COURSE TITLE: Animal Production

SECTION: Principles of Animal Nutrition

COURSE CODE: VETM1111

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Lecture 1

6. Course Objectives

List of Topics

Part 1: Principles of Animal Nutrition

- 1.1 The Animal and its Food
- 1.2 Comparison of the Digestive Systems in Farm Animals and their practical implications in the feeding of Animals and the Balancing of Rations
- 1.3 What is a Feed?
- 1.4 Components of Feeds/ Feed Nutrients
    - 1.4.1 Lipids/Fats
    - 1.4.2 Carbohydrates [Soluble (Sugars), Starches, Structural (Fibre)]
    - 1.4.3 Proteins
        - 1.4.3.1 Animal Acids
        - 1.4.3.2 True Proteins
        - 1.4.3.3 Non Protein Nitrogen
    - 1.4.4 Vitamins
        - 1.4.4.1 Fat Soluble Vitamins
        - 1.4.4.2 Water Soluble Vitamins
    - 1.4.5 Minerals
        - 1.4.5.1 Macro Minerals
        - 1.4.5.2 Micro Minerals
    - 1.4.6 Water
- 1.5 Classification of Feeds and Feedstuffs with particular reference to the Caribbean Region
- 1.6 Feed Additives
    - 1.6.1 Probiotics
    - 1.6.2 Essential Amino Acids
- 1.7 Ideal Protein Concept
- 1.8 Anti Nutritional Factors
- 1.9 What is a Ration?
- 1.10 Evaluation of Foods and Feeds:
    - 1.10.1 Chemical Composition
    - 1.10.2 Digestibility
    - 1.10.3 Energy Content
    - 1.10.4 Partitioning of Feed Energy within the Animal
    - 1.10.5 Systems of expressing the Energy Value of Feeds
    - 1.10.6 Feed Protein
- 1.11 Feed Intake
    - 1.11.1 As Fed
    - 1.11.2 Dry Matter
    - 1.11.3 Voluntary Feed Intake
- 1.12 Feeding Standards
- 1.13 Ration Formulation
    - 1.12.1 Monogastrics
    - 1.12.2 Ruminants
- 1.14 Feed Conversion Ratio
- 1.15 Feed Conversion Efficiency
- 1.16 Economics of Feeding Animals

The role of Animal Nutrition in Veterinary Medicine

- Factor affecting animal production
- Deficiencies, disorders and diseases
- Feeding management
- Public health concerns

The role of Animal Nutrition in Veterinary Medicine

- **Factors affecting Animal Production**
  - Genetics and Breeding
  - Housing and the environment
  - Nutrition and feeding
  - Health and disease
  - Socioeconomics

1.3 What is a feed ?

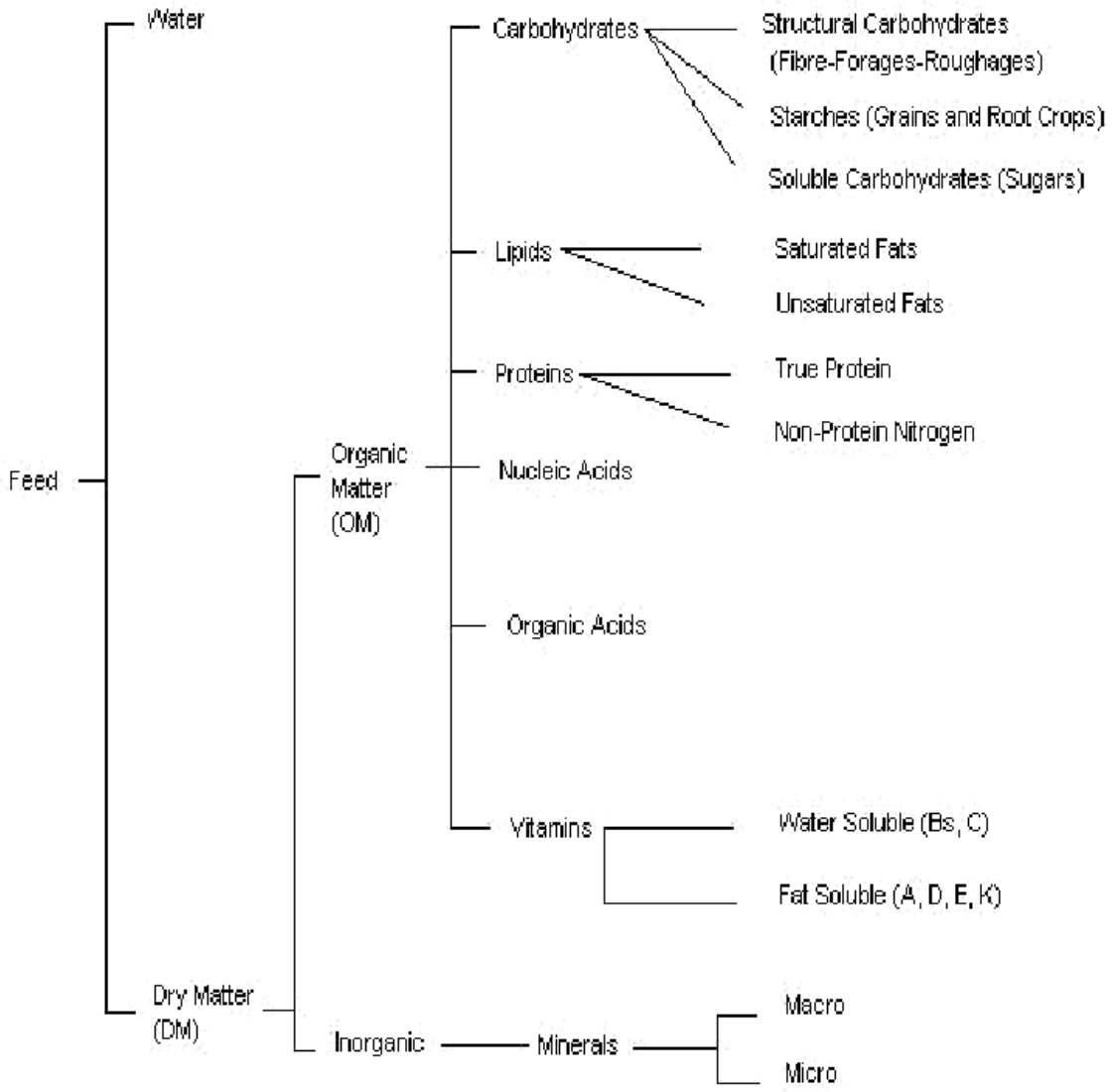
Feed

- Feeds are naturally occurring ingredients/materials fed to animals for the purpose of sustaining them.

- Feedstuff – any product, of natural or artificial origin, that has nutritional value in the ration when properly prepared

- Additives: nutritive/non-nutritive

Components of Foods/Animal Feed Ingredients (of plant and animal origin)



http://www12.brinkster.com/ostasp/courses2.aspx

1.4 Components of Feed/Nutrients

What are Nutrients?

- **A nutrient is any food constituent that functions in support of life.**
  - maintenance & production, reproduction
  - structural/cellular components
  - regulation of body processes and accessory functions: growth, reproduction, lactation etc.

Nutrition

- the various chemical and physiological reactions which change feed elements in body elements

- the process by which living organisms obtain food and use it for growth, metabolism, and repair. The stages of nutrition include ingestion, digestion, absorption, transport, assimilation, and excretion.

