InterTech

presents

Flow of Genetic Information

A Montagud
E Navarro
P Fernández de Córdoba
JF Urchueguía

- Elements
- Nucleic acid
  - DNA
    - building block
    - structure & organization
    - genome
  - RNA
    - building block
    - types
- Amino acid
  - building block
  - side chain
  - protein
- Central Dogma of Molecular Biology
  - Replication : DNA to DNA
  - Replication : RNA to RNA
  - Transcription : DNA to RNA
    - RNA processing
  - Translation : RNA to protein
    - genetic code
- Dogma, revisited
- Horizontal transference
  - transformation
  - conjugation
  - transduction

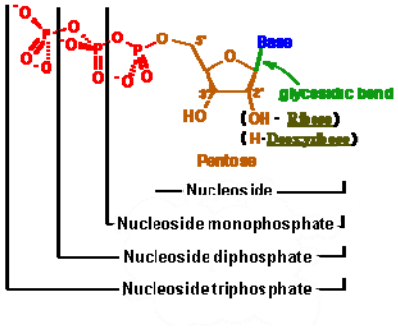
Elements

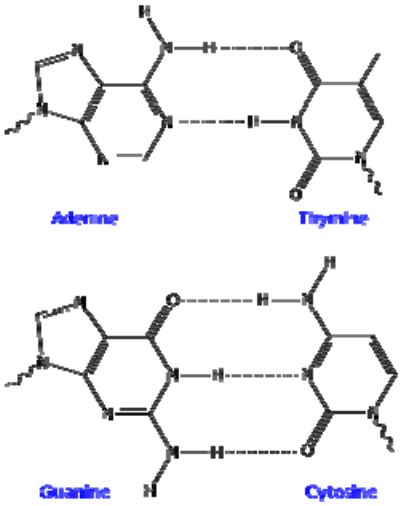
- two monomers and two polymers
  - nucleic acids
    - DNA : stores information
    - RNA : transmits information
  - amino acids
    - protein : catalytic capacity

Nucleic acids

Nucleic acid : DNA

- main function
  - store information





Flow of Genetic Information

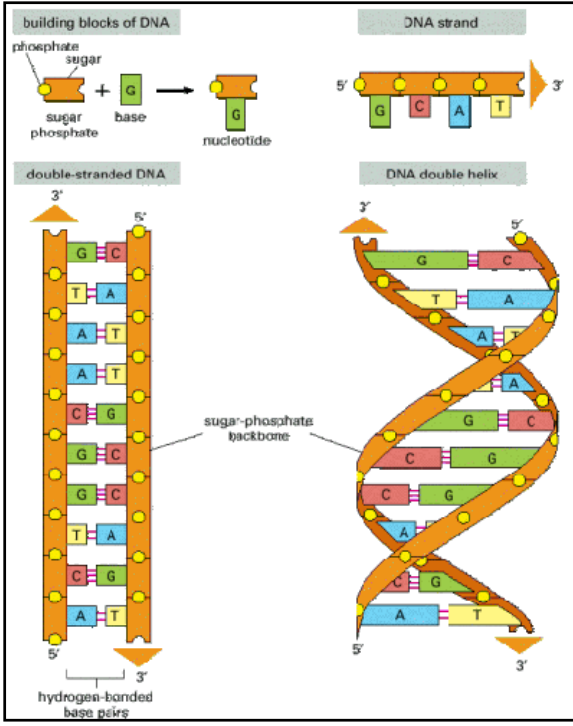
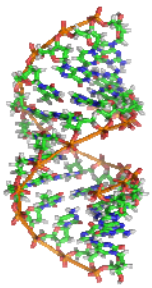


Figure 4-3. DNA and its building blocks. (Alberts *et al*, 2002)

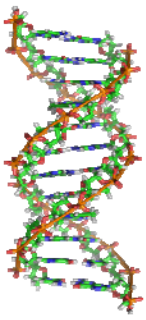
structure and organization

- double helix



A-DNA

more compact



B-DNA

Z-DNA

left-handed

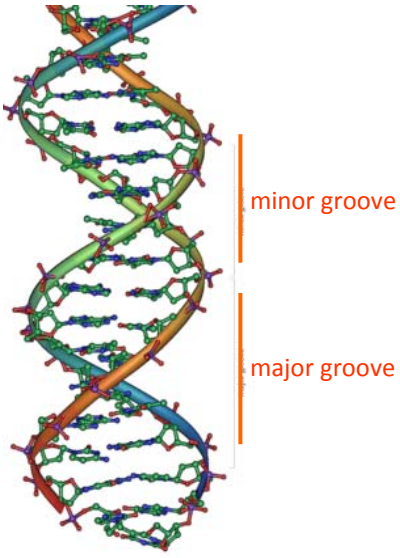
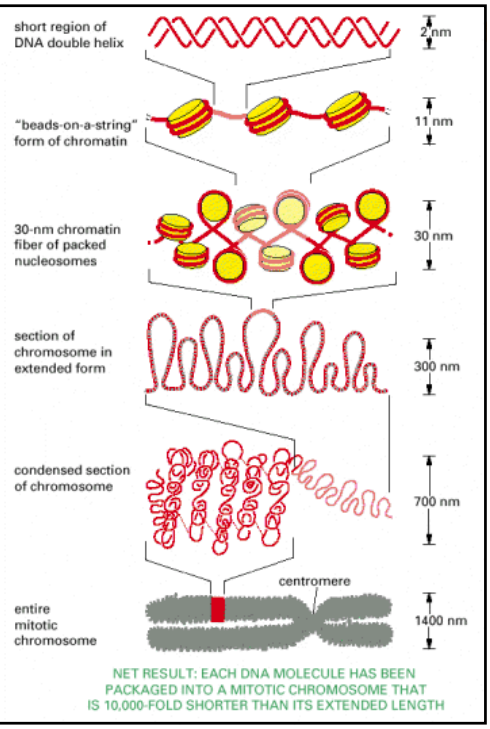


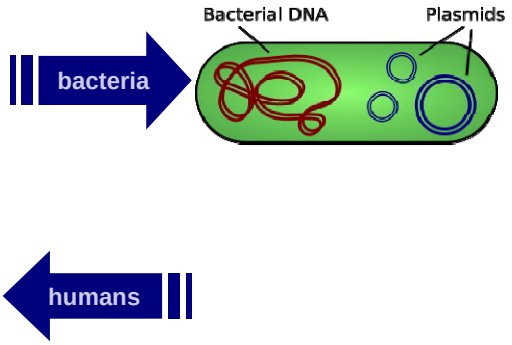
Figure 4-55. Chromatin packing (Alberts *et al*, 2002)

