3

Proteins, Carbohydrates, and Lipids

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Site web compagnon livre Savada *Life 9ème édition* :
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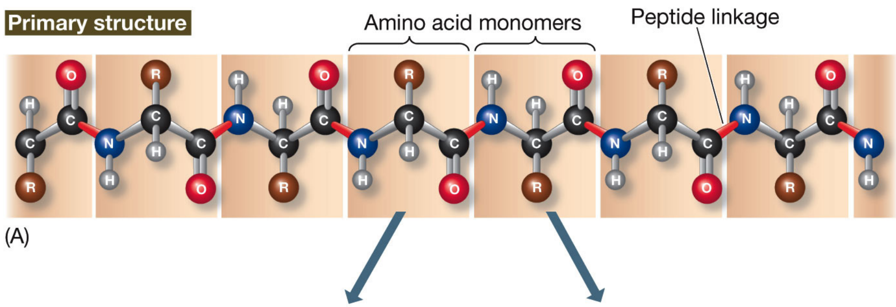
1.4 Proteins



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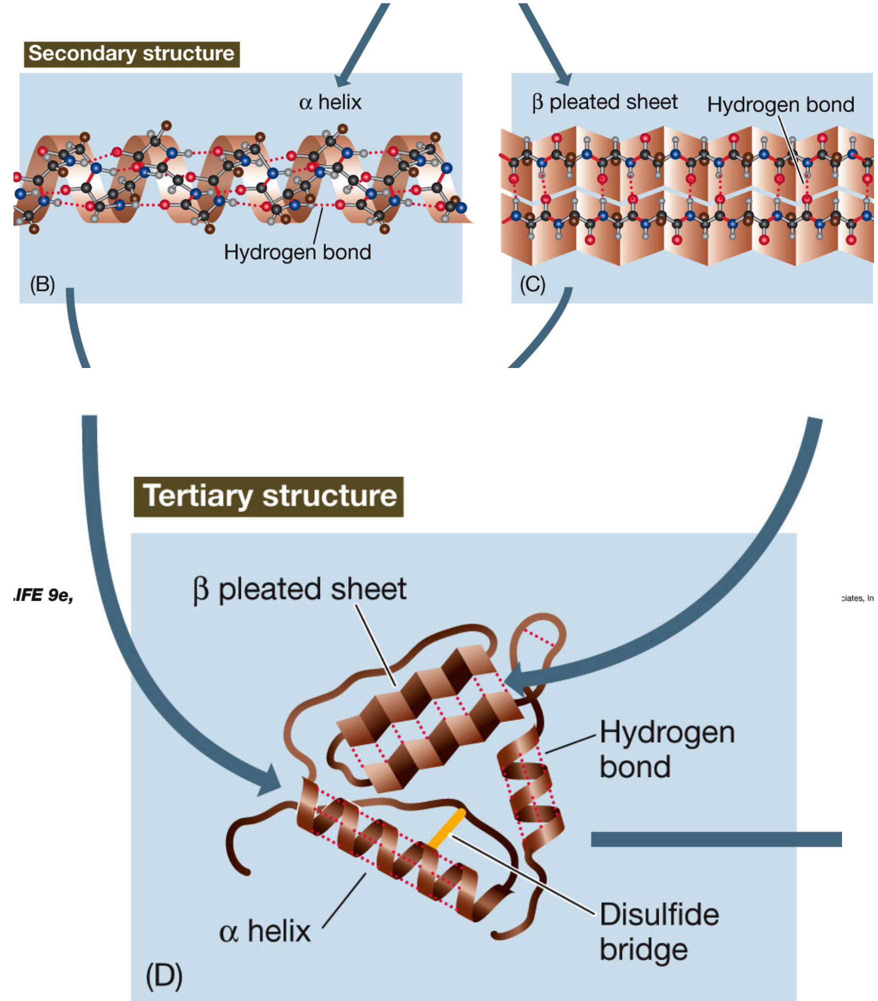
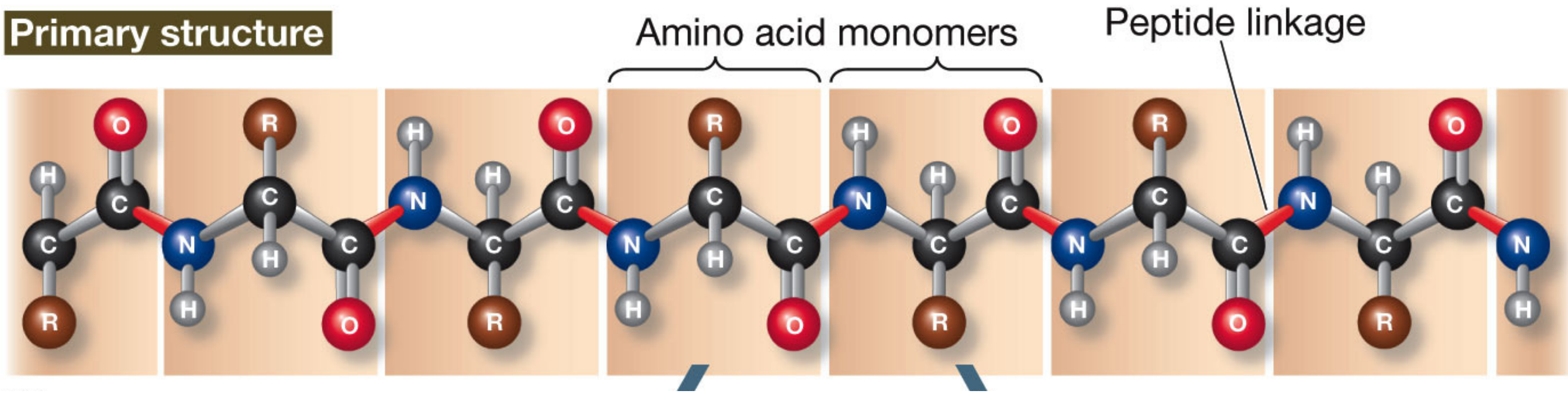


1.4 Proteins



- Biological molecules are **polymers**, constructed from the covalent binding of smaller molecules called **monomers**
- Proteins polymers are linear combination of amino acids monomers

3.3 What Are the Chemical Structures and Functions of Carbohydrates?

Carbohydrates have the general formula $C_n(H_2O)_n$

3 main roles:

- Source of stored energy
- Transport stored energy
- *Carbon skeletons* that can be rearranged to form new molecules

Monosaccharides: simple sugars =>*monomer*

Disaccharides: two simple sugars linked by covalent bonds

Oligosaccharides: three to 20 monosaccharides

Polysaccharides: hundreds or thousands of monosaccharides—starch, glycogen, cellulose

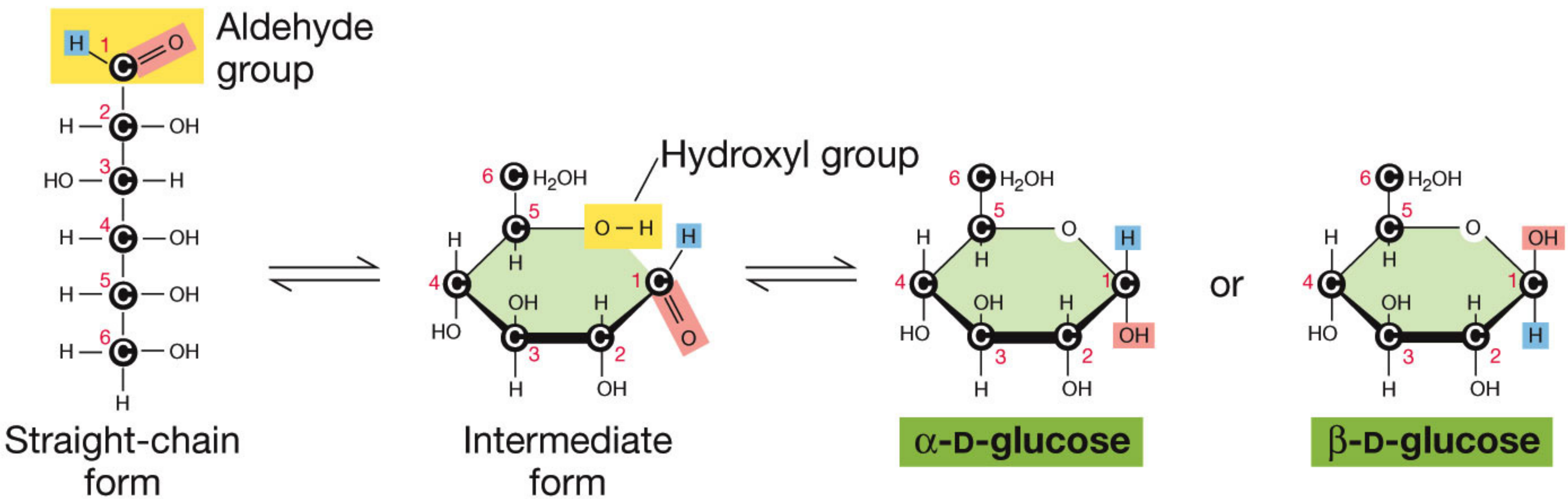
3.3 What Are the Chemical Structures and Functions of Carbohydrates?

All cells use **glucose** (monosaccharide) as an energy source.

"fuel" of the living world

Found for example in honey, fruits

Figure 3.13 From One Form of Glucose to the Other



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All cells use **glucose** (monosaccharide) as an energy source.

Exists as a straight chain or ring form. Ring is more common—it is more stable.

Ring form exists as α- or β-glucose, which can interconvert.

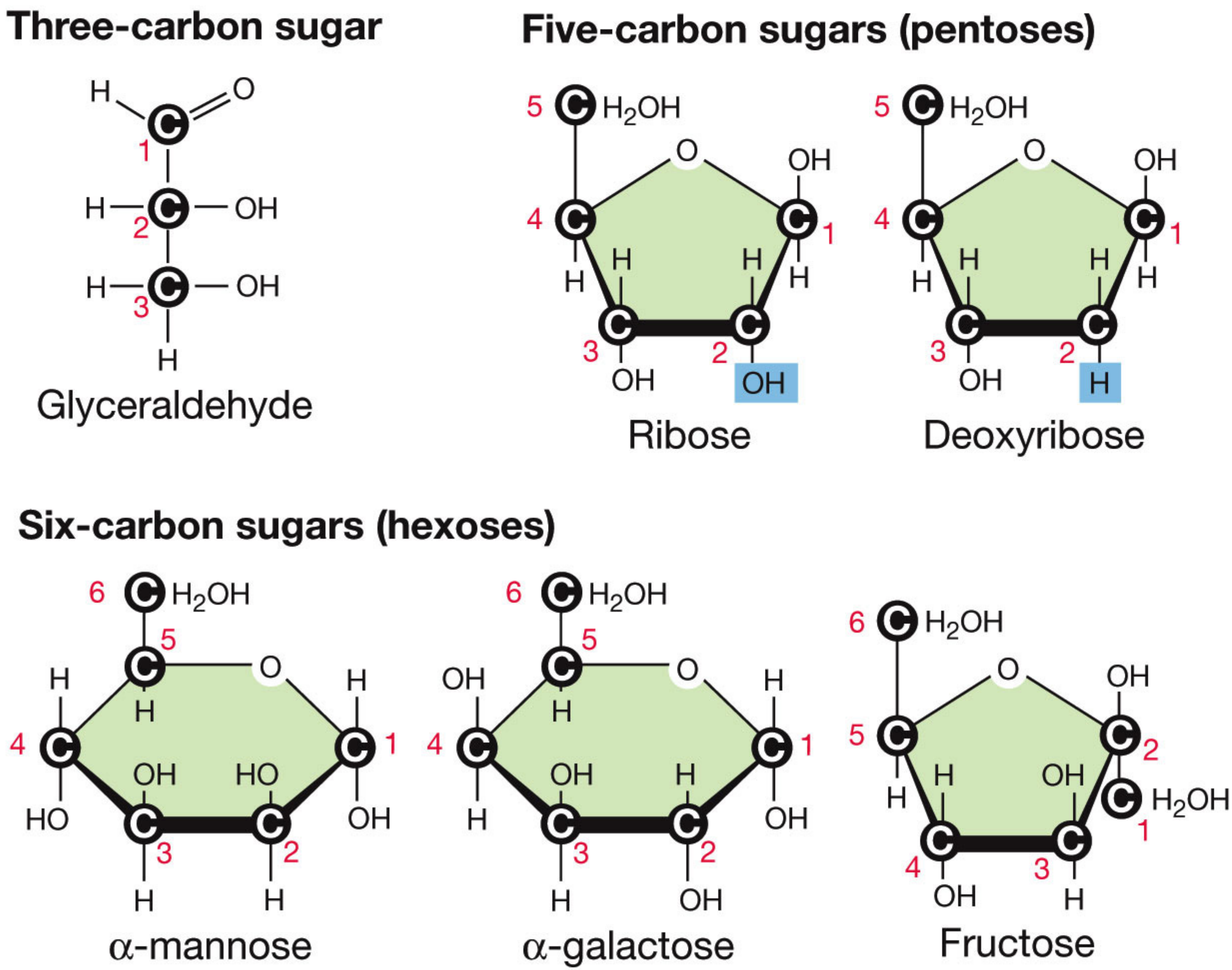
3.3 What Are the Chemical Structures and Functions of Carbohydrates?