Classes of Nutrients

- WATER
- CARBOHYDRATES
- FATS
- PROTEINS
- MINERALS
- VITAMINS

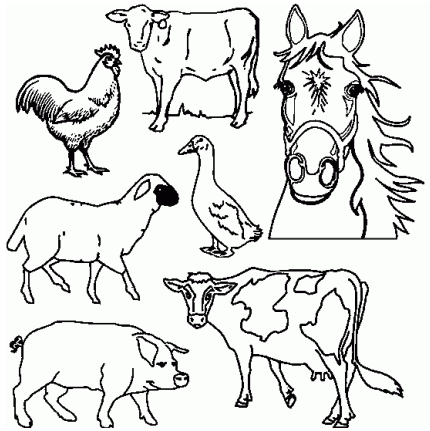
Nutrition – what concerns us ?

- Function of nutrients (biochemistry)
  - *water*
  - carbohydrates
  - lipids
  - proteins
  - minerals
  - Vitamins
- sources
- digestion
- processing/usage (physiology)
- pathologies

A central theme

Biological

- Genetics and Breeding
- Nutrition and feeding
- Health and disease
- Housing and the environment
- Socioeconomics









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Water

Water

- a solvent – for transport of other nutrients and waste products through the body
- temperature regulation; high latent heat of evaporation
- gives body shape or form
- biochemical reactions
- factors affect water intake??

Water

- embryo-90%; newborn-70% and adult-50%
- newborn:750 - 800 g water/kg body wt.
- adult: 500 g water/kg body wt.
- vital to the life of an organism and the water level in the body must be maintained.
- clean fresh water is essential for all animals

Water - Sources

- the animal obtains its water from three (3) sources:

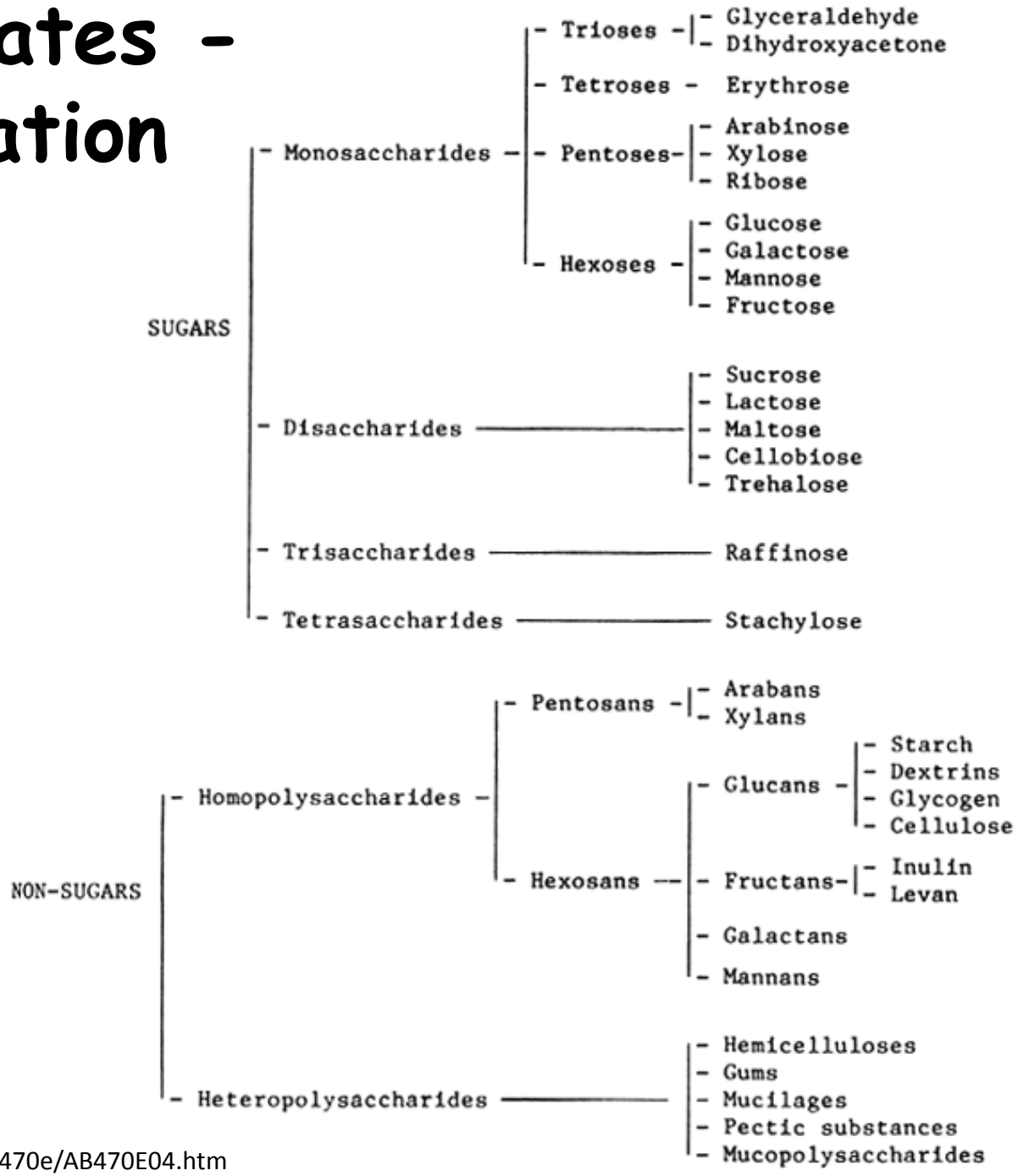
  - drinking

  - food

  - metabolic water (metabolism: oxidation of hydrogen-containing organic nutrients).
- content in food: 60 g/kg in fresh material concentrates to > 900 g/kg in some root crops.
- Animals normally drink what they require.

