codon AUG. A second tRNA, carrying a second amino acid, approaches the adjacent codon.



B The anticodon of the second tRNA pairs with the mRNA codon at a site next to the first tRNA.

Gene Expression

Role of Various Nucleic Acids in Gene Expression

Nucleic Acid	Structure	Function
DNA	Double helix	Stores genetic information that is copied into mRNA during **transcription**
mRNA	Linear single strand	Carries genetic information from DNA to the ribosomes; in eukaryotes, mRNA is processed before it moves to the cytoplasm for **translation**
tRNA	Lobed shape	Carries a particular amino acid to the correct mRNA codon site during **translation**
rRNA	Linear single strand	Combines with a complex of proteins to form ribosomes, which bring together the mRNA strand and tRNA molecules during **translation**

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Mutations

BLM 18.3.1

GUU–CAU–UUG–ACU–CCC–GAA–GAA
val – his – leu – thr – pro – glu – glu

A The normal coding sequence, with the codons in the top row and the resulting amino acids below them.

GUU–CAU–UUG–ACC–CCC–GAA–GAA
val – his – leu – thr – pro – glu – glu

B This mutation is silent, since the change in nucleotide sequence has no effect on the polypeptide product.

GUU–CAU–UUG–ACU–CCC–GUA–GAA
val – his – leu – thr – pro – val – glu

C This is a mis-sense mutation, since it causes the amino acid valine to be inserted in the place of glutamate within the polypeptide chain. The resulting protein is unable to transport oxygen effectively and produces a disorder known as sickle cell disease.

GUU–CAU–UAG
val – his –stop

D This substitution causes a nonsense mutation by changing the codon for the amino acid leucine (UUG) into a premature stop codon. No functional polypeptide will be produced from this gene.

GUU–CAU–UUG–ACU–CCC–GAA–GAA
val – his – leu – thr – pro – glu – glu

A The normal coding sequence, with the codons in the top row and the resulting amino acids below them.

GUU–CAU–GUU–GAC–UCC–CGA–AGA A
val – his – val – asp – ser – arg – arg

B The insertion of a single nucleotide, in this case guanine, results in a frameshift mutation.

A

GUU–CAU–UUG–CUC–CCG–AAG–AA
val – his – leu – leu – pro – lys

C Similarly, a deletion of even a single nucleotide, in this case adenine, also results in a frameshift mutation.

(Left) A nucleotide substitution can have varied effects, as shown on this portion of the gene that codes for human betaglobulin, one of the two polypeptides in the blood protein hemoglobin. (Right) Frameshift mutations are usually nonsense mutations.

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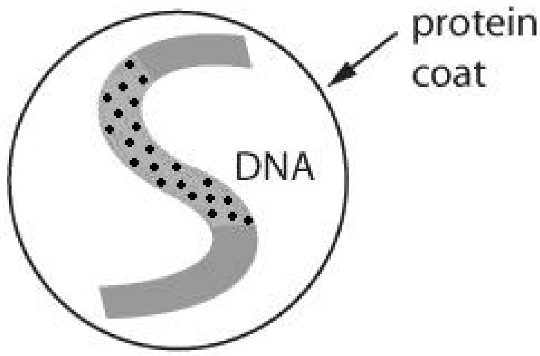
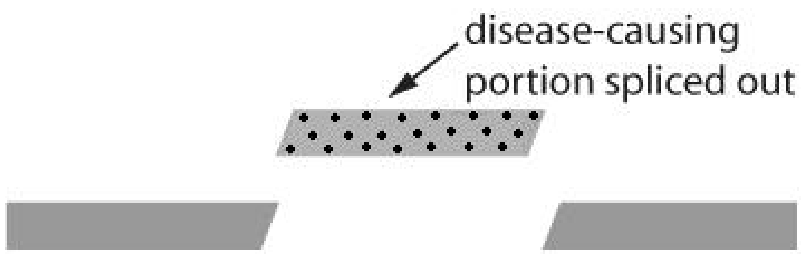
CHAPTER 18 OVERHEAD	**Gene Therapy**	BLM 18.4.6



A The intact virus is made up of a protein coat containing a strand of DNA.



B The viral DNA is isolated and the disease-causing portion of the viral genome (red) is spliced out. Genes coding for the enzymes that allow the virus to insert its DNA into the genome (blue) of its host cell are left intact.

C A working human gene (green) is inserted into the viral genome. The modified viruses are then cultured with human cells. Some of the viruses will transfer the new gene into the cells' genome.

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Gel Electrophoresis

BLM 18.3.9