- chromatin : supercoiling
- chromosome

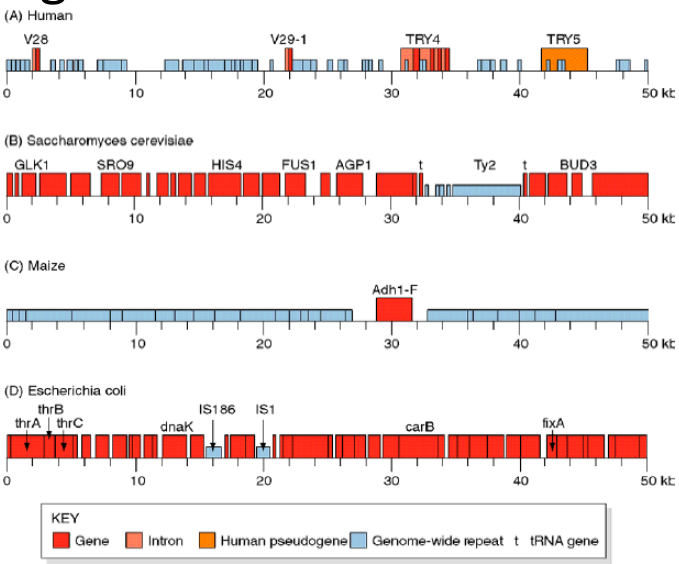


genome

- whole genetic material *necessary* for the survival of a given cell

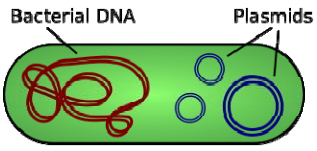


genome : chromosomes

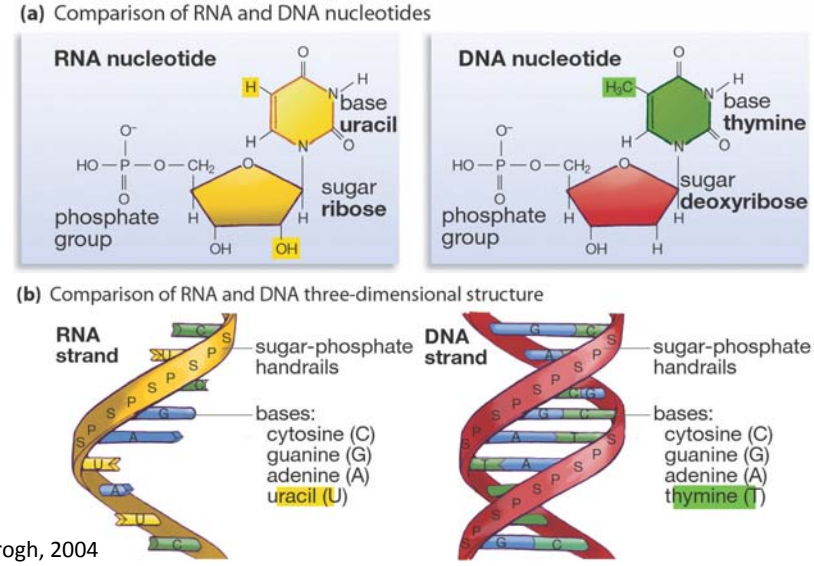


genome : plasmids

- autonomous genetic elements
- not essential –(generally) bacteria survives without
- interesting properties
  - survival on a special condition
  - pathogenicity island
- characteristic copy number



Nucleic acid : RNA



Krogh, 2004

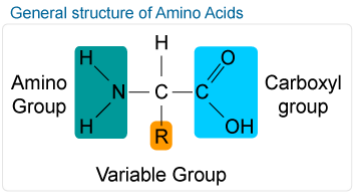
Type of RNA	Functions in	Function
Messenger RNA (mRNA) 	Nucleus, migrates to ribosomes in cytoplasm	Carries DNA sequence information to ribosomes
Transfer RNA (tRNA) 	Cytoplasm	Provides linkage between mRNA and amino acids; transfers amino acids to ribosomes
Ribosomal RNA (rRNA) 	Cytoplasm	Structural component of ribosomes

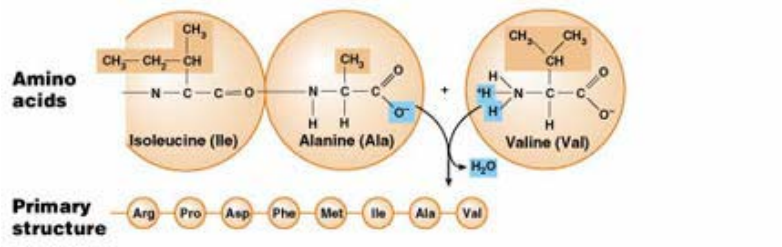
microRNA, has been shown to regulate gene expression.

Krogh, 2004

Amino acids

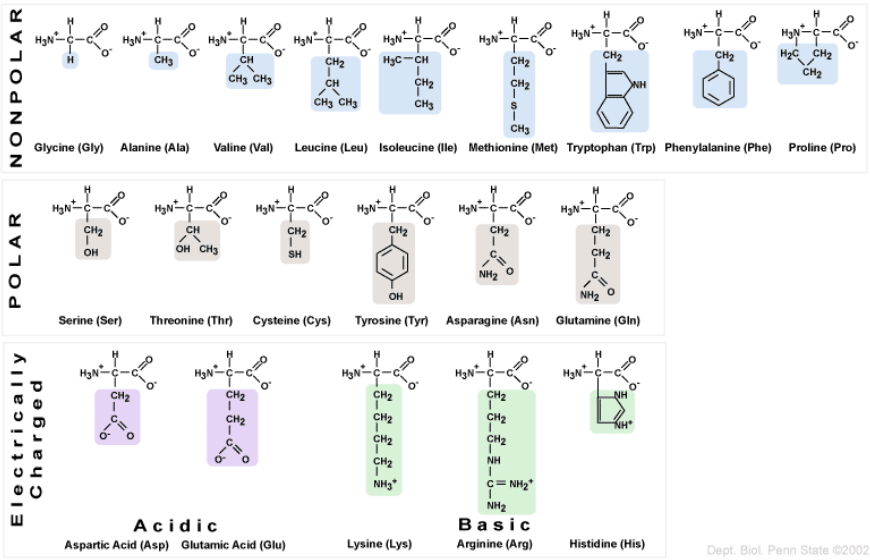
Amino acid : building block





Flow of Genetic Information

Amino acid : side chain



Amino acid : protein

- 2ary structure
  - alpha helix
  - beta sheet
- 3ary structure
  - domains

The sequence of amino acids determines the structure, and therefore the function, of a protein.