Carbohydrates

Carbohydrates - classification

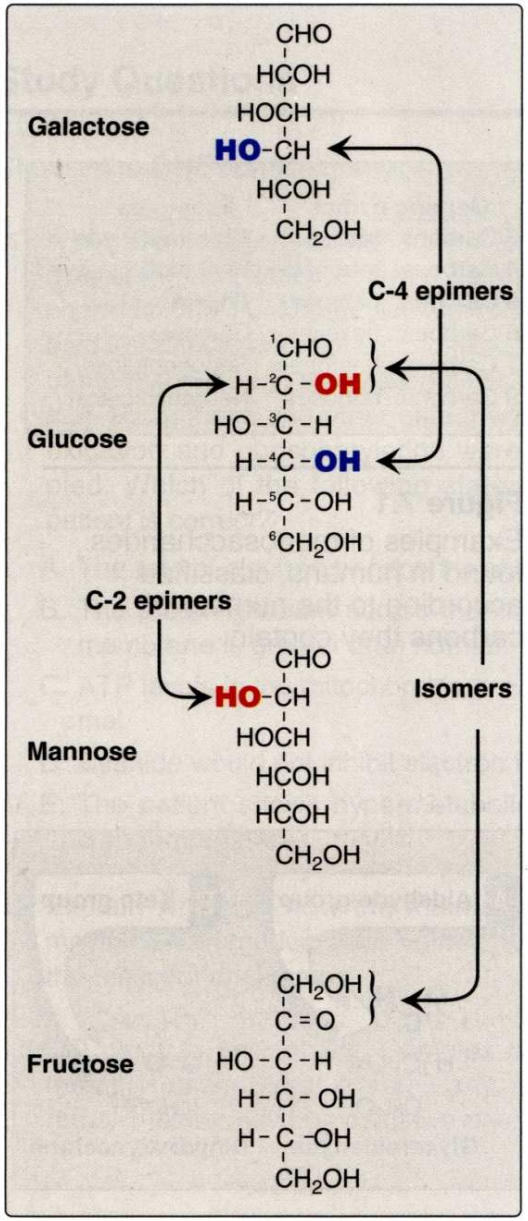


http://www.fao.org/docrep/field/003/ab470e/AB470E04.htm

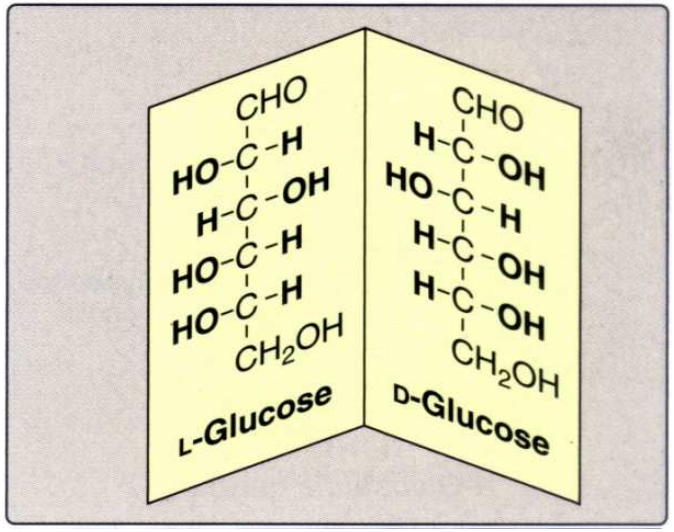
Carbohydrates - classification

- Monosaccharides – simple sugars
  glucose, fructose & galactose
- Oligosaccarides
  Disaccharides - sucrose, maltose & lactose
- Polysaccharides - starch, glycogen,
  hemicellulose & sellulose
- Complex – attached to protein, lipids, rings,
  purines and pyrimidines

Carbohydrates - structure



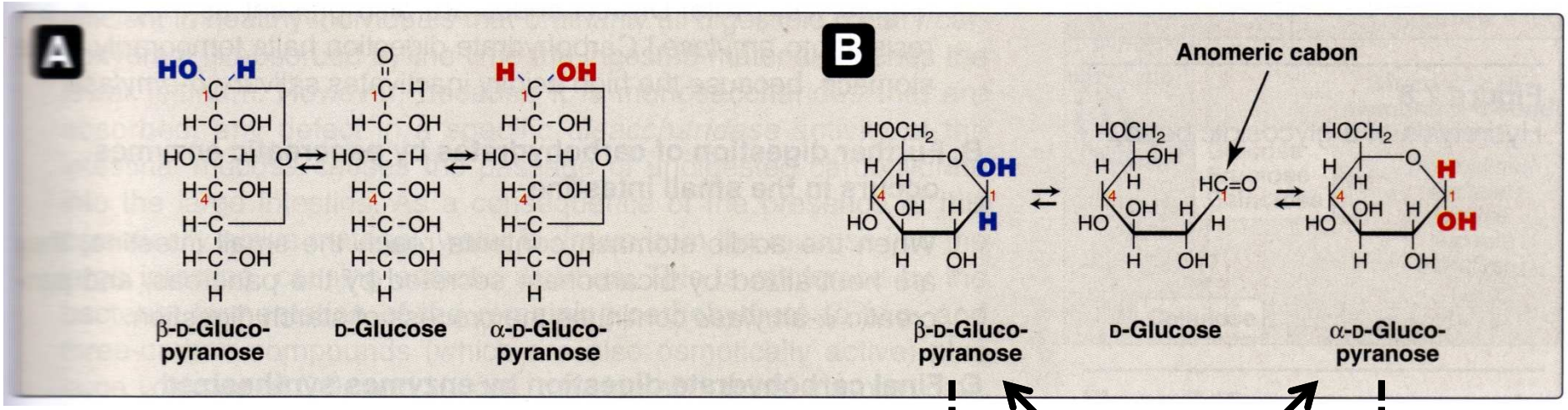
- Isomers – same chemical formulas but different structures
- Epimers – carbohydrate isomers that differ in configuration around only one specific C atom



- Enantiomers – pairs of structures that are mirror images of one another

Harvey R and Ferrier D. 2011. Lippincott's Illustrated Reviews-Biochemistry, 5th ed. LW&W, PA, USA

Carbohydrates - cyclization



Anomers

cellulose

glycogen

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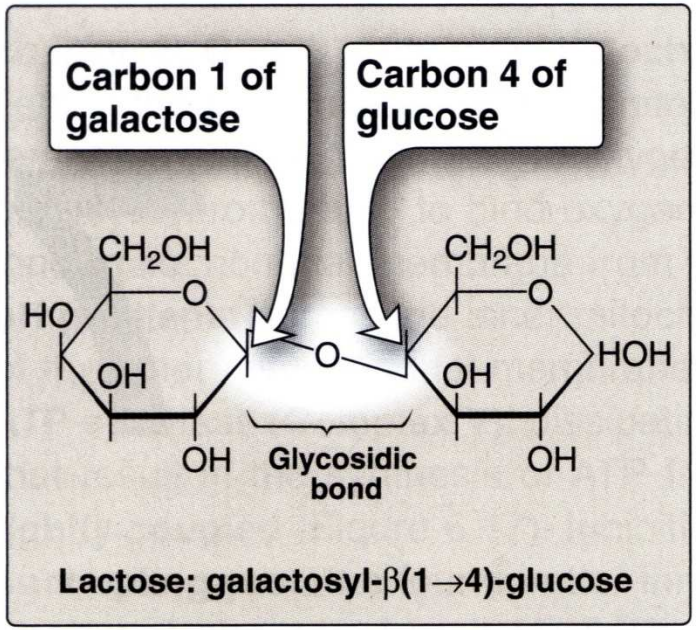
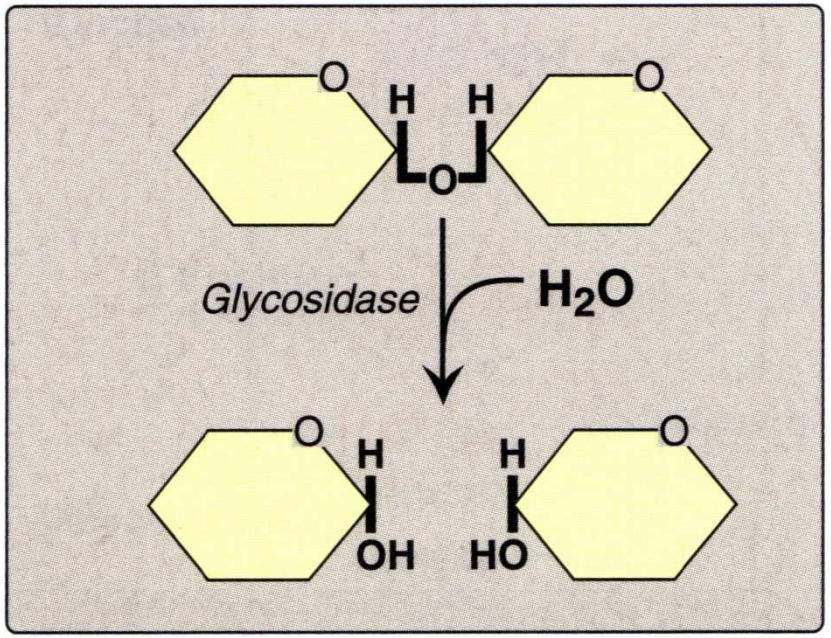
Carbohydrates – glycosidic bonds



