Molecular Structure of DNA & RNA

(CHapter 9- Brooker Text)

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BIO 184
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Nucleotides

• The nucleotide is the repeating structural unit of DNA and RNA

• It has three components
  – A phosphate group
  – A pentose sugar
  – A nitrogenous base
Nucleotides are covalently linked together by phosphodiester bonds. A phosphate connects the 5’ carbon of one nucleotide to the 3’ carbon of another. Therefore the strand has directionality—5’ to 3’. The phosphates and sugar molecules form the backbone of the nucleic acid strand. The bases project from the backbone.
Figure 9.11

Discovery of the Structure of DNA

- In 1953, James Watson and Francis Crick discovered the double helical structure of DNA

- The scientific framework for their breakthrough was provided primarily by:
  - Rosalind Franklin (X-ray diffraction)
  - Erwin Chargaff (chemical composition)
Rosalind Franklin

- She used X-ray diffraction to study wet fibers of DNA
- The diffraction pattern she obtained suggested several structural features of DNA
  - Helical
  - More than one strand
  - 10 base pairs per complete turn

Erwin Chargaff’s Experiment

- Chargaff pioneered many of the biochemical techniques for the isolation, purification and measurement of nucleic acids from living cells

- It was already known then that DNA contained the four bases: A, G, C and T

- Chargaff analyzed the the base composition of DNA in different species to see if there was a pattern
Chargaff’s rule

Percent of adenine = percent of thymine (A=T)
Percent of cytosine = percent of guanine (C=G)
A+G = T+C (or purines = pyrimidines)

<table>
<thead>
<tr>
<th>Organism</th>
<th>Adenine</th>
<th>Thymine</th>
<th>Guanine</th>
<th>Cytosine</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>26.0</td>
<td>23.9</td>
<td>24.9</td>
<td>25.2</td>
</tr>
<tr>
<td><em>Streptococcus pneumoniae</em> (type III)</td>
<td>29.8</td>
<td>31.6</td>
<td>20.5</td>
<td>18.0</td>
</tr>
<tr>
<td>Yeast</td>
<td>31.7</td>
<td>32.6</td>
<td>18.3</td>
<td>17.4</td>
</tr>
<tr>
<td>Turtle red blood cells</td>
<td>28.7</td>
<td>27.9</td>
<td>22.0</td>
<td>21.3</td>
</tr>
<tr>
<td>Salmon sperm</td>
<td>29.7</td>
<td>29.1</td>
<td>20.8</td>
<td>20.4</td>
</tr>
<tr>
<td>Chicken red blood cells</td>
<td>28.0</td>
<td>28.4</td>
<td>22.0</td>
<td>21.6</td>
</tr>
<tr>
<td>Human liver cells</td>
<td>30.3</td>
<td>30.3</td>
<td>19.5</td>
<td>19.9</td>
</tr>
</tbody>
</table>
The DNA Double Helix

• General structural features (Figures 9.17 & 9.18)
  
  – Two strands are twisted together around a common axis
  – There are 10 bases per complete twist
  – The two strands are antiparallel
    • One runs in the 5’ to 3’ direction and the other 3’ to 5’
  – The helix is right-handed in the B form
    • As it spirals away from you, the helix turns in a clockwise direction

The DNA Double Helix

• General structural features (Figures 9.17 & 9.18)
  
  – The double-bonded structure is stabilized by

  • 1. Hydrogen bonding between complementary bases
    – A bonded to T by two hydrogen bonds
    – C bonded to G by three hydrogen bonds

  • 2. Base stacking
    – Within the DNA, the bases are oriented so that the flattened regions are facing each other
The DNA Double Helix

• General structural features (Figures 9.17 & 9.18)
  – There are two asymmetrical grooves on the outside of the helix
    • 1. Major groove
    • 2. Minor groove
  • Certain proteins can bind within these grooves
    – They can thus interact with a particular sequence of bases

Key Features
• Two strands of DNA form a right-handed double helix.
• The bases in opposite strands hydrogen bond according to the A/T and G/C rule.
• The 2 strands are antiparallel with regard to their 5' to 3' directionality.
• There are ~10.0 nucleotides in each strand per complete 360° turn of the helix.

Figure 9.17
RNA Structure

- The primary structure of an RNA strand is much like that of a DNA strand
- RNA strands are typically several hundred to several thousand nucleotides in length
- In RNA synthesis, only one of the two strands of DNA is used as a template
• Although usually single-stranded, RNA molecules can form short double-stranded regions
  – This secondary structure is due to complementary base-pairing
    • A to U and C to G
  – This allows short regions to form a double helix

• RNA double helices typically
  – Are right-handed (11-12 base pairs per turn)

• Different types of RNA secondary structures are possible
• the tertiary structure of tRNA\textsubscript{phe} (transfer RNA carrying the amino acid phenylalanine)