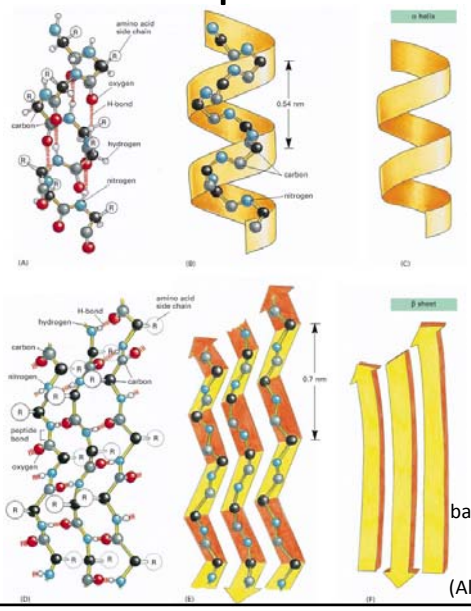


Figure 3-9. The regular conformation of the polypeptide backbone observed in the α helix and the β sheet. (Alberts *et al*, 2002)

Amino acid : examples

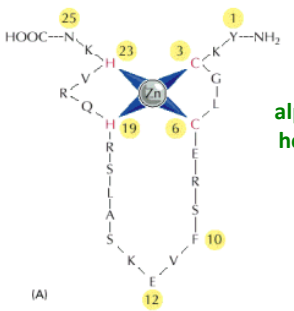
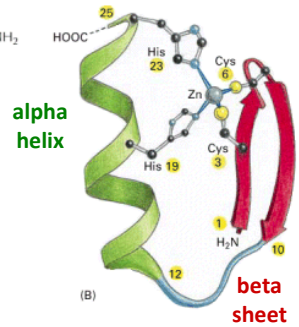


Figure 7-17. One type of zinc finger protein. (Alberts *et al*, 2002)



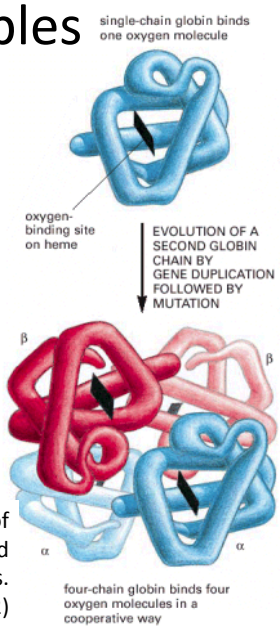


Figure 7-115. A comparison of the structure of one-chain and four-chain globins. (Alberts *et al*, 2002)

Amino acid : protein and function

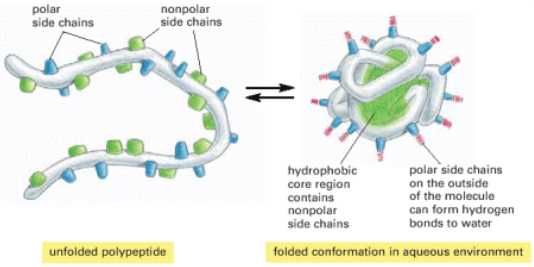


Figure 3-6. How a protein folds into a compact conformation. (Alberts *et al*, 2002)

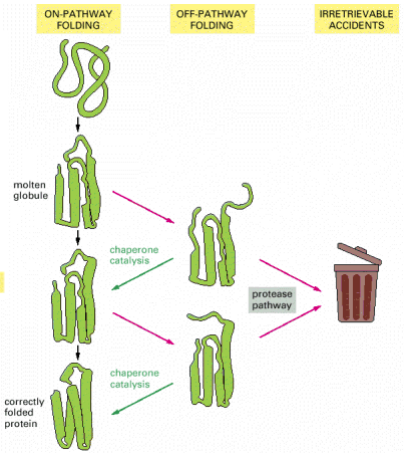
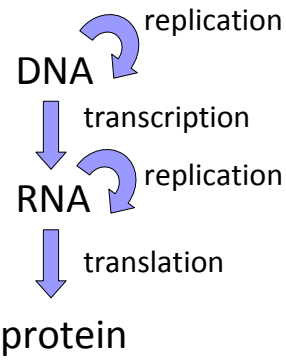


Figure 6-82. A current view of protein folding. (Alberts *et al*, 2002)

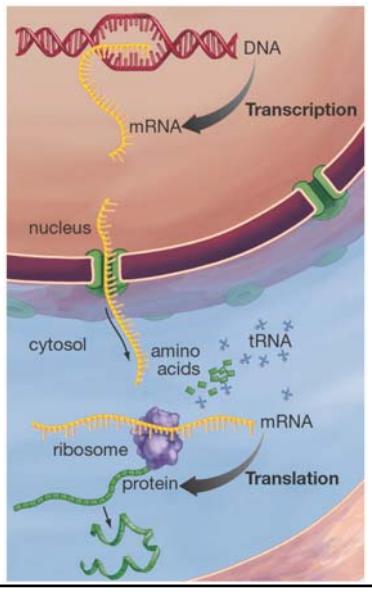
Correct folding is critical for correct function

Central Dogma of Molecular Biology

Central Dogma of Molecular Biology



Francis Crick, *Ideas on protein synthesis.* **Symp Soc Exp Biol.**, 1956



Replication : DNA to DNA

- DNA polymerase DNA dependent
- DNA nucleotides
- many enzymes more!
  - helicase, topoisomerase, etc

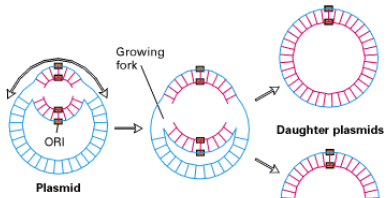
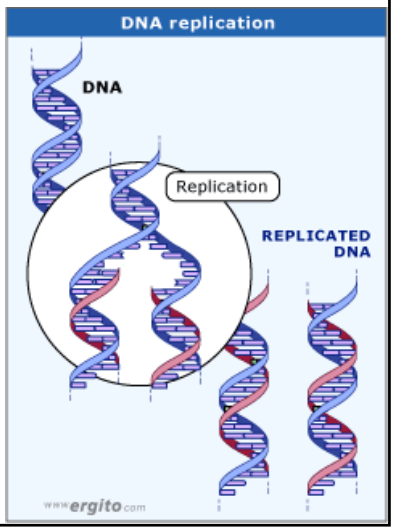


Figure 7-2. Plasmid DNA replication. (Lodish *et al*, 2000)