Monosaccharides have different numbers of carbons:

Hexoses: six carbons—structural isomers

Pentoses: five carbons

Figure 3.14 Monosaccharides Are Simple Sugars



LIFE 9e, Figure 3.14

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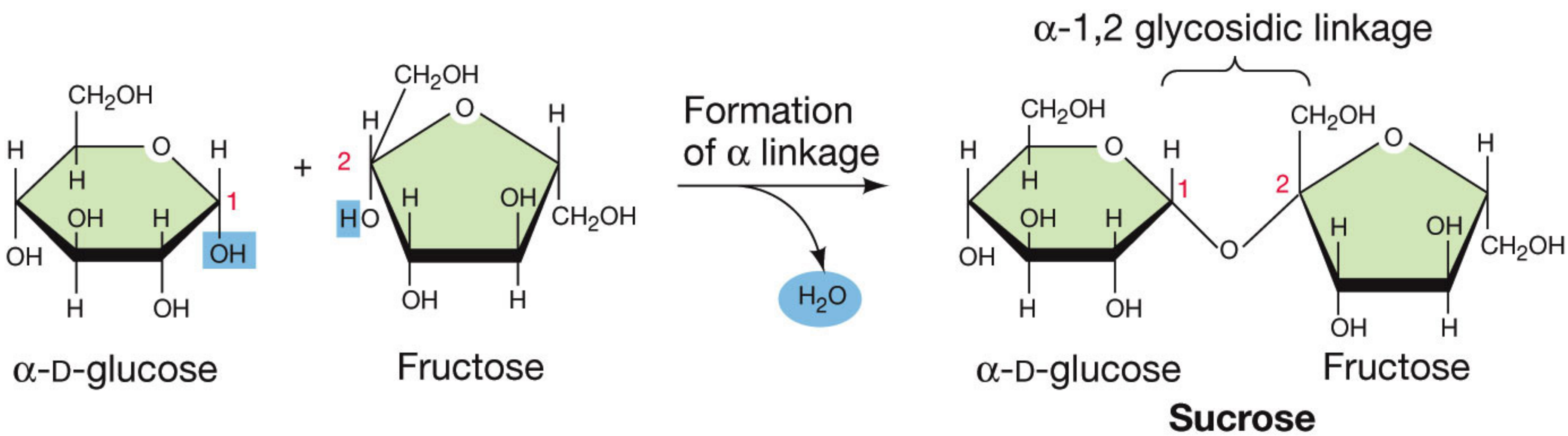
3.3 What Are the Chemical Structures and Functions of Carbohydrates?

Monosaccharides bind together in condensation reactions to form **glycosidic linkages**.

Glycosidic linkages can be α or β.

Figure 3.15 Disaccharides Form by Glycosidic Linkages (Part 1)



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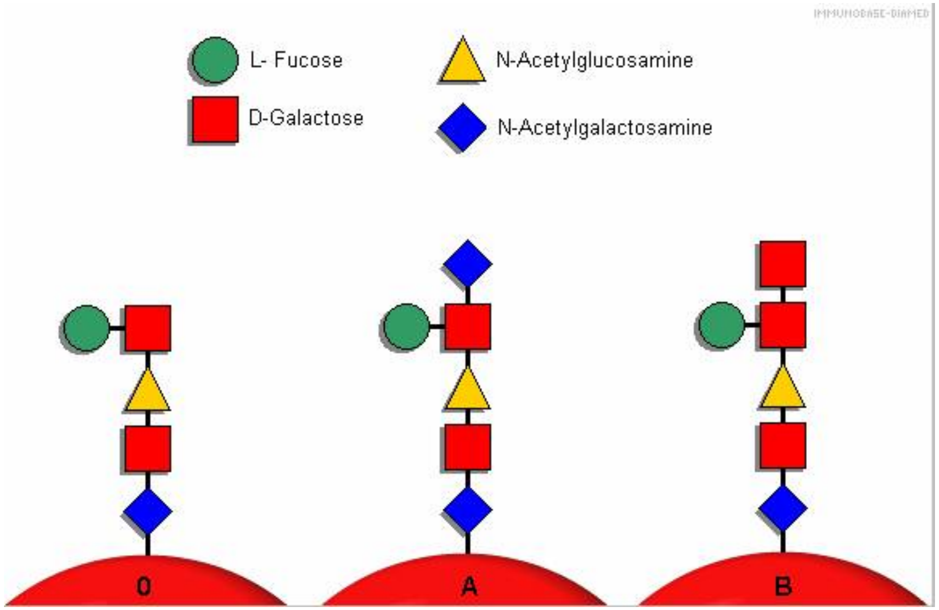
3.3 What Are the Chemical Structures and Functions of Carbohydrates?

Often covalently bonded to proteins and lipids on cell surfaces and act as recognition signals.

Human blood groups get specificity from oligosaccharide chains.



http://www.ftlpo.net

Polysaccharides are giant polymers of monosaccharides.

Polysaccharides of glucose:

Starch (amidon): storage of glucose in plants

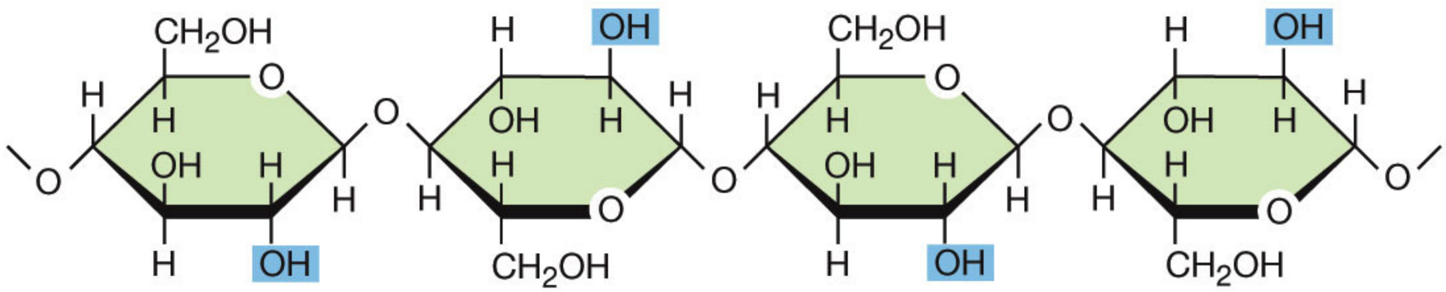
Glycogen: storage of glucose in animals

Cellulose: very stable, good for structural components

Figure 3.16 Representative Polysaccharides (Part 1)

(A) Molecular structure

Cellulose



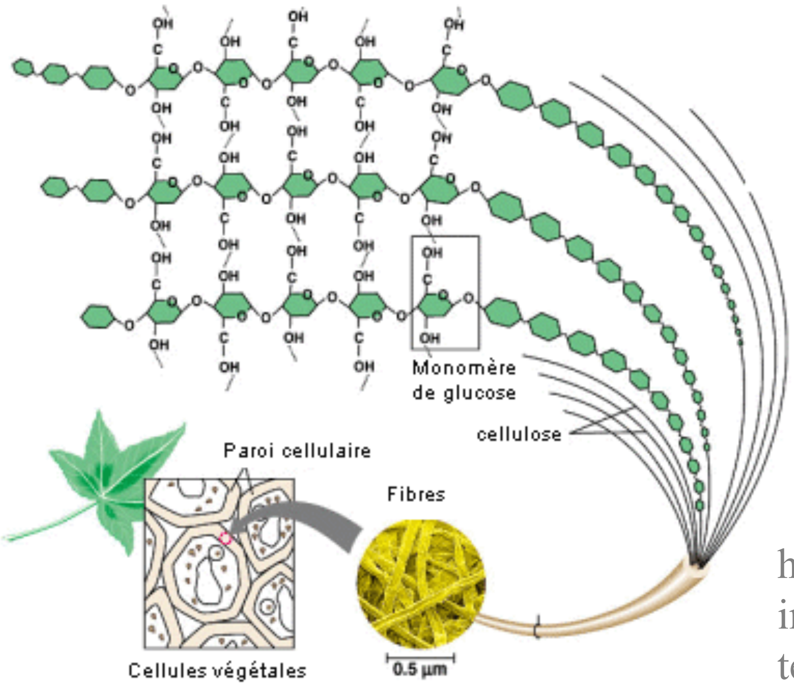


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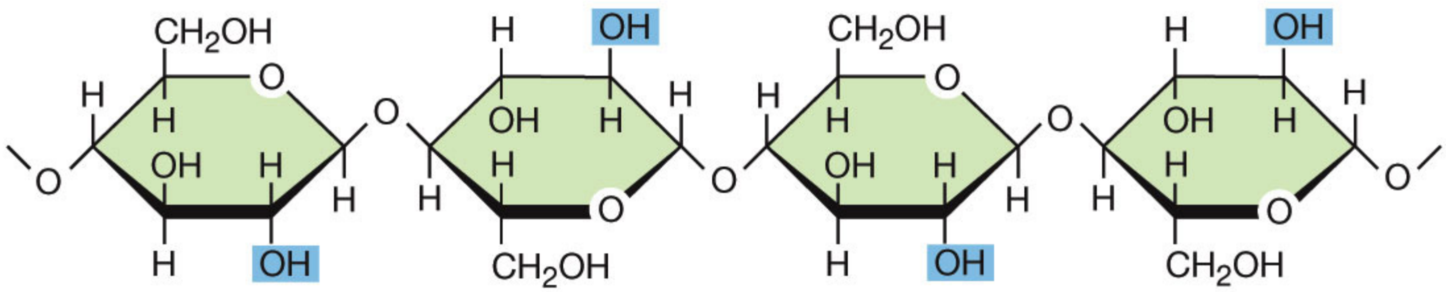
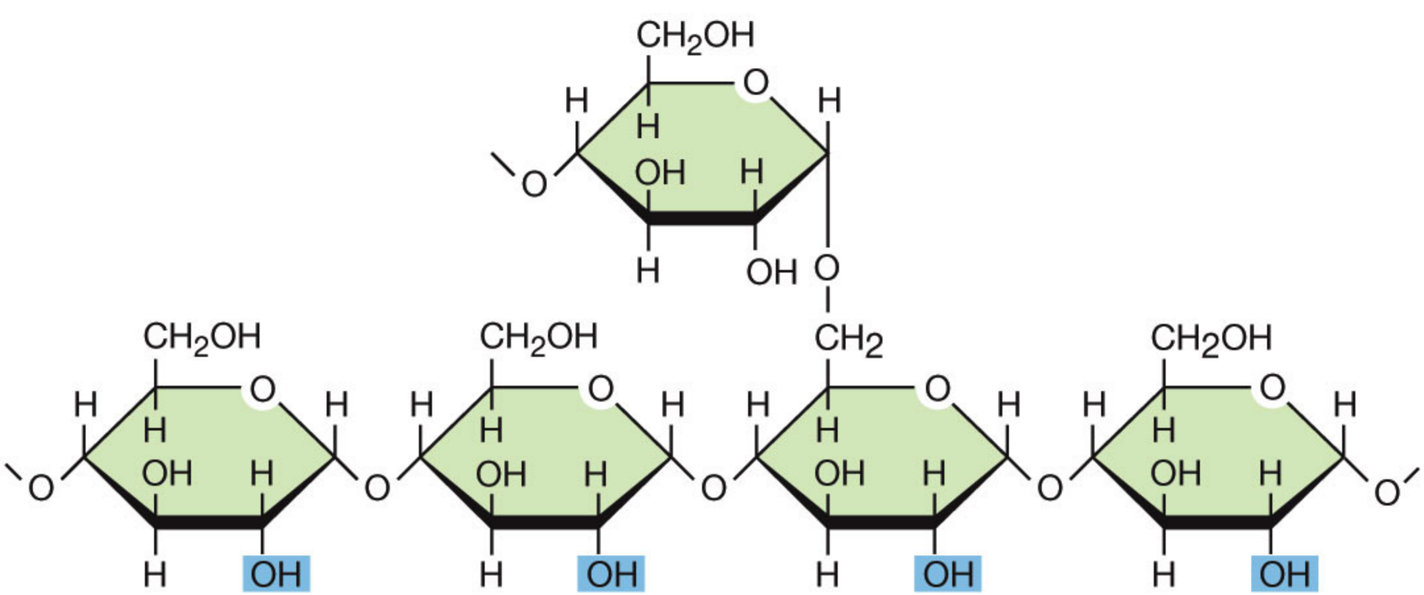
Figure 3.16 Representative Polysaccharides (Part 1)