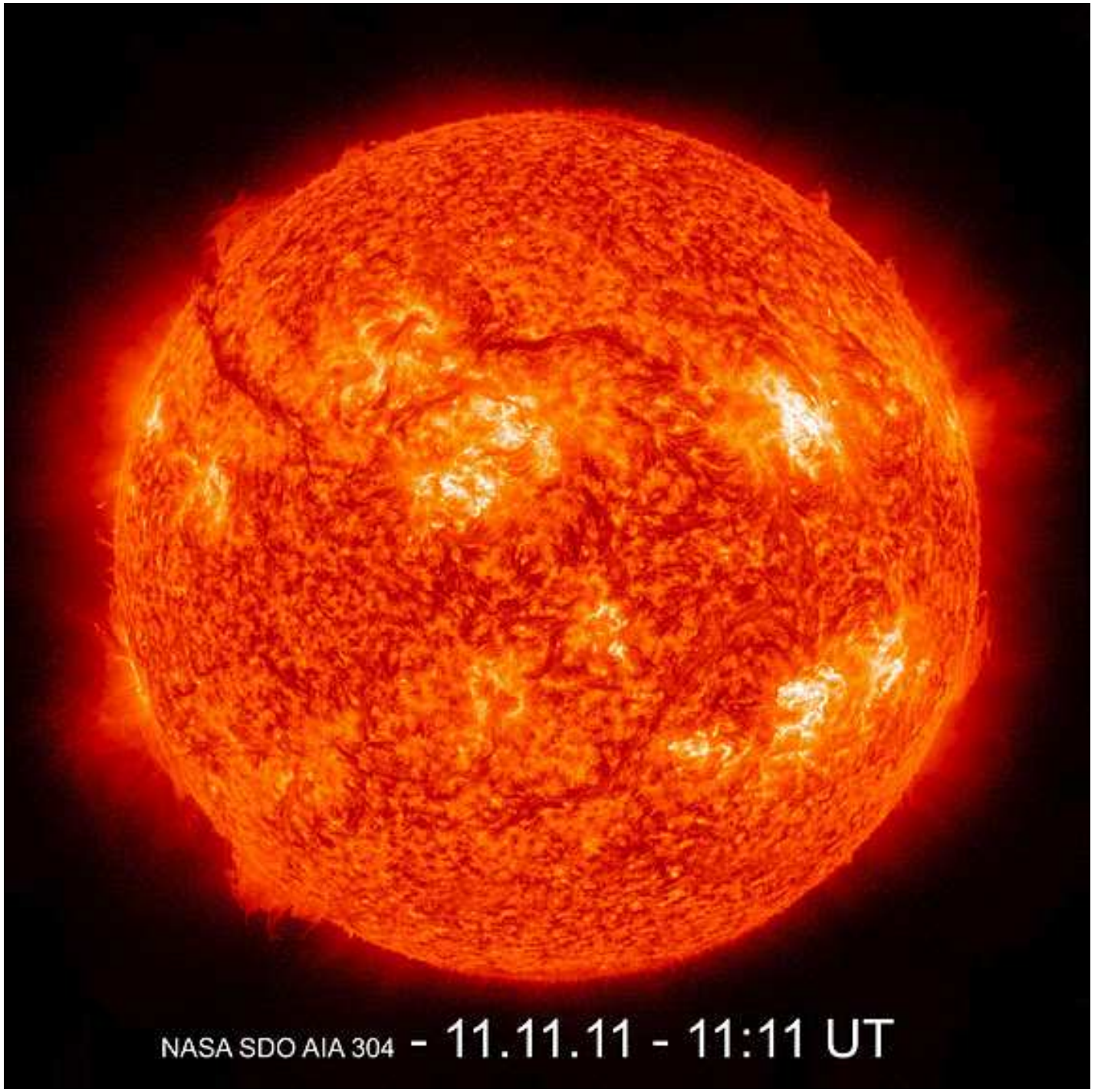


Catalysed by glucosyltransferases

Harvey R and Ferrier D. 2011. Lippincott's Illustrated Reviews-Biochemistry, 5th ed. LW&W, PA, USA

Carbohydrates

- Lactose: galactose + glucose
- Sucrose: fructose + glucose
- Maltose: glucose + glucose
- Polymers of glucose:
  - glycogen
  - starch
  - cellulose: $\beta(1\rightarrow4)$ glycosidic bonds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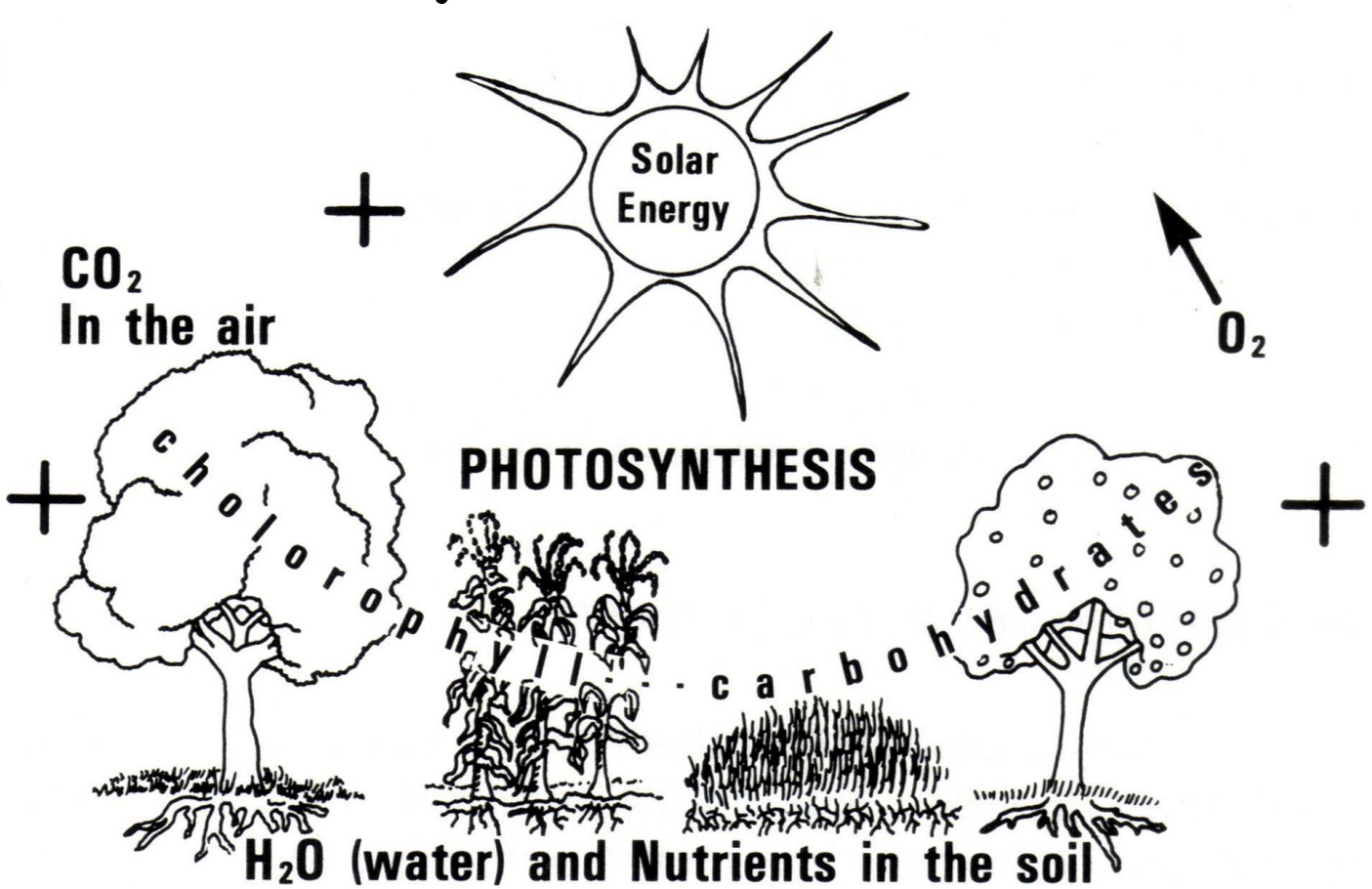
Carbohydrates - Sources