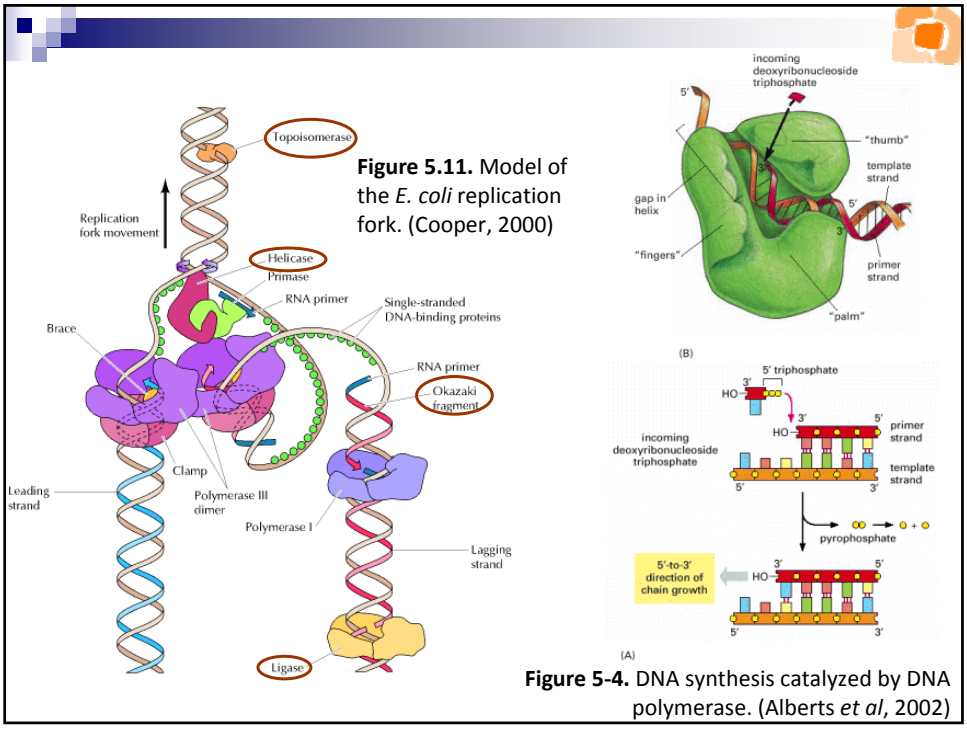


Figure 5.11. Model of the *E. coli* replication fork. (Cooper, 2000)

Figure 5-4. DNA synthesis catalyzed by DNA polymerase. (Alberts *et al*, 2002)

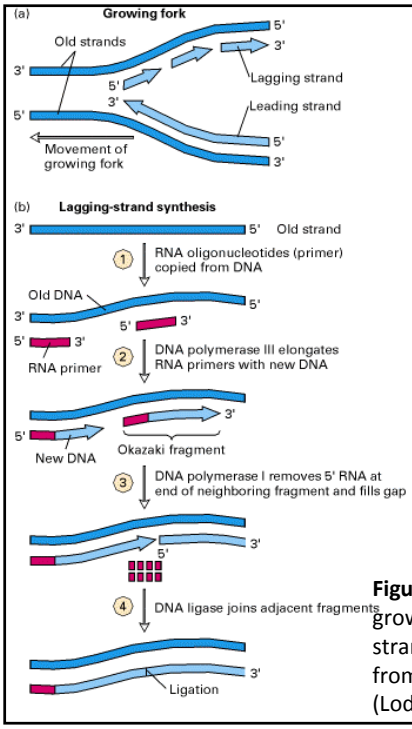


Figure 12-9. At a growing fork, one strand is synthesized from multiple primers. (Lodish *et al*, 2000)

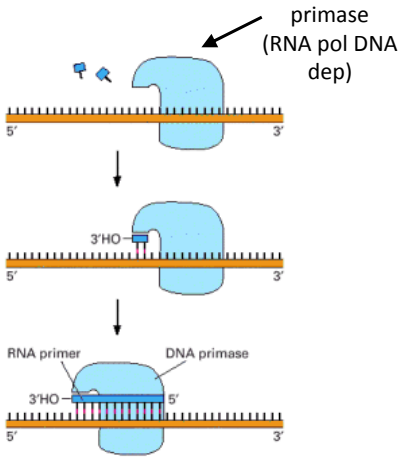
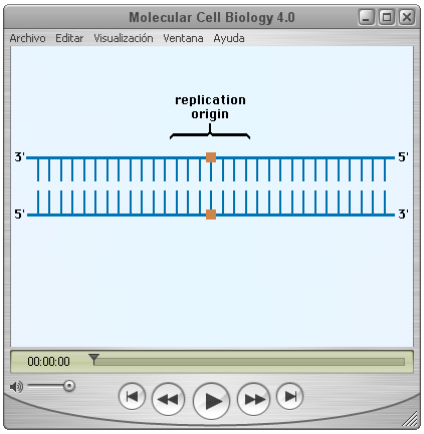


Figure 5-12. RNA primer synthesis. (Albert *et al*, 2002)

movie : replication

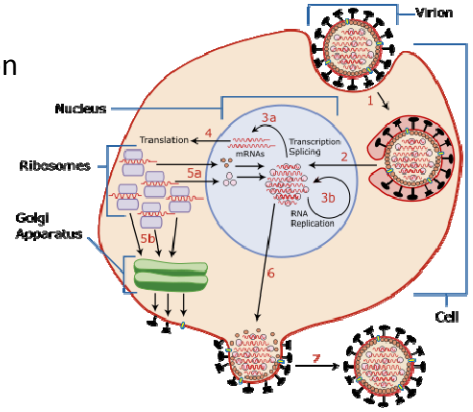


Ch12anim1. Lodish *et al*, 2000

Replication : RNA to RNA

DNA → (replication) DNA
DNA → (transcription) RNA
RNA → (replication) RNA
RNA → (translation) protein

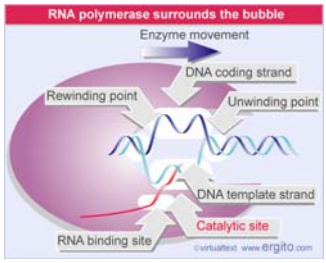
- RNA polymerase RNA dependent
- RNA viruses
  - have RNA as information storage
  - live in the *RNA world*
- use cell machinery