(A) Molecular structure

Cellulose



Starch and glycogen



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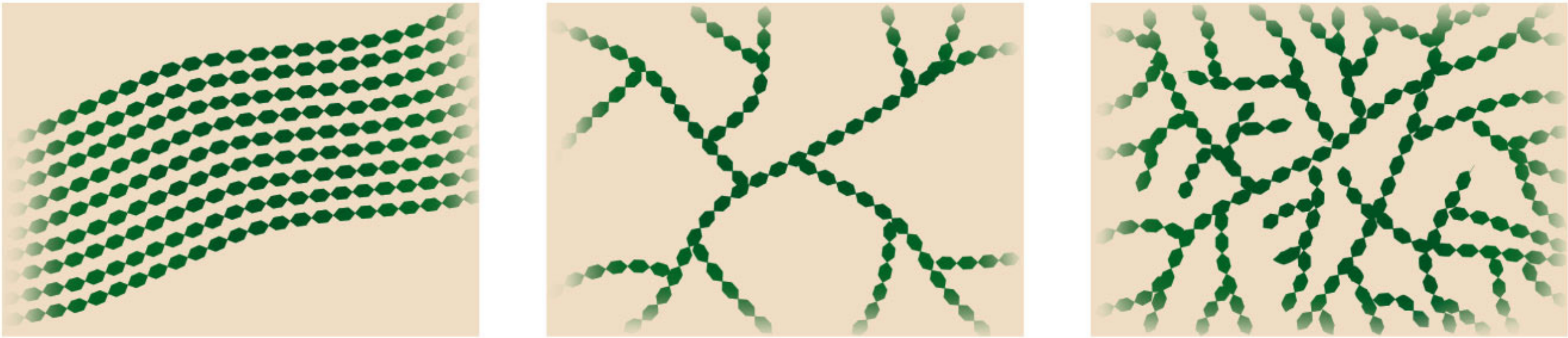
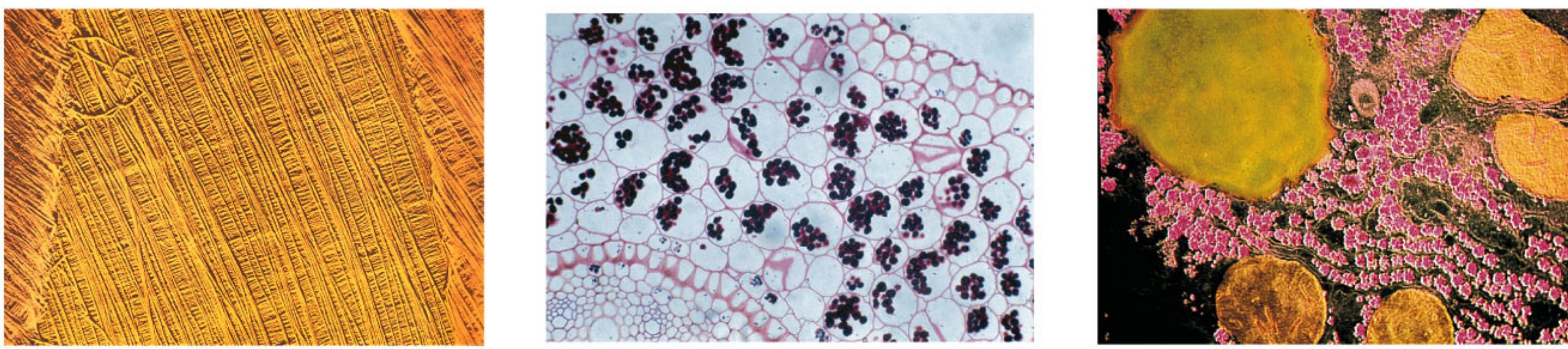
(B) Macromolecular structure

Linear (cellulose) Branched (starch) Highly branched (glycogen)



(C) Polysaccharides in cells



Carbohydrates can be modified by the addition of functional groups:

Sugar phosphate

Amino sugars (eg. Glucosamine)

Chitin

3.4 summary

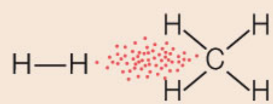
Proteins formed by a linear combination of amino acids monomers (among 20) by peptide linkage

Carbohydrates formed by linear or branched combination of monosaccharides monomers by glycosidic linkage

3.4 What Are the Chemical Structures and Functions of Lipids?

Lipids are nonpolar hydrocarbons.

When sufficiently close together, weak but additive van der Waals forces hold them together.

van der Waals interaction	Interaction of electrons of nonpolar substances		1

Not polymers in the strict sense, because they are not covalently bonded. Aggregates of individual lipids

3.4 What Are the Chemical Structures and Functions of Lipids?

- Fats and oils store energy
- Phospholipids—structural role in cell membranes
- Carotenoids and chlorophylls—capture light energy in plants (photoreceptor)
- Steroids and modified fatty acids—hormones and vitamins
- Animal fat—thermal insulation
- Lipid coating around nerves provides electrical insulation
- Oil and wax on skin, fur, and feathers repels water

3.4 What Are the Chemical Structures and Functions of Lipids?

Fats and oils are *triglycerides*

(*simple lipids*):

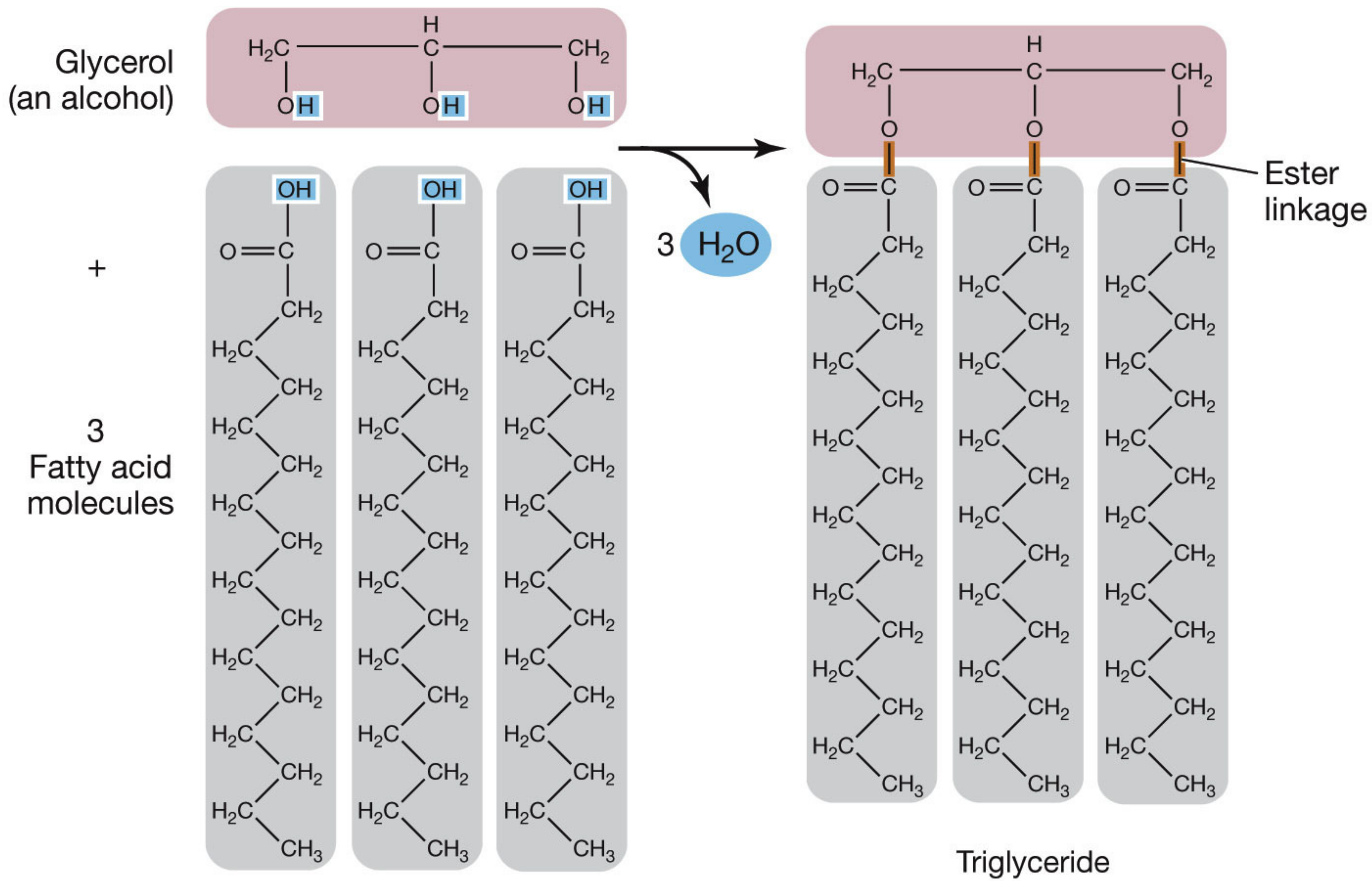
composed of fatty acids and glycerol

Glycerol: 3 —OH groups (an alcohol)

Fatty acid: nonpolar hydrocarbon with a polar carboxyl group

Carboxyls bond with hydroxyls of glycerol in an **ester linkage**.

Figure 3.18 Synthesis of a Triglyceride



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Saturated fatty acids: no double bonds between carbons—it is saturated with H atoms.

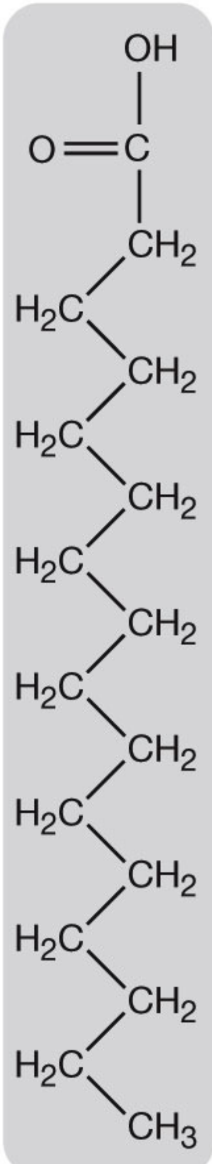
Unsaturated fatty acids: some double bonds in carbon chain.