TREE, LEAVES WOOD, BARK	GRAIN	FORAGE	FRUIT
containing	containing	containing	containing
cellulose	starch	starch	starch
hemicellulose	cellulose	sugar	suger
sugar (maple)		cellulose	cellulose

Ensminger ME, Oldfield JE, Heinemann WW. 1990. Feeds and Nutrition. The Ensminger Publ. Com. CA, US

Carbohydrates

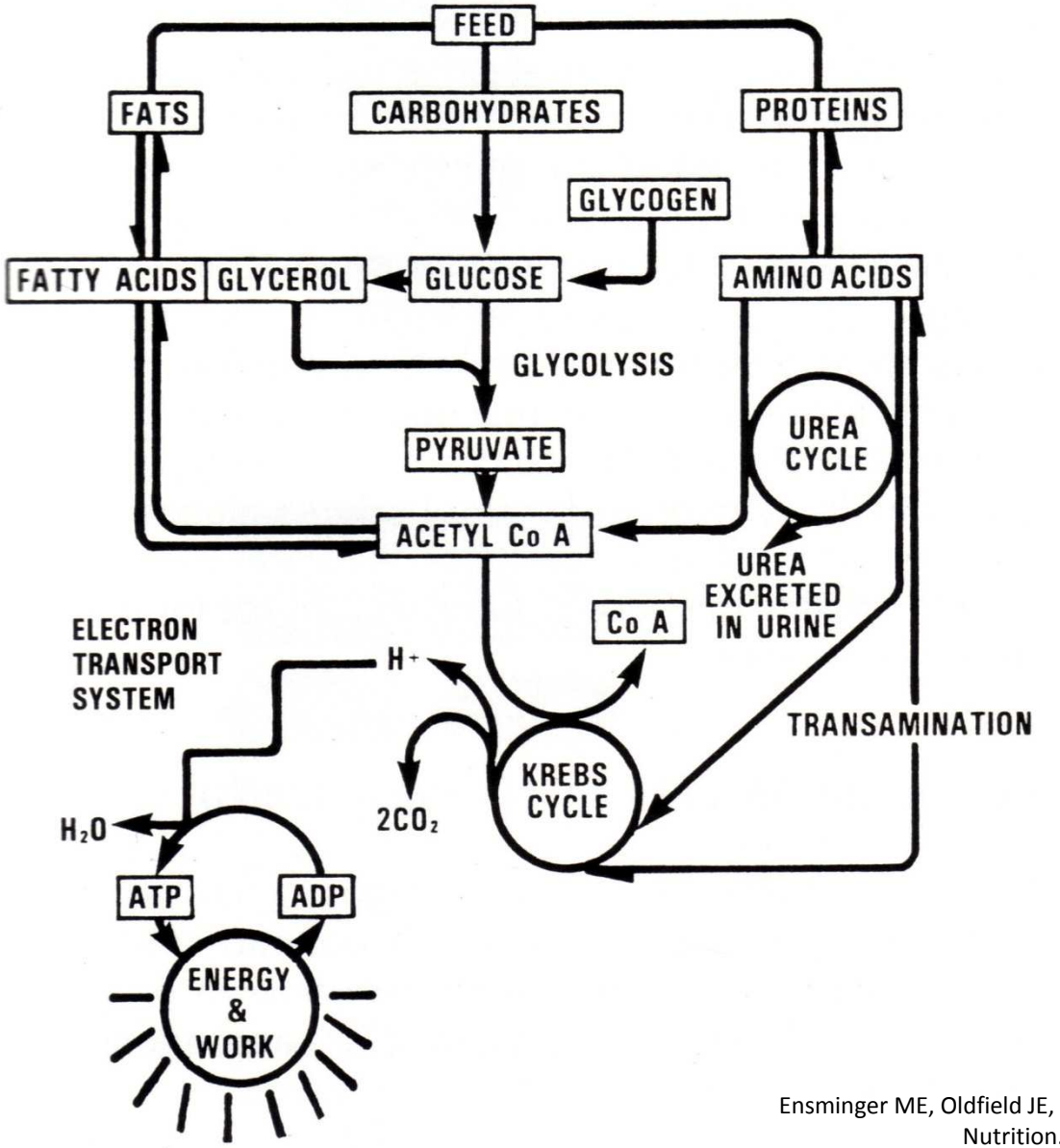
photosynthesis

$$6CO_2 + 6H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Carbohydrates – energy production



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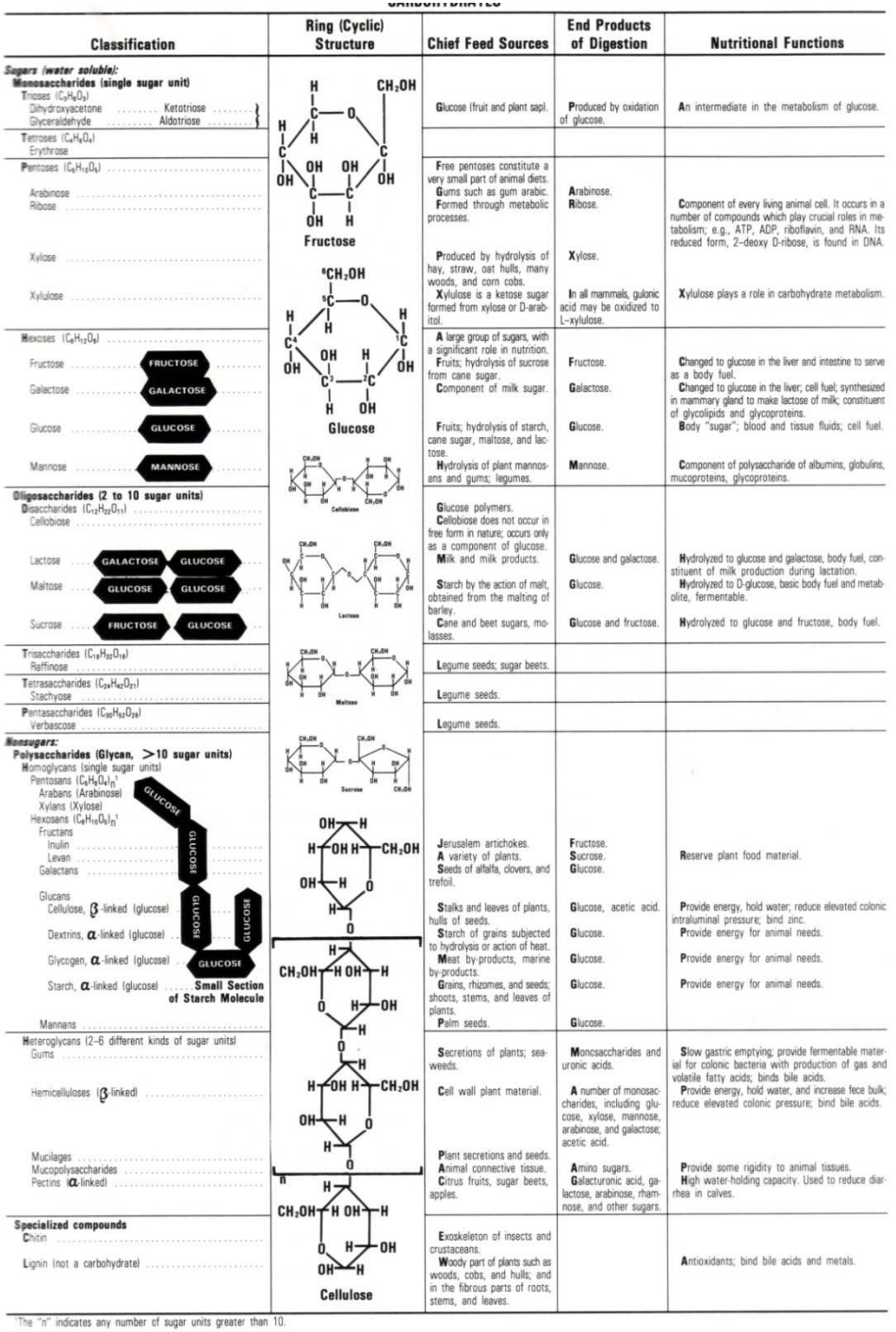
Carbohydrates - Sources