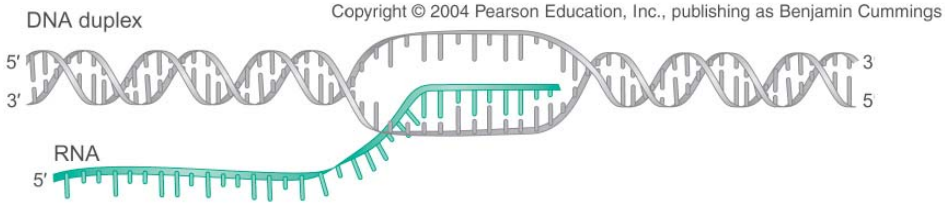


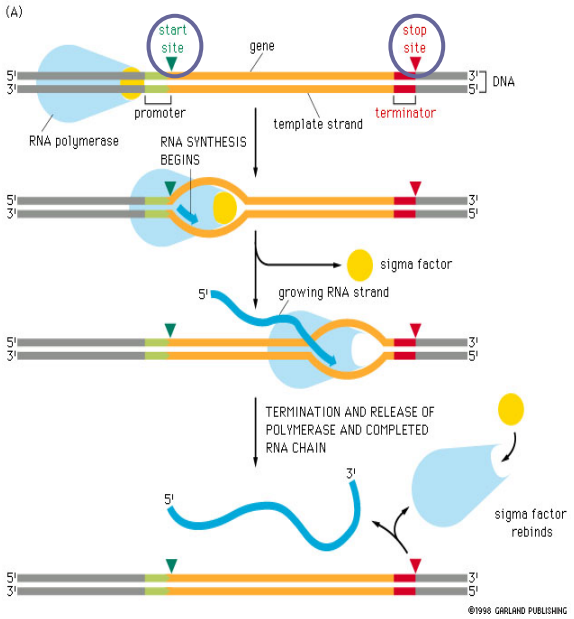
Transcription : DNA to RNA

DNA —replication→ DNA
DNA —transcription→ RNA —replication→ RNA
RNA —translation→ protein

- RNA polymerase DNA dependent
- RNA nucleotides
- many enzymes more!
  - helicase, topoisomerase, etc
- transcription factors : regulation







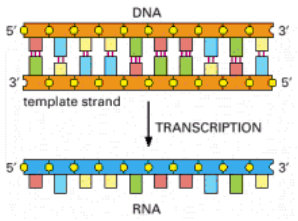
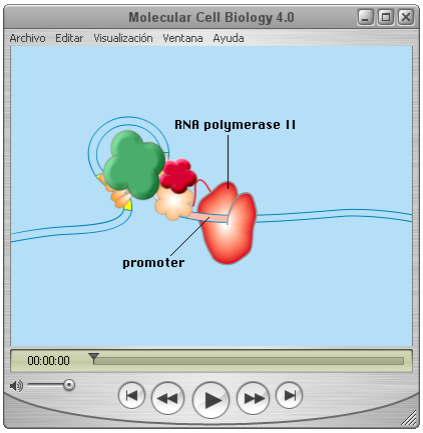


Figure 6-7. DNA transcription produces a single-stranded RNA molecule that is complementary to one strand of DNA. (Alberts *et al*, 2002)

movie : transcription



Ch4anim1. Lodish *et al*, 2000

DNA —replication→ DNA
DNA —transcription→ RNA
RNA —replication→ RNA
RNA —translation→ protein

RNA processing

- mRNA gets processed, mainly in eukaryotes
  - 5'-capping
    - protection from degradation

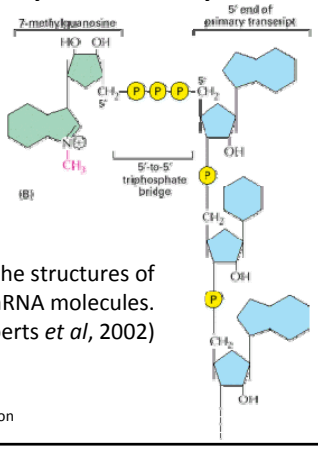
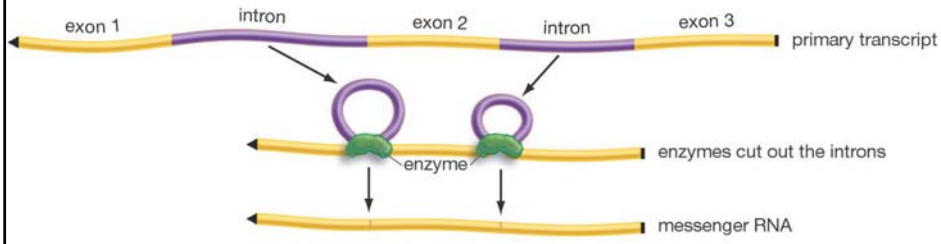


Figure 6-22. A comparison of the structures of procaryotic and eucaryotic mRNA molecules. (Alberts *et al*, 2002)

RNA processing

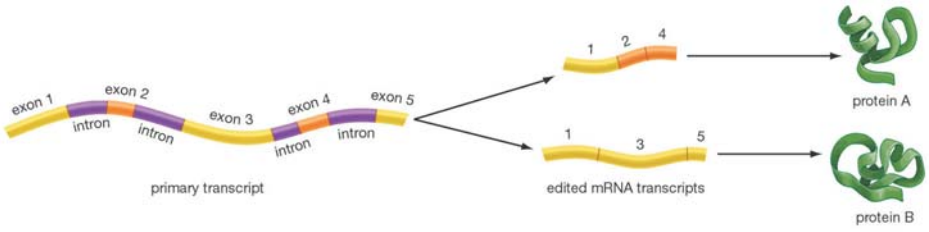
- mRNA gets processed, mainly in eukaryotes
  - splicing



Krogh, 2004

RNA processing

- mRNA gets processed, mainly in eukaryotes
  - alternative splicing



Krogh, 2004

RNA processing

- mRNA gets processed, mainly in eukaryotes
  - 3’-polyadenylation
    - protection from degradation

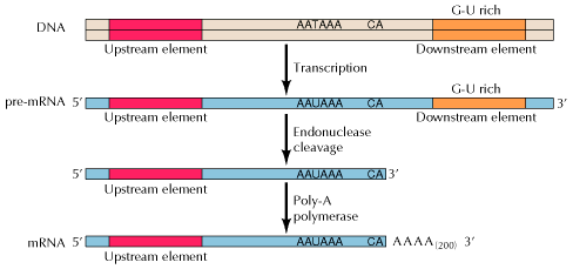
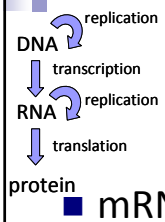


Figure 6.40. Formation of the 3 ’ ends of eukaryotic mRNAs. (Cooper, 2000)



RNA processing

- mRNA gets processed, mainly in eukaryotes
  - 5’-capping
  - splicing, alternative splicing
  - 3’-polyadenylation