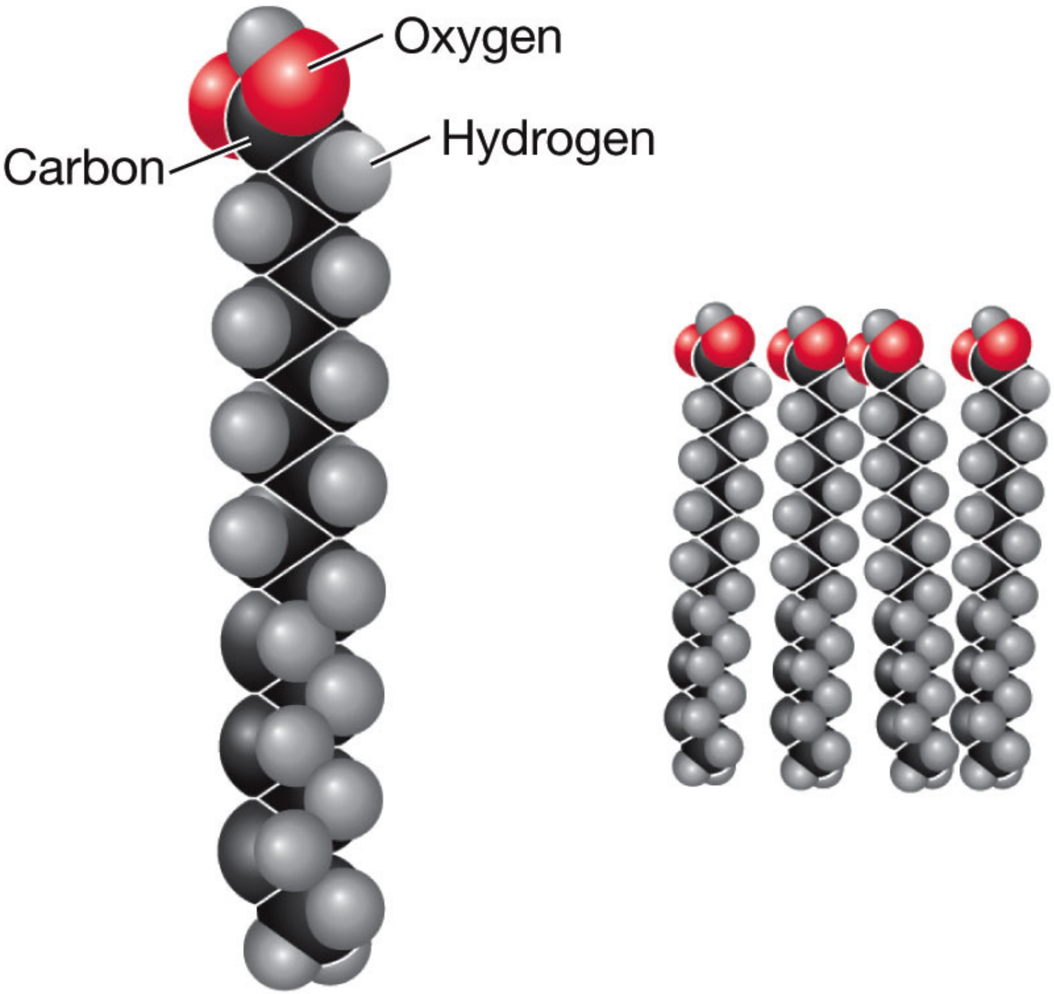
monounsaturated: one double bond

polyunsaturated: more than one

Figure 3.19 Saturated and Unsaturated Fatty Acids (Part 1)

(A) Palmitic acid





LIFE 9e, Figure 3.19 (Part 1)

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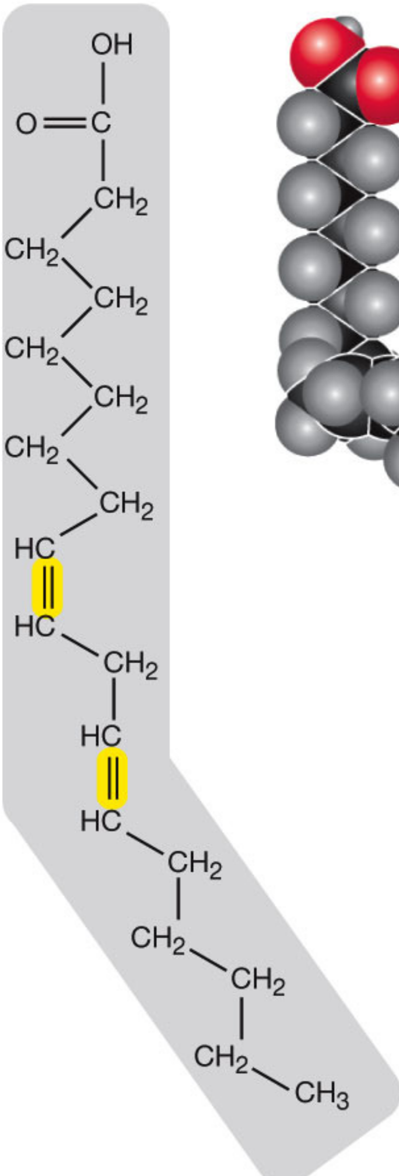
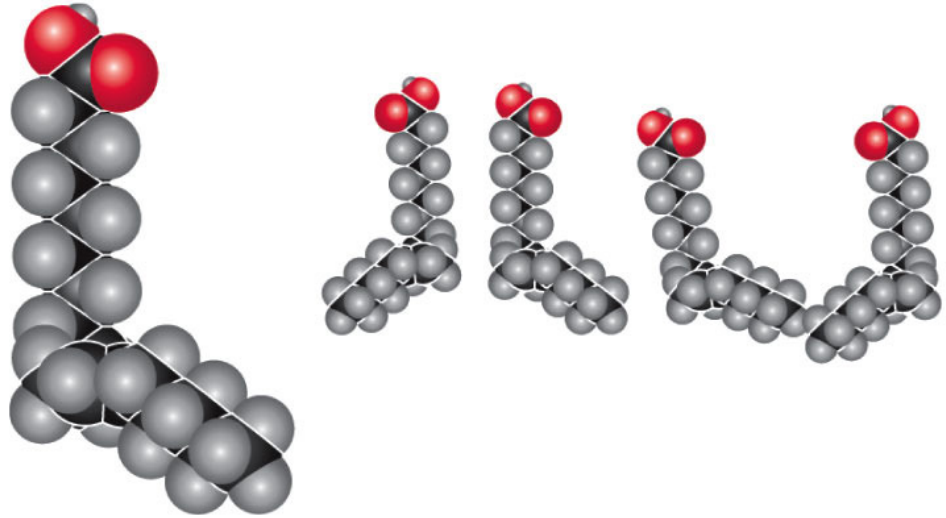
Figure 3.19 Saturated and Unsaturated Fatty Acids (Part 2)

(B) Linoleic acid





LIFE 9e, **Figure 3.19 (Part 2)**

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3.4 What Are the Chemical Structures and Functions of Lipids?

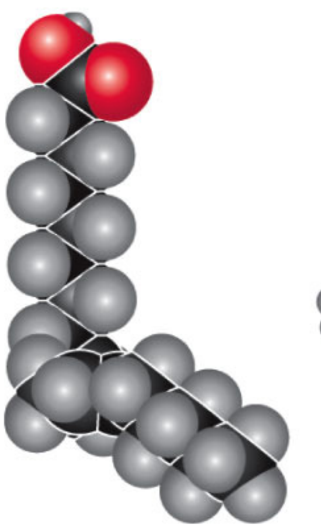
Animal **fats** tend to be saturated: packed together tightly; solid at room temperature.

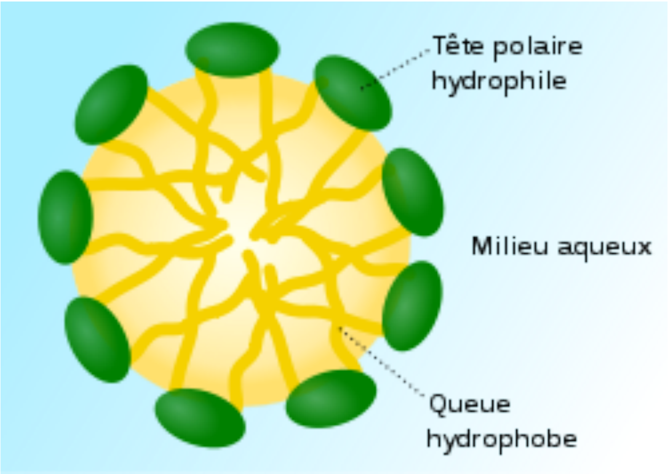
Plant **oils** tend to be unsaturated: the "kinks" prevent packing; liquid at room temperature.

3.4 What Are the Chemical Structures and Functions of Lipids?

Fatty acids are **amphipathic**: they have opposing chemical properties.

When the carboxyl group ionizes it forms COO– and is strongly hydrophilic; the other end is hydrophobic.





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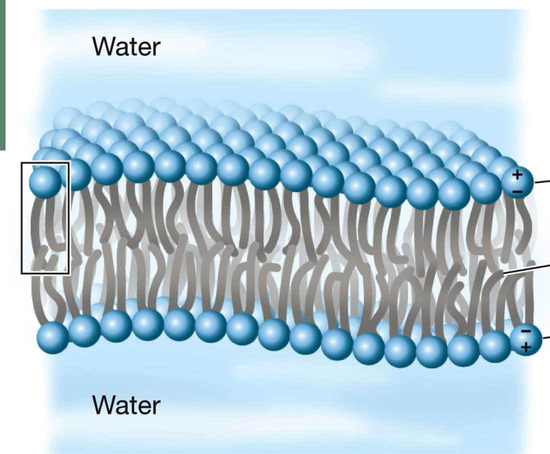
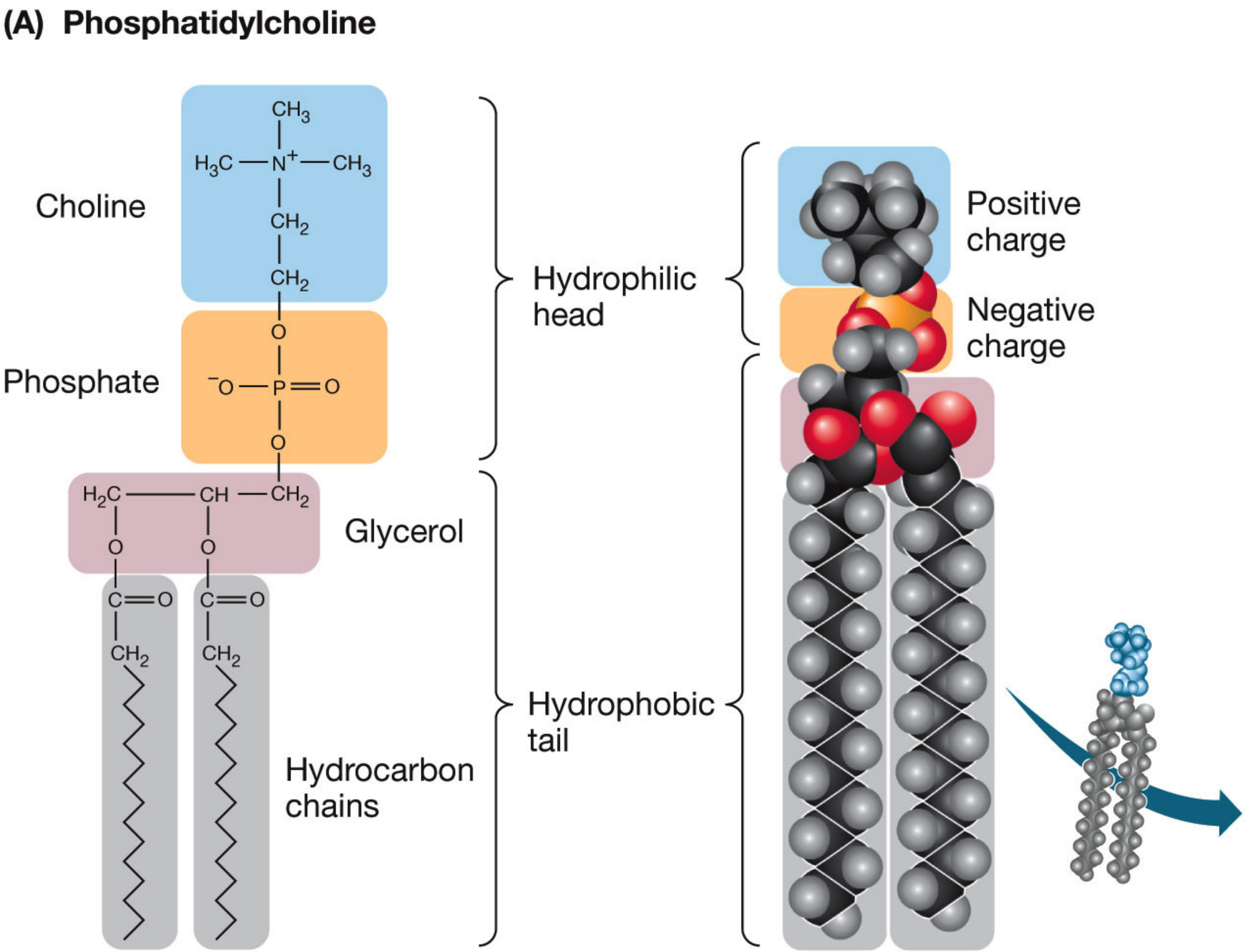
3.4 What Are the Chemical Structures and Functions of Lipids?