Classification	Ring (Cyclic) Structure	Chief Feed Sources	End Products of Digestion	Nutritional Functions
Sugars (water soluble):				
Monosaccharides (single sugar unit)				
Trioses ($C_3H_6O_3$)				
Dihydroxyacetone ..... Ketotriose				
Glyceraldehyde ..... Aldotriose		Glucose (fruit and plant sapl.	Produced by oxidation of glucose.	An intermediate in the metabolism of glucose.
Tetroses ($C_4H_8O_4$)				
Erythrose				
Pentoses ($C_5H_{10}O_5$)		Free pentoses constitute a very small part of animal diets.		
Arabinose		Gums such as gum arabic.	Arabinose.	
Ribose		Formed through metabolic processes.	Ribose.	Component of every living animal cell. It occurs in a number of compounds which play crucial roles in metabolism; e.g., ATP, ADP, riboflavin, and RNA. Its reduced form, 2-deoxy D-ribose, is found in DNA.
	Fructose			
Xylose		Produced by hydrolysis of hay, straw, oat hulls, many woods, and corn cobs.	Xylose.	
Xylulose		Xylulose is a ketose sugar formed from xylose or D-arabitol.	In all mammals, guloric acid may be oxidized to L-xylulose.	Xylulose plays a role in carbohydrate metabolism.
Hexoses ($C_6H_{12}O_6$)		A large group of sugars, with a significant role in nutrition.		
Fructose ..... FRUCTOSE		Fruits; hydrolysis of sucrose from cane sugar.	Fructose.	Changed to glucose in the liver and intestine to serve as a body fuel.
Galactose ..... GALACTOSE		Component of milk sugar.	Galactose.	Changed to glucose in the liver; cell fuel; synthesized in mammary gland to make lactose of milk; constituent of glycolipids and glycoproteins.
Glucose ..... GLUCOSE	Glucose	Fruits; hydrolysis of starch, cane sugar, maltose, and lactose.	Glucose.	Body "sugar"; blood and tissue fluids; cell fuel.
Mannose ..... MANNOSE		Hydrolysis of plant mannosans and gums; legumes.	Mannose.	Component of polysaccharide of albumins, globulins, mucoproteins, glycoproteins.
Oligosaccharides (2 to 10 sugar units)				
Disaccharides ($C_{12}H_{22}O_{11}$)		Glucose polymers.		
Cellobiose		Cellobiose does not occur in free form in nature; occurs only as a component of glucose.		
Lactose ..... GALACTOSE GLUCOSE		Milk and milk products.	Glucose and galactose.	Hydrolyzed to glucose and galactose, body fuel, constituent of milk production during lactation.
Maltose ..... GLUCOSE GLUCOSE		Starch by the action of malt, obtained from the malting of barley.	Glucose.	Hydrolyzed to D-glucose, basic body fuel and metabolite, fermentable.
Sucrose ..... FRUCTOSE GLUCOSE		Cane and beet sugars, molasses.	Glucose and fructose.	Hydrolyzed to glucose and fructose, body fuel.
Trisaccharides ($C_{18}H_{32}O_{16}$)				
Raffinose		Legume seeds; sugar beets.		
Tetrasaccharides ($C_{24}H_{42}O_{21}$)				
Stachyose		Legume seeds.		
Pentasaccharides ($C_{30}H_{52}O_{26}$)				
Verbascose		Legume seeds.		
Nonsugars:				
Polysaccharides (Glycan, >10 sugar units)				
Homoglycans (single sugar units)				
Pentosans ($C_5H_8O_4)_n$[1]				
Arabans (Arabinose)				
Xylans (Xylose)				
Hexosans ($C_6H_{10}O_5)_n$[1]				
Fructans				
Inulin		Jerusalem artichokes.	Fructose.	
Levan		A variety of plants.	Sucrose.	
Galactans		Seeds of alfalfa, clovers, and trefoil.	Glucose.	Reserve plant food material.
Glucans				
Cellulose, β-linked (glucose)		Stalks and leaves of plants, hulls of seeds.	Glucose, acetic acid.	Provide energy, hold water; reduce elevated colonic intraluminal pressure; bind zinc.
Dextrins, α-linked (glucose)		Starch of grains subjected to hydrolysis or action of heat.	Glucose.	Provide energy for animal needs.
Glycogen, α-linked (glucose)		Meat by-products, marine by-products.	Glucose.	Provide energy for animal needs.
Starch, α-linked (glucose) ..... Small Section of Starch Molecule		Grains, rhizomes, and seeds; shoots, stems, and leaves of plants.	Glucose.	Provide energy for animal needs.
Mannans		Palm seeds.	Glucose.	
Heteroglycans (2–6 different kinds of sugar units)				
Gums		Secretions of plants; seaweeds.	Monosaccharides and uronic acids.	Slow gastric emptying; provide fermentable material for colonic bacteria with production of gas and volatile fatty acids; binds bile acids.
Hemicelluloses (β-linked)		Cell wall plant material.	A number of monosaccharides, including glucose, xylose, mannose, arabinose, and galactose; acetic acid.	Provide energy, hold water, and increase fece bulk; reduce elevated colonic pressure; bind bile acids.
Mucilages		Plant secretions and seeds.		
Mucopolysaccharides		Animal connective tissue.	Amino sugars.	Provide some rigidity to animal tissues.
Pectins (α-linked)		Citrus fruits, sugar beets, apples.	Galacturonic acid, galactose, arabinose, rhamnose, and other sugars.	High water-holding capacity. Used to reduce diarrhea in calves.
Specialized compounds				
Chitin		Exoskeleton of insects and crustaceans.		
Lignin (not a carbohydrate)		Woody part of plants such as woods, cobs, and hulls; and in the fibrous parts of roots, stems, and leaves.		Antioxidants; bind bile acids and metals.
	Cellulose			

[1]The "n" indicates any number of sugar units greater than 10.