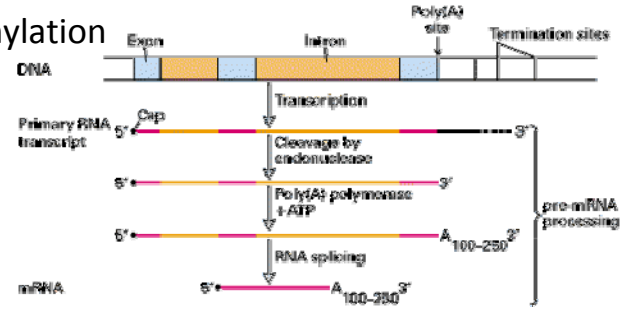
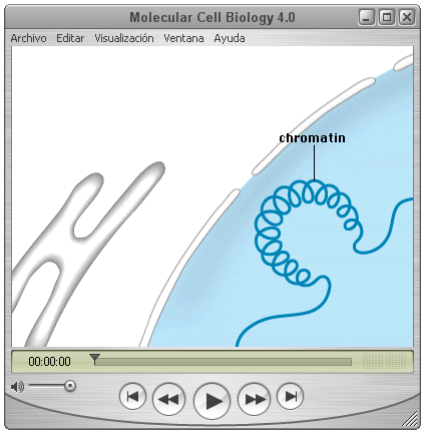


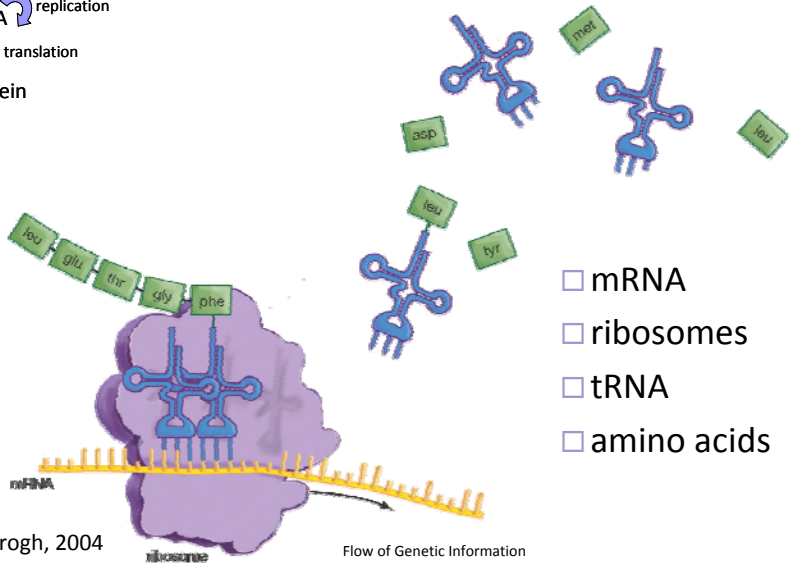
Figure 11-7. Overview of mRNA processing in eukaryotes. (Lodish *et al*, 2000)

movie : RNA processing



Ch11anim1. Lodish *et al*, 2000

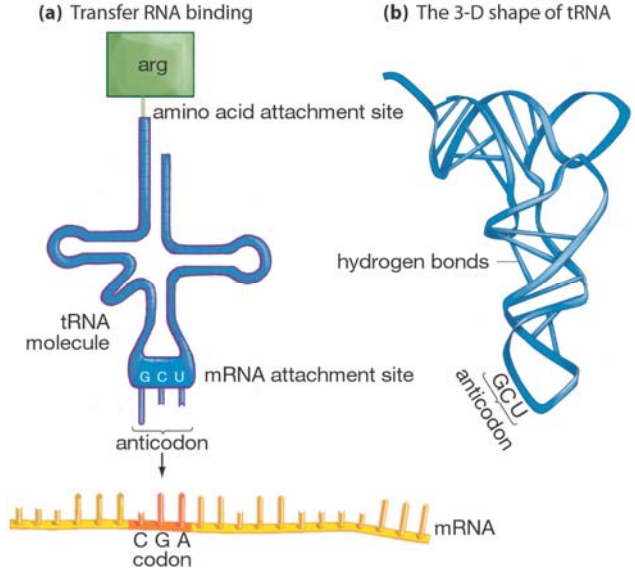
Translation : RNA to protein



- mRNA
- ribosomes
- tRNA
- amino acids

Krogh, 2004

Translation : RNA to protein



Krogh, 2004

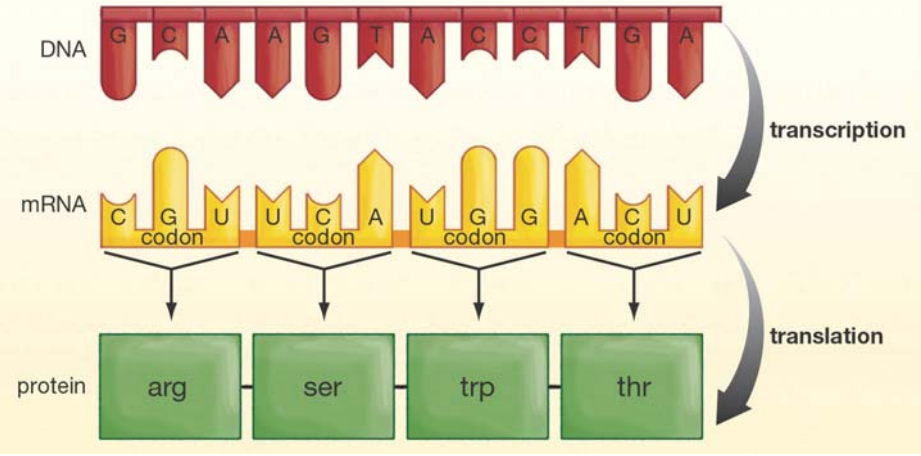
Translation : genetic code

second base

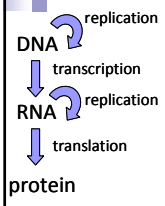
first base	U	C	A	G	third base
U	UUU phe UUC UUA leu UUG	UCU UCC UCA UCG ser	UAU tyr UAC UAA **Stop** UAG **Stop**	UGU cys UGC UGA **Stop** UGG trp	U C A G
C	CUU CUC CUA CUG leu	CCU CCC CCA CCG pro	CAU his CAC CAA gln CAG	CGU CGC CGA CGG arg	U C A G
A	AUU AUC AUA ile AUG met (start)	ACU ACC ACA ACG thr	AAU asn AAC AAA lys AAG	AGU ser AGC AGA arg AGG	U C A G
G	GUU GUC GUA GUG val	GCU GCC GCA GCG ala	GAU asp GAC GAA glu GAG	GGU GGC GGA GGG gly	U C A G