Phospholipids: fatty acids bound to glycerol; a phosphate group replaces one fatty acid.

- Phosphate group is hydrophilic—the “head”
- “Tails” are fatty acid chains—hydrophobic
- They are amphipathic

Figure 3.20 Phospholipids (Part 1)



LIFE 9e, Figure 3.20 (Part 1)

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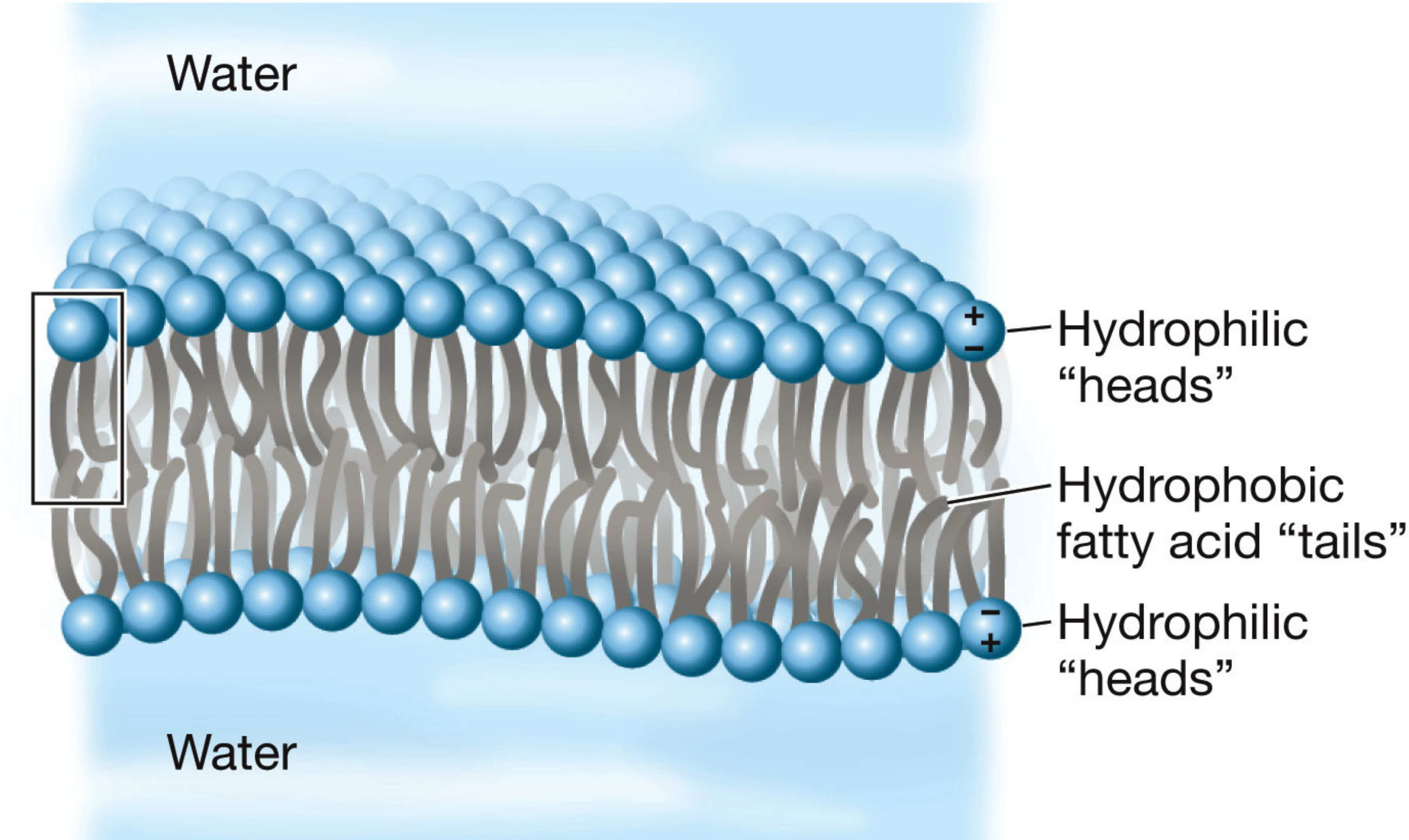
3.4 What Are the Chemical Structures and Functions of Lipids?

In water, phospholipids line up with the hydrophobic “tails” together and the phosphate “heads” facing outward, to form a **bilayer**.

Biological membranes have this kind of **phospholipid bilayer** structure.

(B) Phospholipid bilayer



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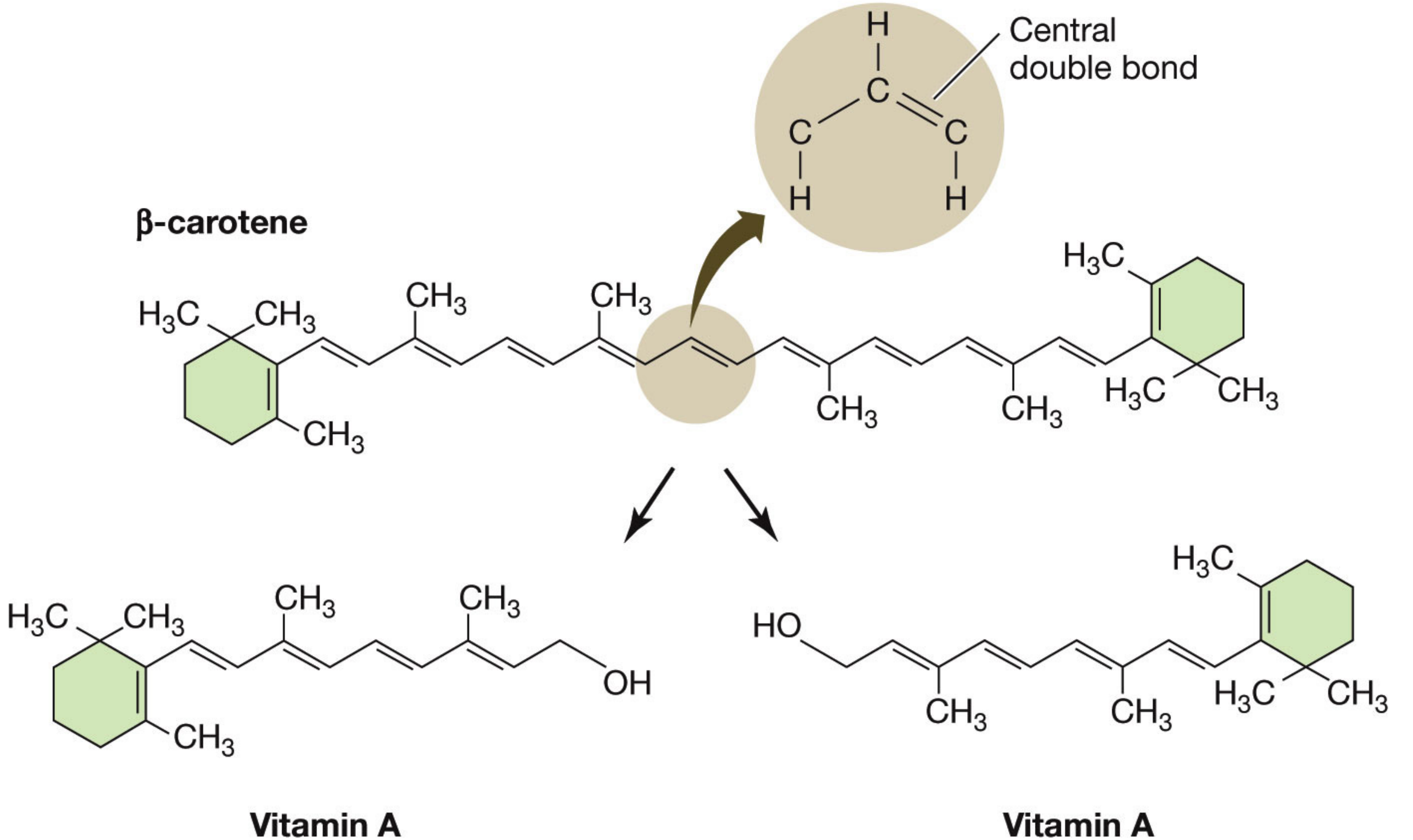
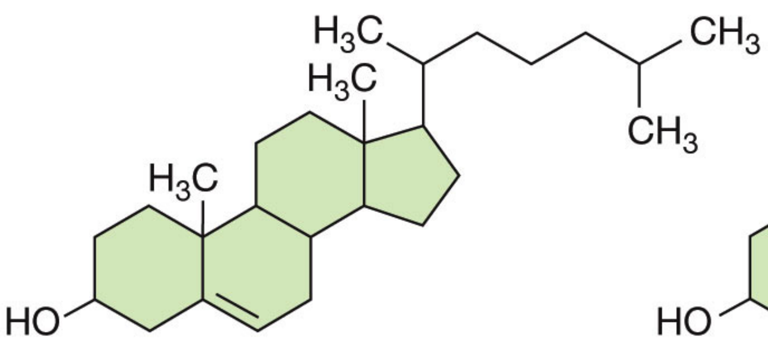
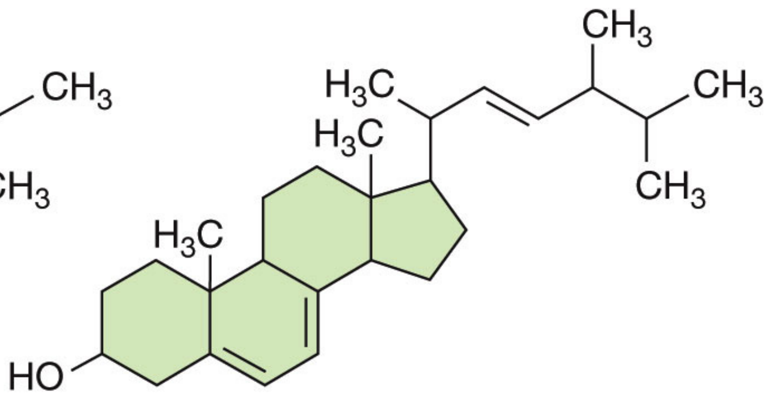
Carotenoids: light-absorbing pigments



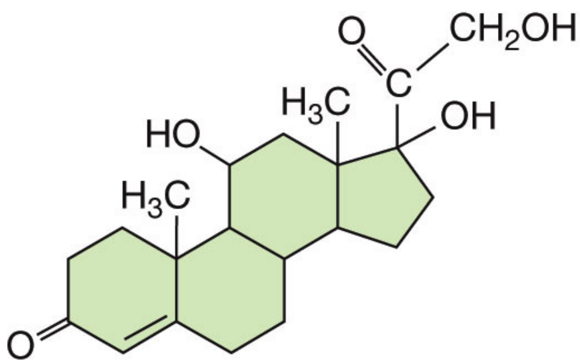
Steroids: multiple rings share carbons



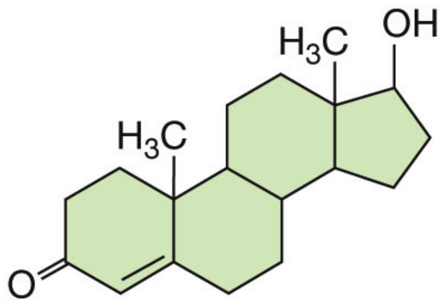
Cholesterol



Vitamin D_2



Cortisol



Testosterone

3.4 What Are the Chemical Structures and Functions of Lipids?

Vitamins—small molecules not synthesized by the body and must be acquired in the diet.

Not all vitamins are lipids !

=> vitamin A, K, D, E

3.4 summary

Proteins formed by a linear combination of amino acids monomers (among 20) by peptide linkage

Carbohydrates formed by linear or branched combination of monosaccharides monomers by glycosidic linkage

Lipids form large structures but the interactions are not covalent. Non polar and amphiphatic molecules

3

Nucleic Acids and the Origin of Life

4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

Nucleic acids are polymers specialized for the storage, transmission, and use of genetic information.