Ensminger ME, Oldfield JE, Heinemann WW. 1990. Feeds and Nutrition. The Ensminger Publ. Com. CA, US

Proteins

Proteins - biological role

Structure: Membranes, muscle, connective tissues, organs

Enzymes: catalyses numerous reactions

Hormones: regulate metabolic processes

Transport: carriers for various substances

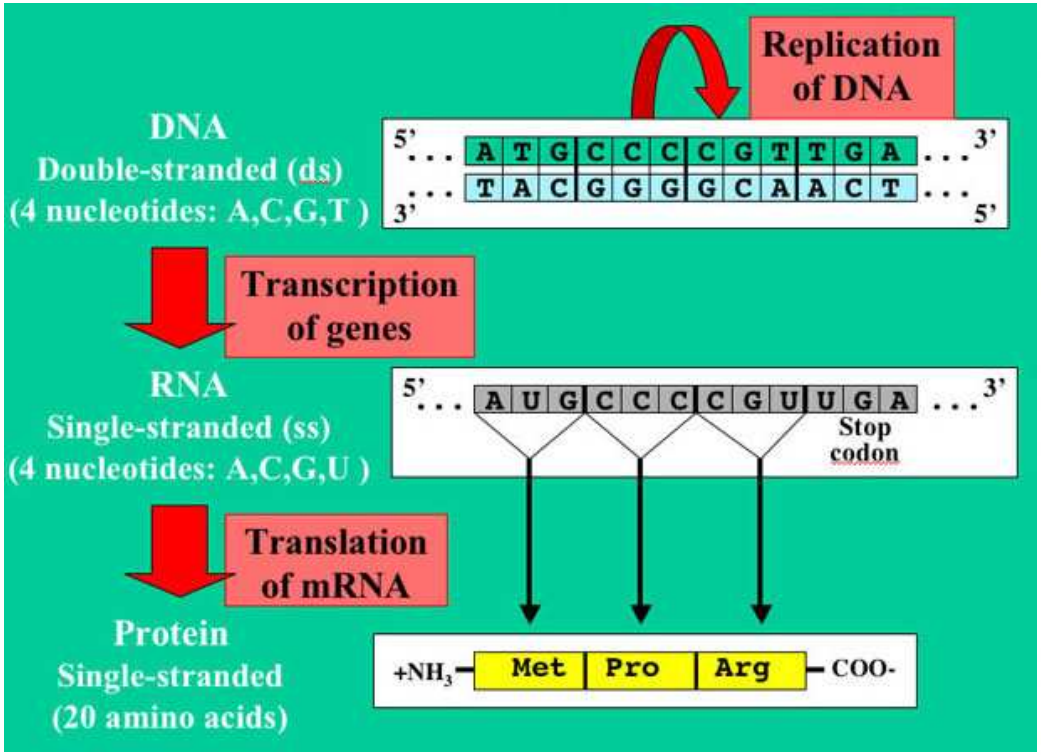
Receptors and transmission: transmission of compound across membranes; transductions of signals intracellularly

Storage: in different tissues

Buffers: maintains cellular pH

Proteins

- long chain of amino acids
- average 16% N (100/16 = 6.25)
- >300 amino acids described in nature; only 20 found in mammalian proteins; these are coded for by DNA
- plants synthesize amino acids
- rumen microorganisms can synthesize amino acids and protein



Biological information flow (serc.carleton.edu)

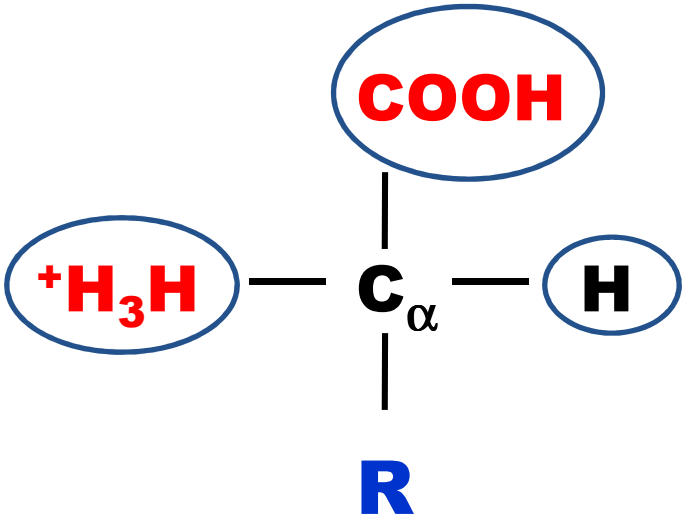
First Base	Second Base				Third Base
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	**stop**	**stop**	A
	leucine	serine	**stop**	**tryptophan**	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	(start) methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

The genetic code has 61 amino acid coding nucleotide triplets and three stop codons
(Barnum SR, 2005)

α-amino acids

The α-carbon atom is attached to four different chemical groups; it is a chiral or optically active carbon atom

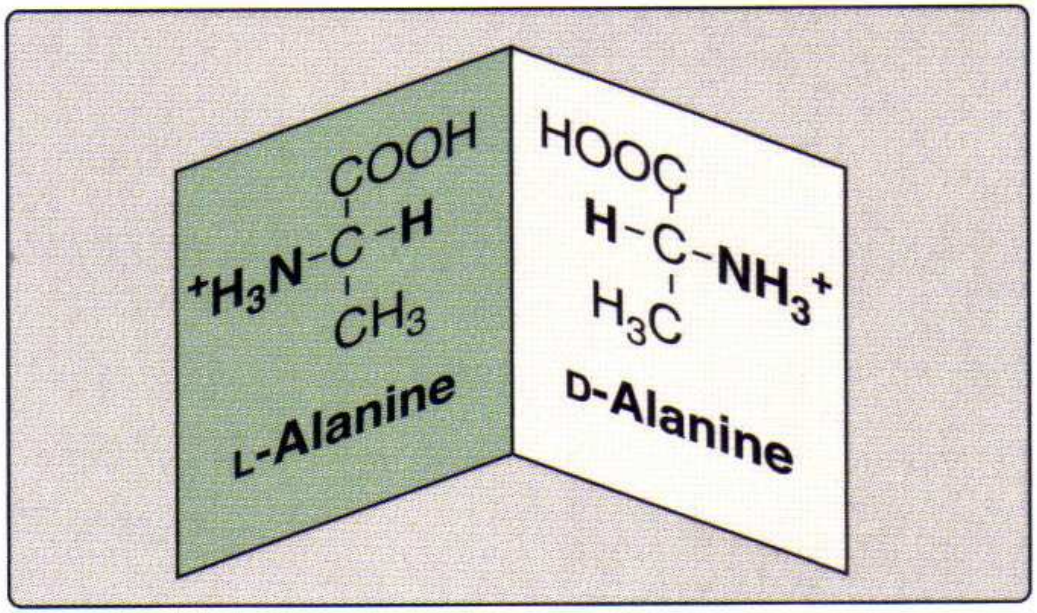
Each amino acid consists of:
An chiral carbon atom (α-carbon)
An amino group (-NH_2)
A carboxyl group (-COOH)
A distinctive side chain (R group)