Krogh, 2004

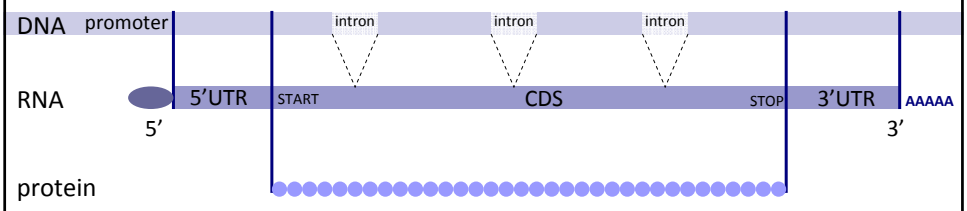
The Triplet Code



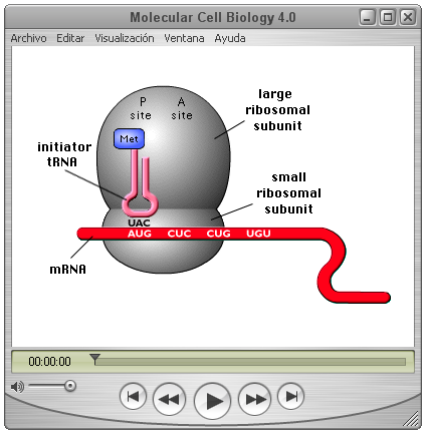
Krogh, 2004



from DNA to protein



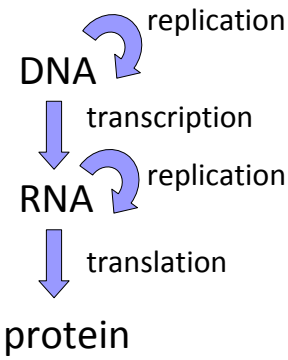
movie : traduction



Ch4anim3. Lodish *et al*, 2000

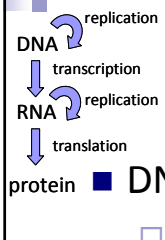
Dogma, revisited

Dogma, revisited



*As it turned out, the use of the word **dogma** caused almost more trouble than it was worth.... I used the word the way I myself thought about it, not as most of the world does, and simply applied it to a **grand hypothesis** that, however plausible, had **little direct experimental support**.*

-Francis Crick, What Mad Pursuit, 1988



Dogma, revisited

- DNA reverse transcriptase
  - retroviruses

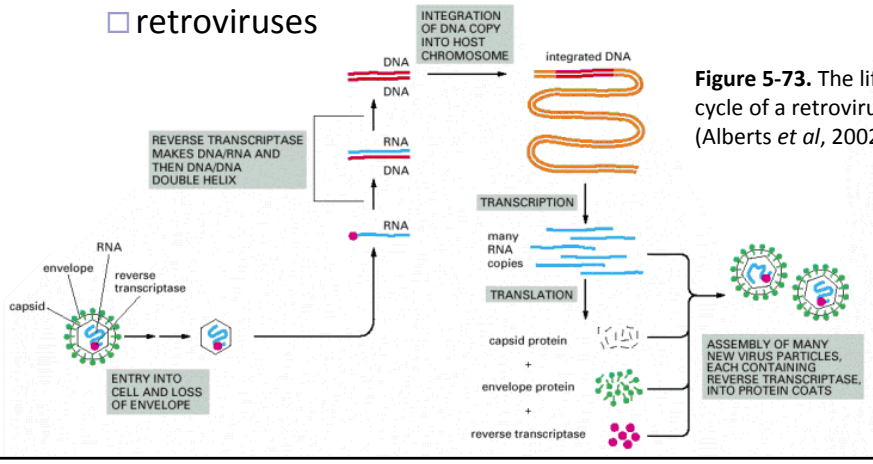
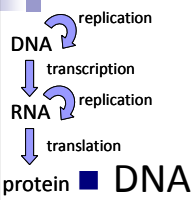


Figure 5-73. The life cycle of a retrovirus. (Alberts *et al*, 2002)

Dogma, revisited



- DNA reverse transcriptase
  - telomeres

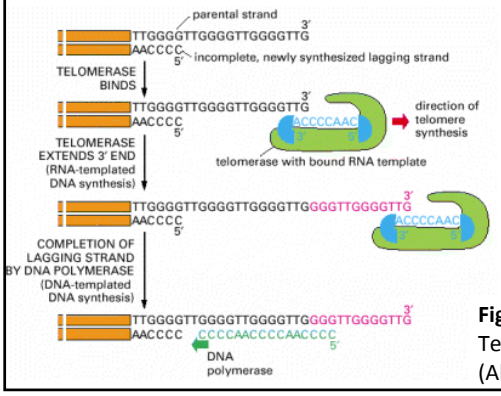


Figure 5-43. Telomere replication. (Alberts *et al*, 2002)

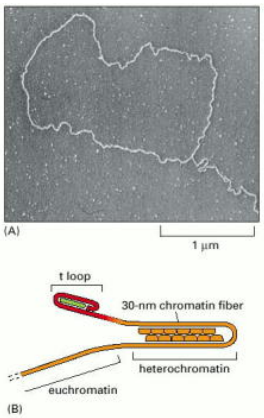
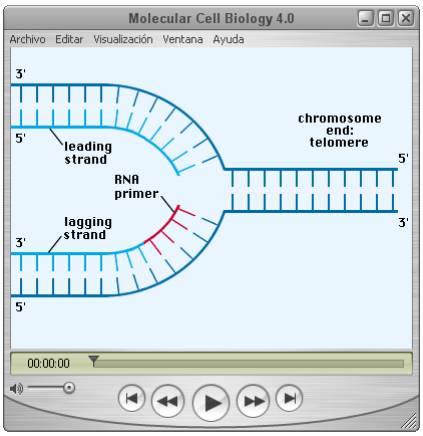