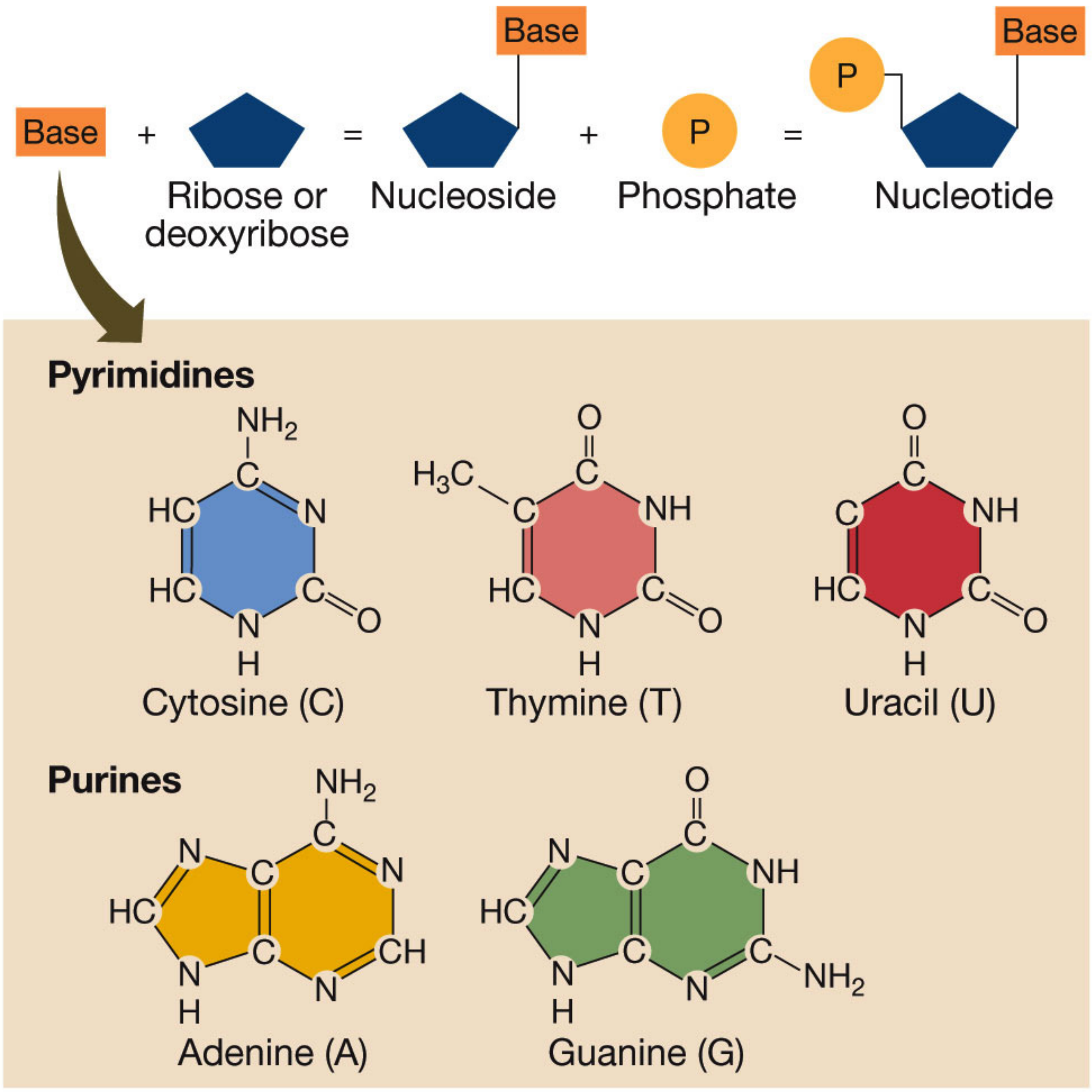
DNA = deoxyribonucleic acid

RNA = ribonucleic acid

4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

The monomeric units are **nucleotides**.

Nucleotides consist of a pentose sugar, a phosphate group, and a nitrogen-containing **base**.



***LIFE 9e*, Figure 4.1**

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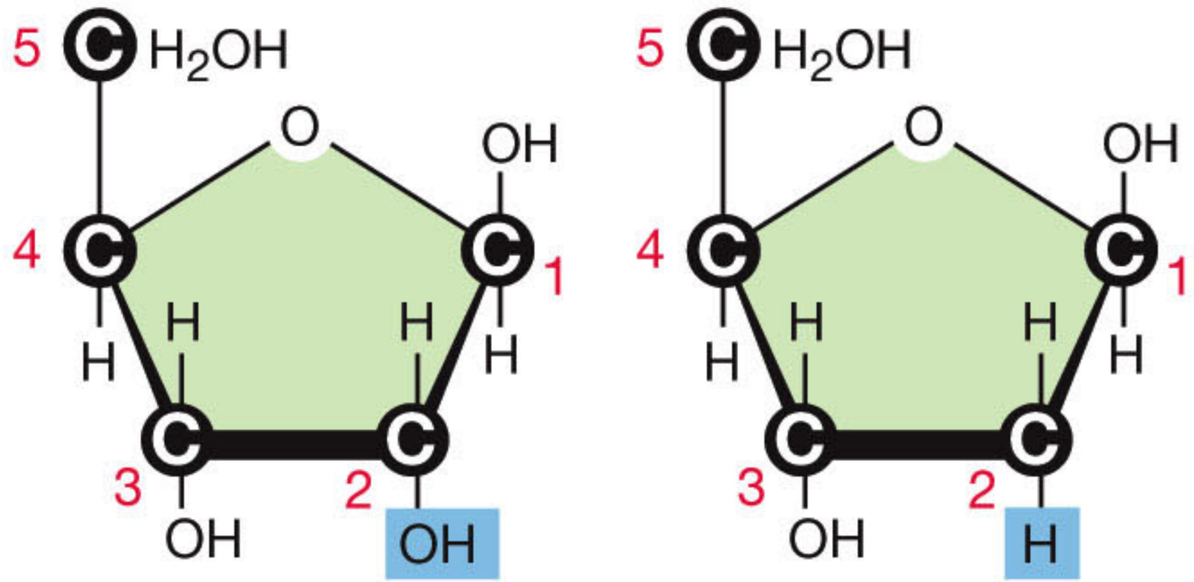
4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

RNA has **ribose**

DNA has **deoxyribose**



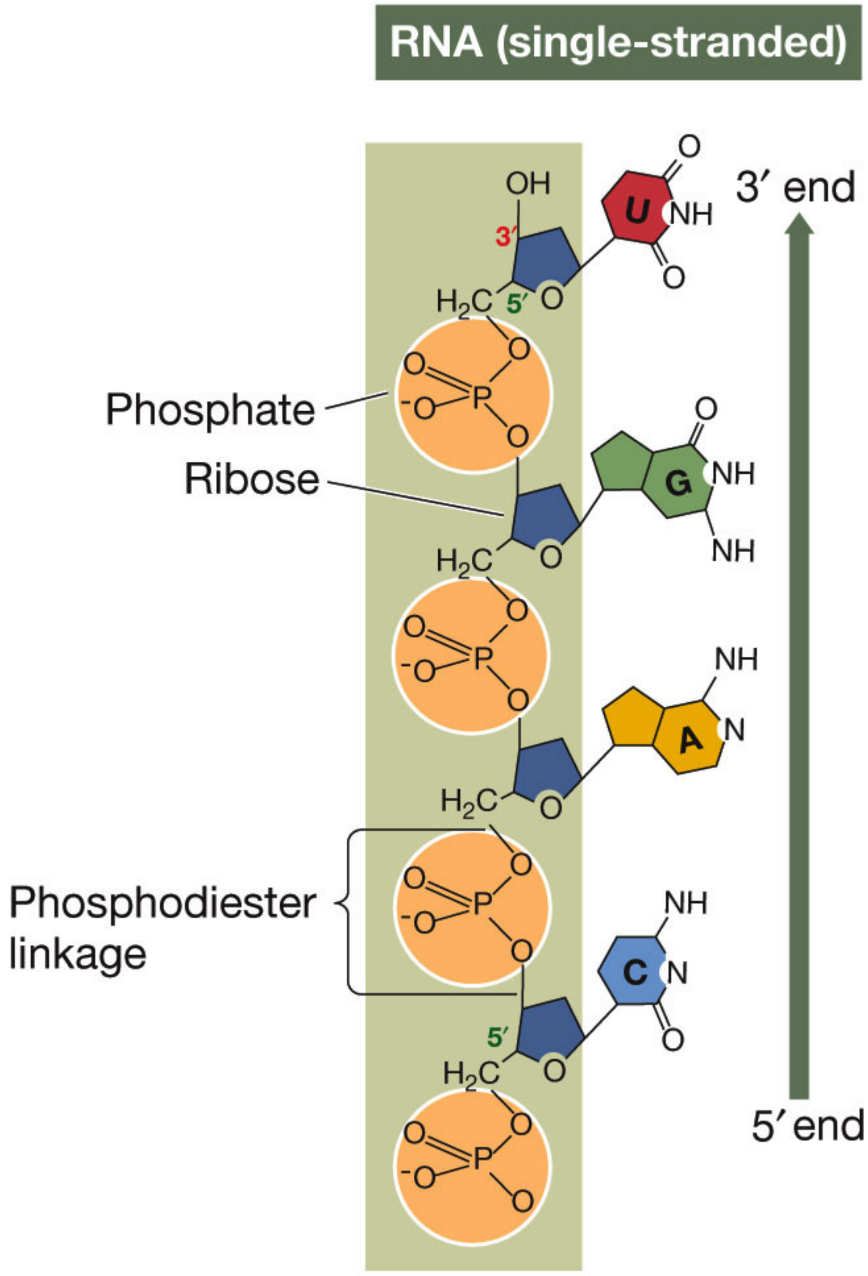
Ribose Deoxyribose

The “backbone” of DNA and RNA is a chain of sugars and phosphate groups, bonded by **phosphodiester linkages**.

The phosphate groups link carbon 3′ in one sugar to carbon 5′ in another sugar.

The two strands of DNA run in opposite directions (*antiparallel*).

Figure 4.2 Distinguishing Characteristics of DNA and RNA Polymers (Part 1)



LIFE 9e, Figure 4.2 (Part 1)

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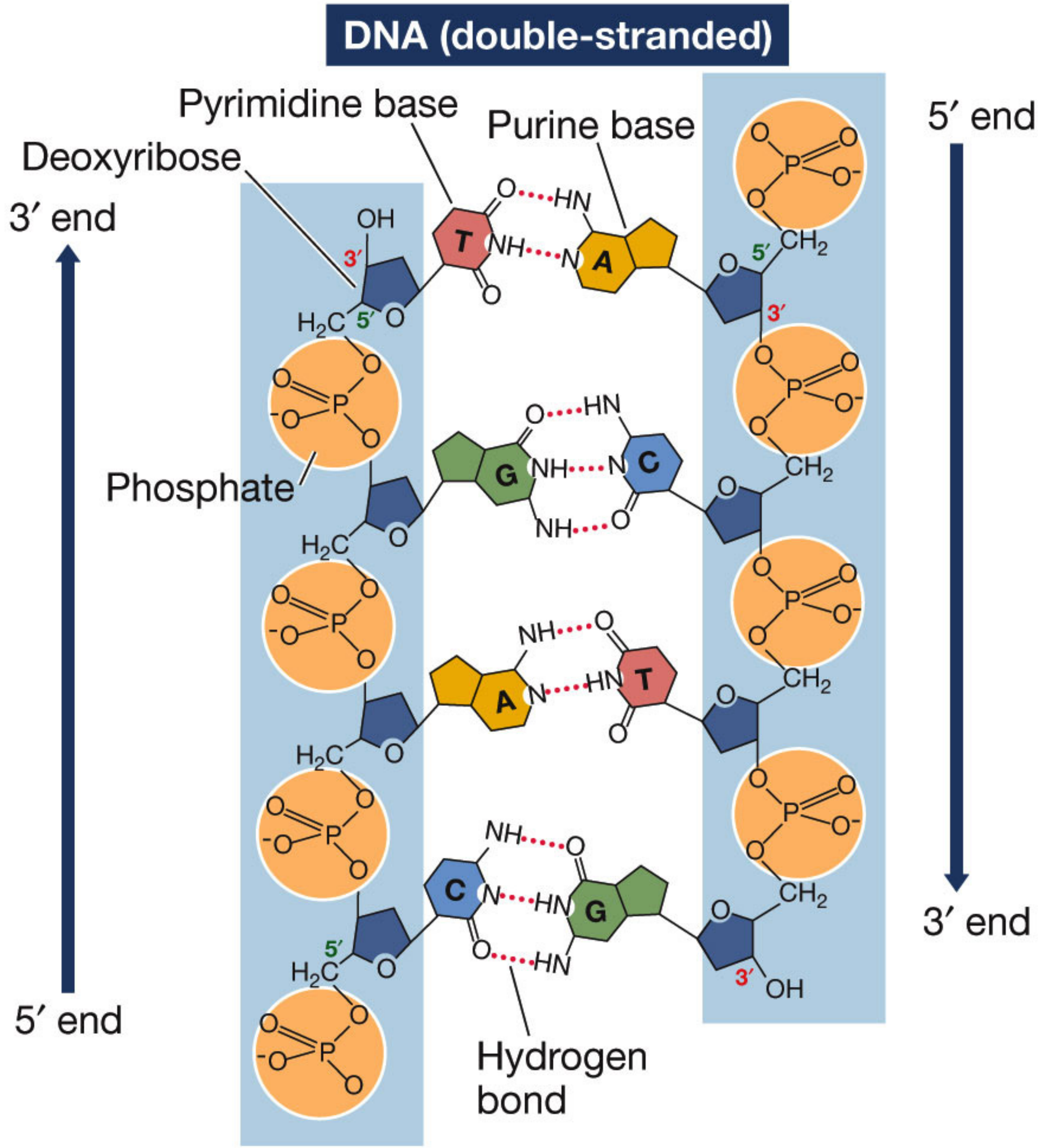
Figure 4.2 Distinguishing Characteristics of DNA and RNA



