Flow of Genetic Information

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- 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
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Nucleic acid: DNA

- main function
  - store information

![Diagram of DNA structure]

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

- chromatin: supercoiling
- chromosome

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

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

![Diagram of genome and chromosomes](image-url)

**genome**: chromosomes

- (A) Human
- (B) Saccharomyces cerevisiae
- (C) Maize
- (D) Escherichia coli

**KEY**
- Red: Gene
- Orange: Intron
- Blue: Human pseudogene
- Green: Genome-wide repeat
- Pink: tRNA gene
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**genome : plasmids**

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

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**Nucleic acid : RNA**

(a) Comparison of RNA and DNA nucleotides

(b) Comparison of RNA and DNA three-dimensional structure

Krogh, 2004
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<table>
<thead>
<tr>
<th>Type of RNA</th>
<th>Functions in</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messenger RNA (mRNA)</td>
<td>Nucleus, migrates to cytoplasm</td>
<td>Carries DNA sequence information to ribosomes</td>
</tr>
<tr>
<td>Transfer RNA (tRNA)</td>
<td>Cytoplasm</td>
<td>Provides linkage between mRNA and amino acids; transfers amino acids to ribosomes</td>
</tr>
<tr>
<td>Ribosomal RNA (rRNA)</td>
<td>Cytoplasm</td>
<td>Structural component of ribosomes</td>
</tr>
</tbody>
</table>

microRNA, has been shown to regulate gene expression.

Krogh, 2004
Amino acid: building block

Amino acid: side chain
Amino acid: protein

- 2ndary structure
  - alpha helix
  - beta sheet

- 3rdary 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 alpha helix and the beta 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

Correct folding is critical for correct 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)

Central Dogma of Molecular Biology
Central Dogma of Molecular Biology


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 5-9.** At a growing fork, one strand is synthesized from multiple primers. (Lodish *et al.*, 2000)
movie: replication

Replication: RNA to RNA

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

Ch12anim1. Lodish et al, 2000

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Transcription: DNA to RNA

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

DNA transcription produces a single-stranded RNA molecule that is complementary to one strand of DNA.

(Alberts et al, 2002)
movie: transcription

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)

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RNA processing

- mRNA gets processed, mainly in eukaryotes

  - splicing

  [Diagram showing splicing process with exons and introns]

  Krogh, 2004

RNA processing

- mRNA gets processed, mainly in eukaryotes

  - alternative splicing

  [Diagram showing alternative splicing with multiple exon structures]

  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)
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**movie : RNA processing**

Ch11anim1. Lodish *et al.*, 2000

**Translation : RNA to protein**

- mRNA
- ribosomes
- tRNA
- amino acids

Krogh, 2004
Translation: RNA to protein

(a) Transfer RNA binding
(b) The 3-D shape of tRNA

Krogh, 2004

Translation: genetic code

Krogh, 2004
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The Triplet Code

Krogh, 2004

from DNA to protein

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movie: traduction

Ch4anim3. Lodish et al, 2000

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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

**DNA reverse transcriptase**

- retroviruses

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

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

Crick, Central Dogma of Molecular Biology, Nature, 1970

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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)

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Horizontal transference
Horizontal transference

- special in prokaryotes
- transformation
- conjugation
- transduction

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)
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- vcell.ndsu.edu
  - transcription
  - mRNA processing

Sources

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