Figure 5-44. The t-loops at the end of mammalian chromosomes. (Alberts *et al*, 2002)

movie : telomerase



Ch12anim5. Lodish *et al*, 2000

replication
DNA
transcription
RNA
replication
translation
protein ■ prions

Dogma, revisited

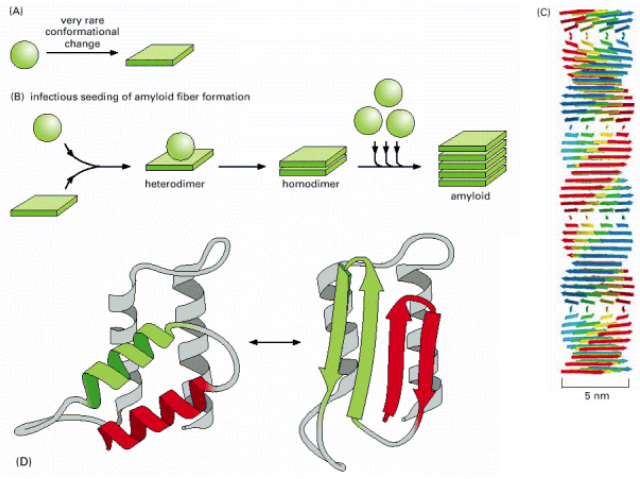


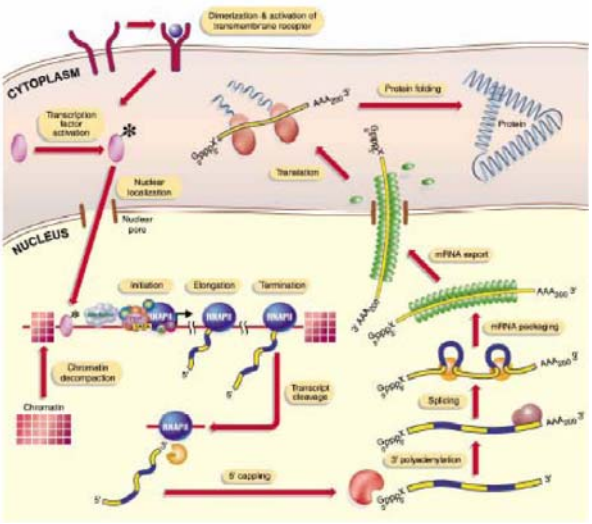
Figure 6-89. Protein aggregates that cause human disease. (Alberts *et al*, 2002)

Dogma, revisited

replication
DNA
reverse transcription
transcription
RNA
replication
translation
protein
protein aggregation

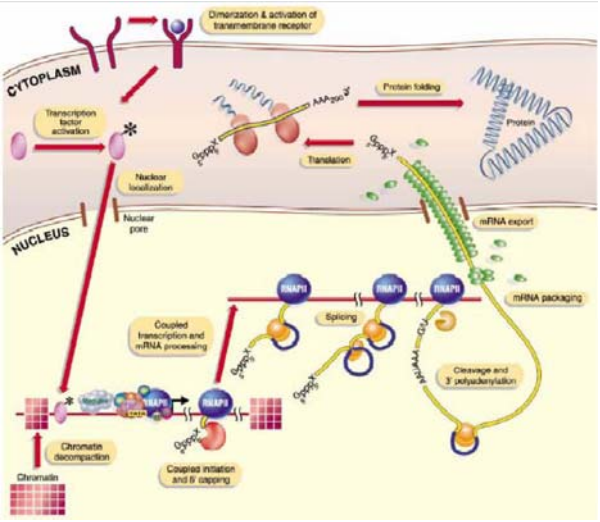
Crick, *Central Dogma of Molecular Biology*, **Nature**, 1970

Dogma's overview



- static
- stepwise
- simplistic

Dogma's overview



- dynamic
- continuous reactions
- complex

transcription and translation

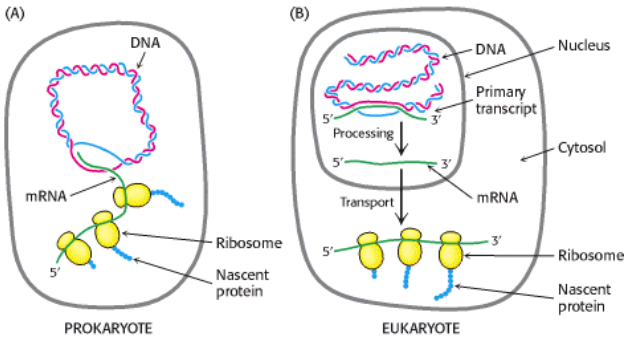


Figure 28.15. Transcription and Translation. (Berg *et al*, 2002)

Horizontal transference

Horizontal transference

- special in prokaryotes

- transformation
- conjugation
- transduction

Horizontal transference

- conjugation
  - F plasmid & *tra* genes
  - pilus

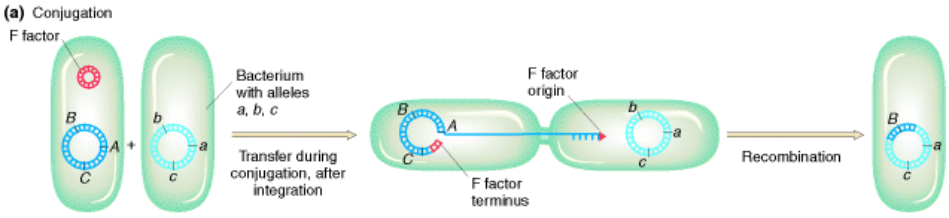


Figure 7-35.
(Griffiths *et al*, 2000)

Horizontal transference

- transformation
  - bacteria recombines free DNA as its own

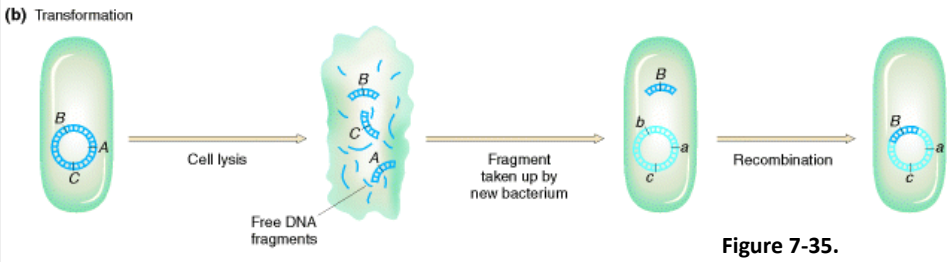


Figure 7-35.
(Griffiths *et al*, 2000)

Horizontal transference

- transduction
  - phage lysis
  - phage encapsulates bacterial DNA

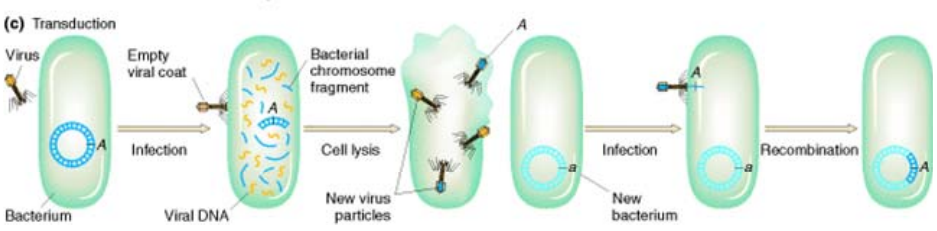


Figure 7-35.
(Griffiths *et al*, 2000)

more

- vcell.ndsu.edu
  - transcription
  - mRNA processing

sources

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