***LIFE 9e*, Figure 4.2 (Part 2)**

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DNA bases: **adenine** (**A**), **cytosine** (**C**), **guanine** (**G**), and **thymine** (**T**)

Complementary base pairing:

A–T

C–G

Purines pair with pyrimidines by hydrogen bonding.

Instead of thymine, RNA uses the base **uracil** (**U**).

TABLE 4.1

Distinguishing RNA from DNA

NUCLEIC ACID	SUGAR	BASES	STRANDS
RNA	Ribose	Adenine Cytosine Guanine Uracil	Single
DNA	Deoxyribose	Adenine Cytosine Guanine Thymine	Double

LIFE 9e, Table 4.1

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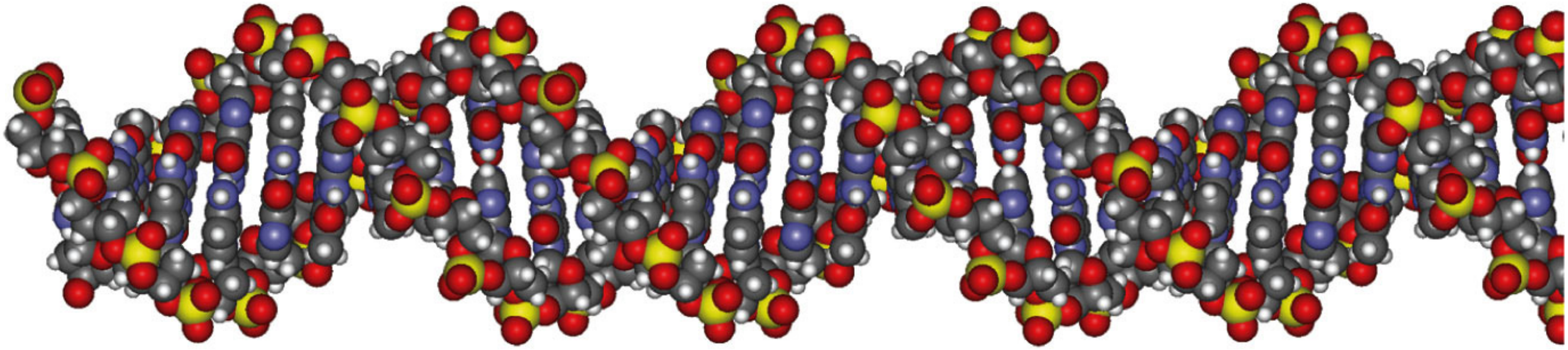
4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

The two strands of a DNA molecule form a **double helix**.

All DNA molecules have the same structure; diversity lies in the sequence of base pairs.

DNA is an *informational* molecule: information is encoded in the sequences of bases.



The two functions of DNA comprise the *central dogma of molecular biology*:

- DNA can reproduce itself (*replication*).
- DNA can copy its information into RNA (*transcription*). RNA can specify a sequence of amino acids in a polypeptide (*translation*).

4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

The complete set of DNA in a living organism is called its **genome**.

DNA carries hereditary information between generations.

Determining the sequence of bases helps reveal evolutionary relationships.

The closest living relative of humans is the chimpanzee (share 98% DNA sequence).

4.1 What Are the Chemical Structures and Functions of Nucleic Acids?

Other roles for nucleotides:

ATP—energy transducer in biochemical reactions

Unity of life through biochemical unity

Implies a common origin of life

4.2 How and Where Did the Small Molecules of Life Originate?

In the current conditions on Earth, living organisms arise from other living organisms

Eons ago,conditions on Earth and in the atmosphere were vastly different.

About 4 billion years ago, chemical conditions, including the presence of water, became just right for life.

4.2 How and Where Did the Small Molecules of Life Originate?

Chemical evolution: conditions on primitive Earth led to formation of simple molecules (prebiotic synthesis); these molecules led to formation of life forms.

Scientists have experimented with reconstructing those primitive conditions.

4.2 How and Where Did the Small Molecules of Life Originate?

Miller and Urey (1950s) set up an experiment with gases thought to have been present in Earth's early atmosphere.

An electric spark simulated lightning as a source of energy to drive chemical reactions.

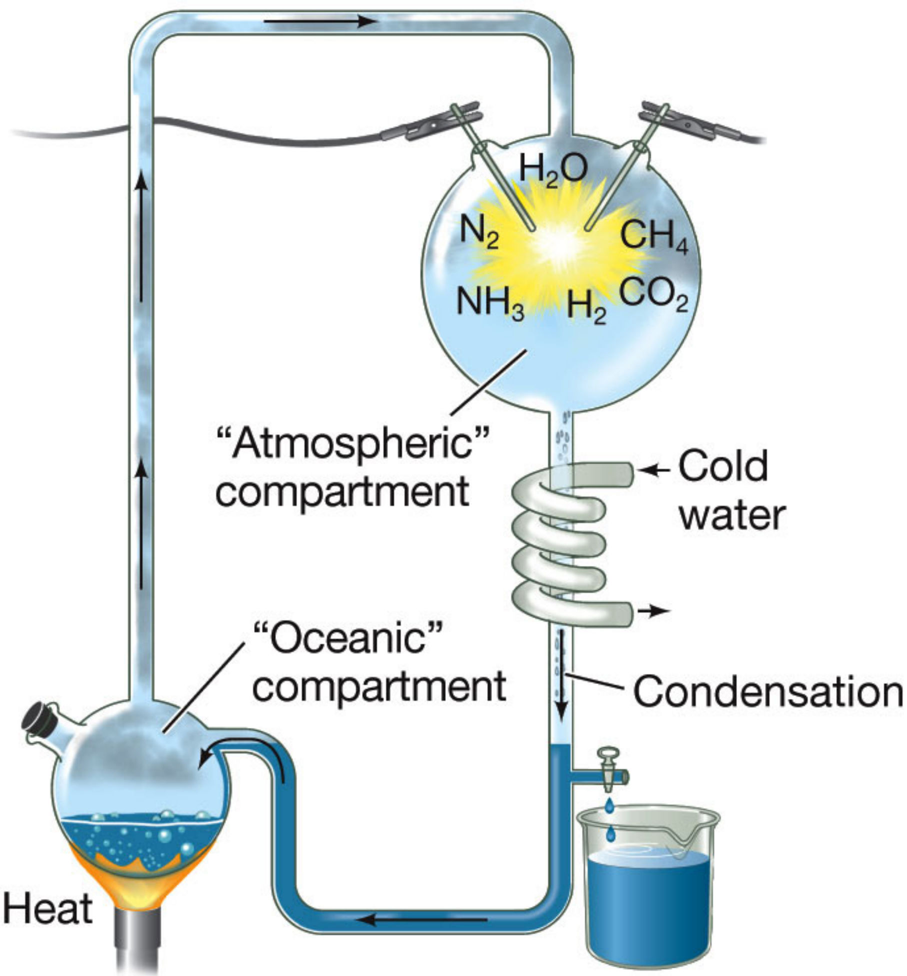
After several days, amino acids, purines, and pyrimidines were formed.

Figure 4.9 Miller & Urey Synthesized Prebiotic Molecules in an

INVESTIGATING LIFE

HYPOTHESIS **Organic chemical compounds can be generated under conditions similar to those that existed in the atmosphere of primitive Earth.**

METHOD



***LIFE 9e*, Figure 4.9 (Part 1)**

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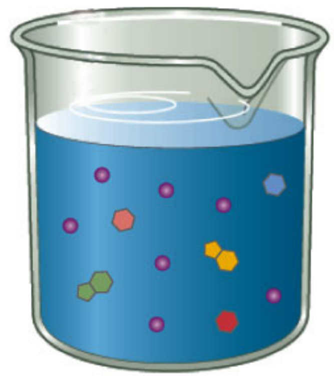
Figure 4.9 Miller & Urey Synthesized Prebiotic Molecules in an

INVESTIGATING LIFE

RESULTS



CONCLUSION The chemical building blocks of life could have been generated in the probable atmosphere of early Earth.

LIFE 9e, Figure 4.9 (Part 2)

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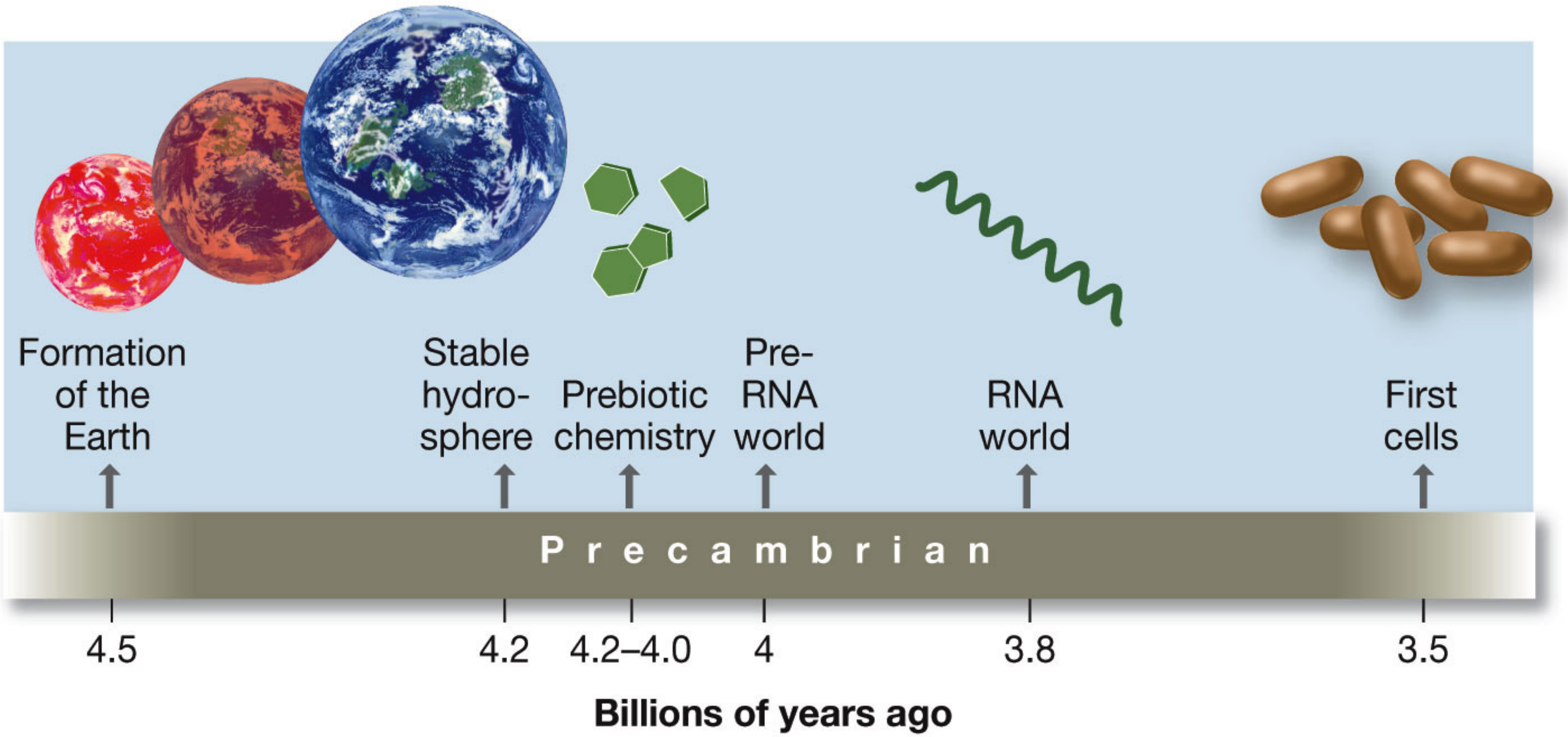
Evidence that supports the "RNA World" hypothesis:

- Certain short RNA sequences catalyze formation of RNA polymers.
- "Ribozyme" can catalyze assembly of short RNAs into a longer molecule.
- RNA as genetic material and able to perform metabolic processes



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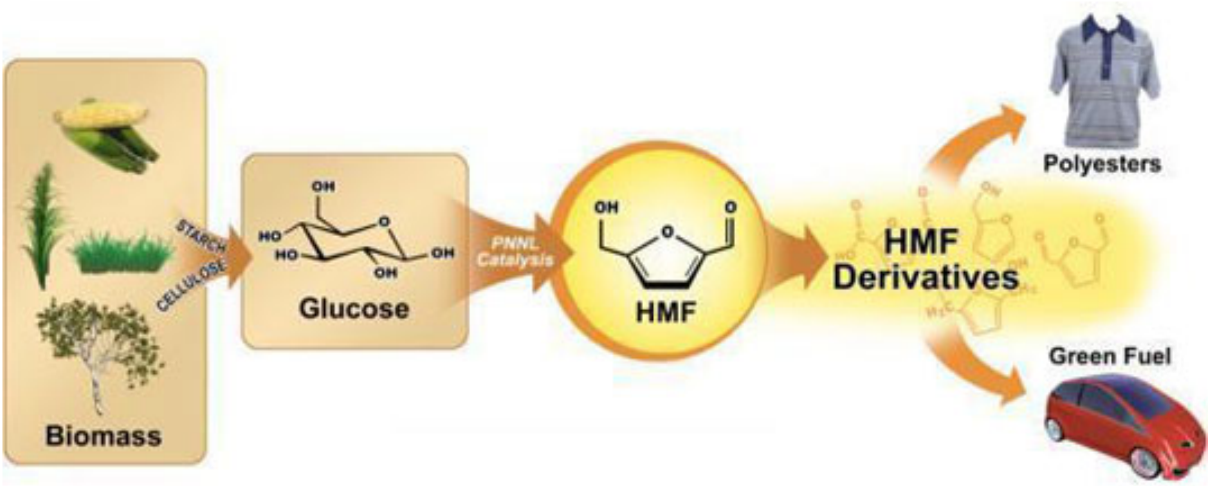
What about chemistry/engineering ?

- Bioplastics: derived from biopolymers such as cellulose and starch
- Biofuels



- Companies dedicated to chemistry of renewable biomass to produce chemicals for use in a wide variety of everyday products including plastics

What about chemistry/engineering ?

- DNA computers, DNA databases
  - 2013: Scientists have recorded data including Shakespearean sonnets and an MP3 file on strands of DNA

LETTER

doi:10.1038/nature11875

Towards practical, high-capacity, low-maintenance information storage in synthesized DNA

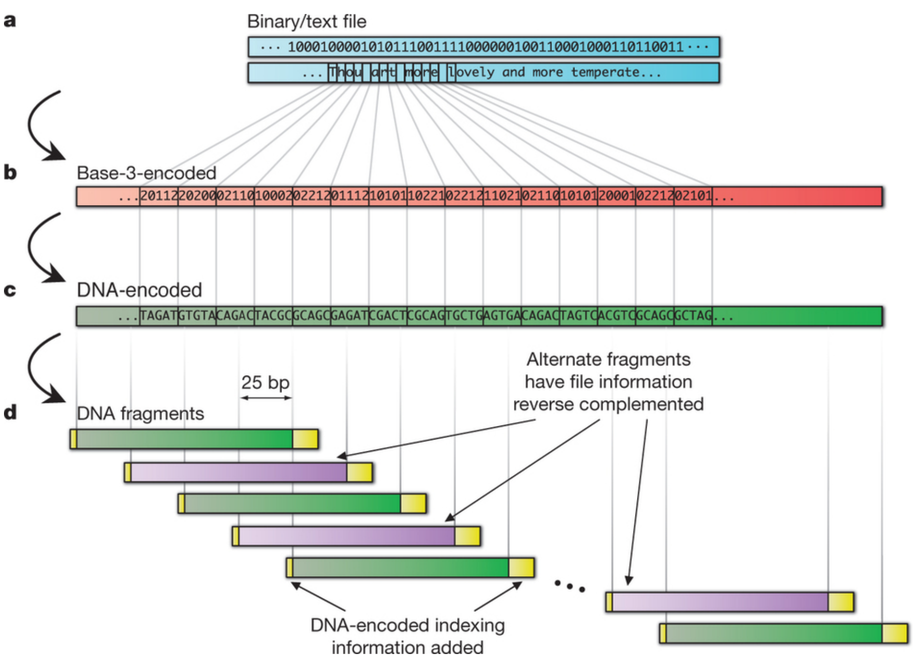
Nick Goldman[1], Paul Bertone[1], Siyuan Chen[2], Christophe Dessimoz[1], Emily M. LeProust[2], Botond Sipos[1] & Ewan Birney[1]

Digital production, transmission and storage have revolutionized how we access and use information but have also made archiving an increasingly complex task that requires active, continuing maintenance of digital media. This challenge has focused some interest on DNA as an attractive target for information storage[1] because of its capacity for high-density information encoding, longevity under easily achieved conditions[2–4] and proven track record as an information bearer. Previous DNA-based information storage approaches have encoded only trivial amounts of information[5–7] or were not amenable to scaling-up[8], and used no robust error-correction and lacked examination of their cost-efficiency for large-scale information archival[9]. Here we describe a scalable method that can reliably store more information than has been handled before. We encoded computer files totalling 739 kilobytes of hard-disk storage and with an estimated Shannon information[10] of 5.2×10^6 bits into a DNA code, synthesized this DNA, sequenced it and reconstructed the original files with 100% accuracy. Theoretical analysis indicates that our DNA-based storage scheme could be scaled far beyond current global information volumes and offers a realistic technology for large-scale, long-term and infrequently accessed digital archiving. In fact, current trends in technological advances are reducing DNA synthesis costs at a pace that should make our scheme cost-effective for sub-50-year archiving within a decade.

Although techniques for manipulating, storing and copying large amounts of existing DNA have been established for many years[11–13], digits (ASCII text), giving a total of 757,051 bytes or a Shannon information[10] of 5.2×10^6 bits (see Supplementary Information and Supplementary Table 1 for full details).

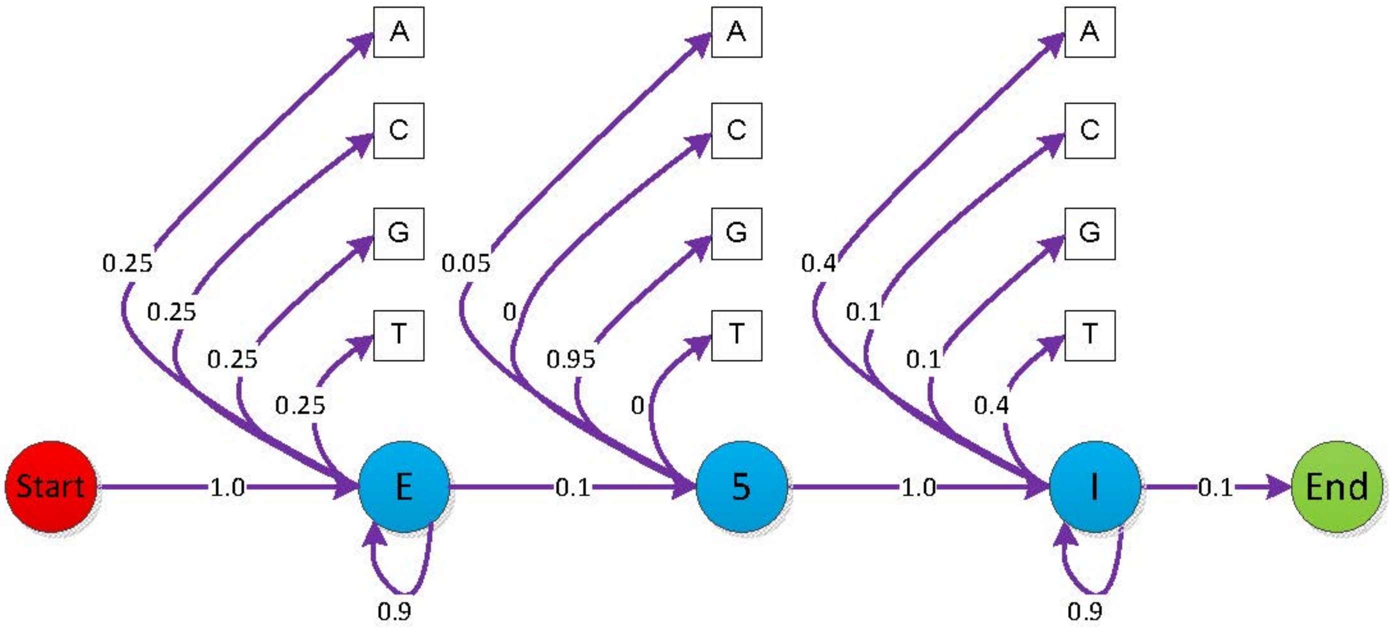
The bytes comprising each file were represented as single DNA sequences with no homopolymers (runs of ≥ 2 identical bases, which are associated with higher error rates in existing high-throughput sequencing technologies[19] and led to errors in a recent DNA-storage experiment[9]). Each DNA sequence was split into overlapping segments, generating fourfold redundancy, and alternate segments were converted to their reverse complement (see Fig. 1 and Supplementary Information). These measures reduce the probability of systematic failure for any particular string, which could lead to uncorrectable errors and data loss. Each segment was then augmented with indexing information that permitted determination of the file from which it originated and its location within that file, and simple parity-check error-detection[10]. In all, the five files were represented by a total of 153,335 strings of DNA, each comprising 117 nucleotides (nt). The perfectly uniform fragment lengths and absence of homopolymers make it obvious that the synthesized DNA does not have a natural (biological) origin, and so imply the presence of deliberate design and encoded information[2].

We synthesized oligonucleotides (oligos) corresponding to our designed DNA strings using an updated version of Agilent Technologies' OLS (oligo library synthesis) process[20], creating $\sim 1.2 \times 10^7$ copies of each DNA string. Errors occur only rarely ($\sim$1 error per 500



What about maths ?

- Markov models used in DNA sequence analysis
  - Gene prediction in DNA sequences



- Models for DNA evolution

What about physics/engineering?

- Biomaterials: matter, surface, or construct that interacts with biological systems
  - Medecine: Artificial ligaments and tendons, Dental implants..

What about physics/engineering?

Thermodynamics of molecular modelling

=> computational techniques used to model or mimic the behaviour of molecules

http://cen.acs.org/articles/90/web/2012/04/Ion-Channel-Caught-Act.html

Innovation : engineering spider silk

- Protein fiber with exceptional mechanical properties,

=> absorb a lot of energy before breaking

=> able to stretch up to five times their relaxed length without breaking

- artificially synthesize spider silk into fibers
  - Genetically modified organisms (bacteria,silkworms, goat)to express spider proteins then purified

- 2013 : fibers produced by German company