Stereoisomers

α-amino acids can exist in the D or L form; mirror images of each other

All amino acids in proteins are of the L-configuration



D and L forms of alanine are mirror images

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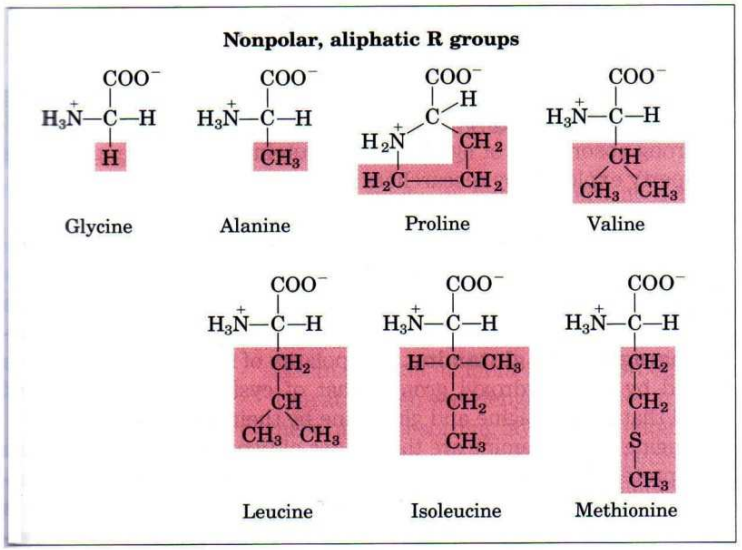
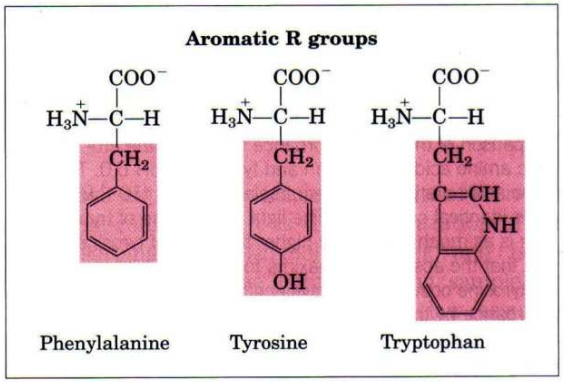
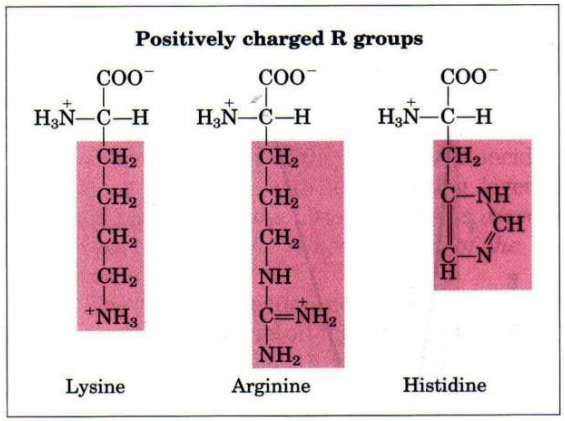
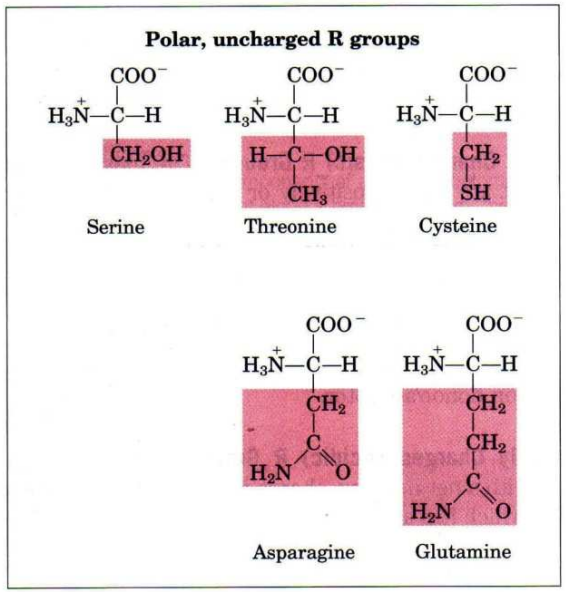
Non polar side chains

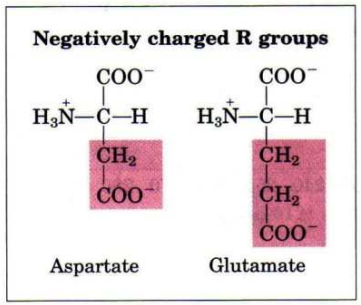






Basic
- side chain is protonated and generally has a +ve charge at pH 7.4



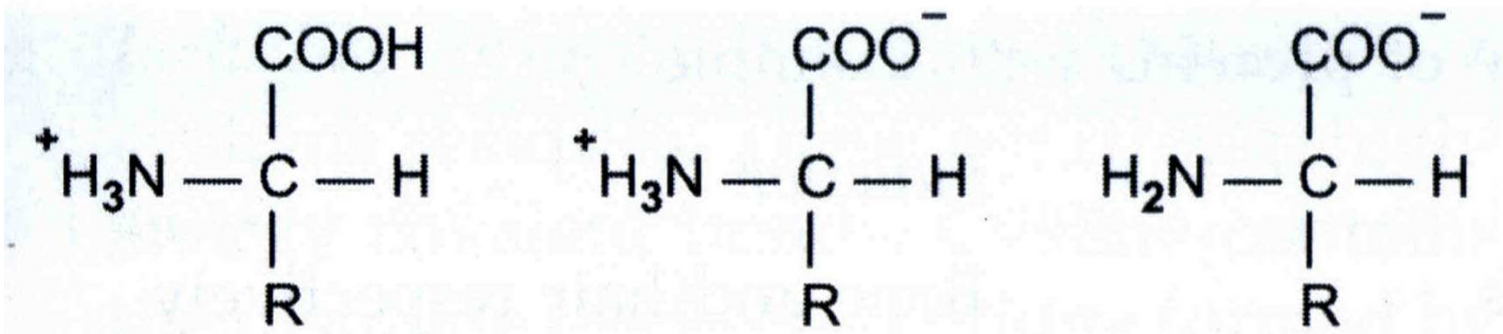


Acidic
- side chain dissociates to –COO at pH 7.4

20 standard amino acids

Adapted from :Nelson DL and Cox MM. 2008.Lehninger Principles of Biochemistry. Worth

Charge properties of amino acids



1. Cation form at acidic pH,

2. Zwitterion form at isoelectric pH,

3. Anionic form at basic pH

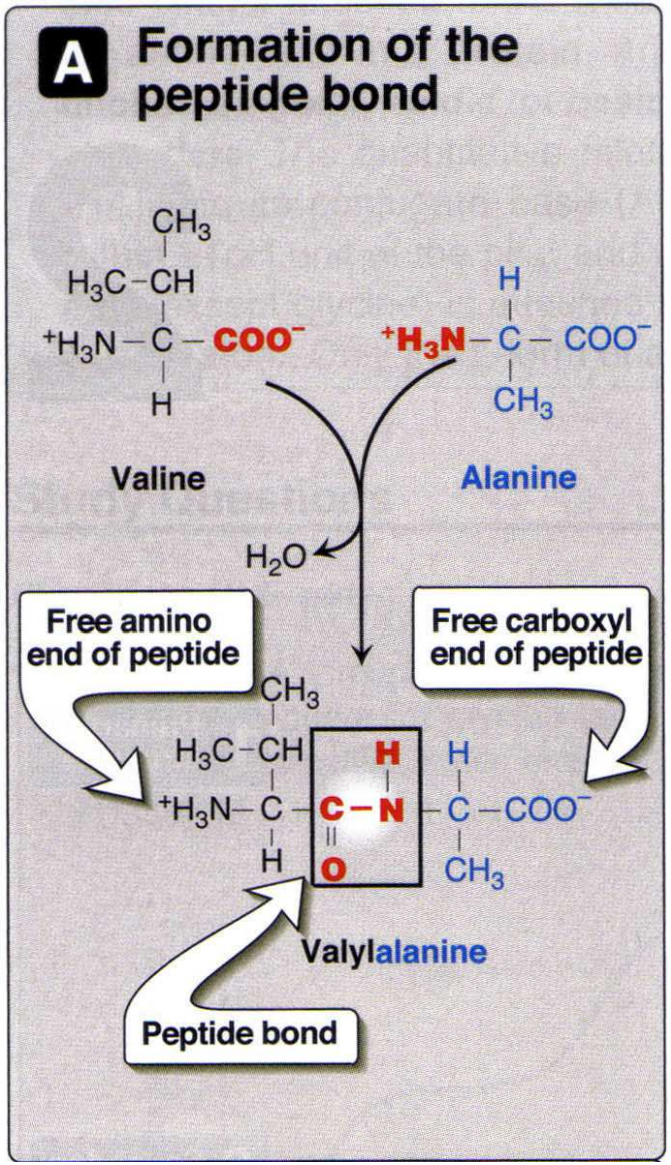
-NH_2 behaves as a base

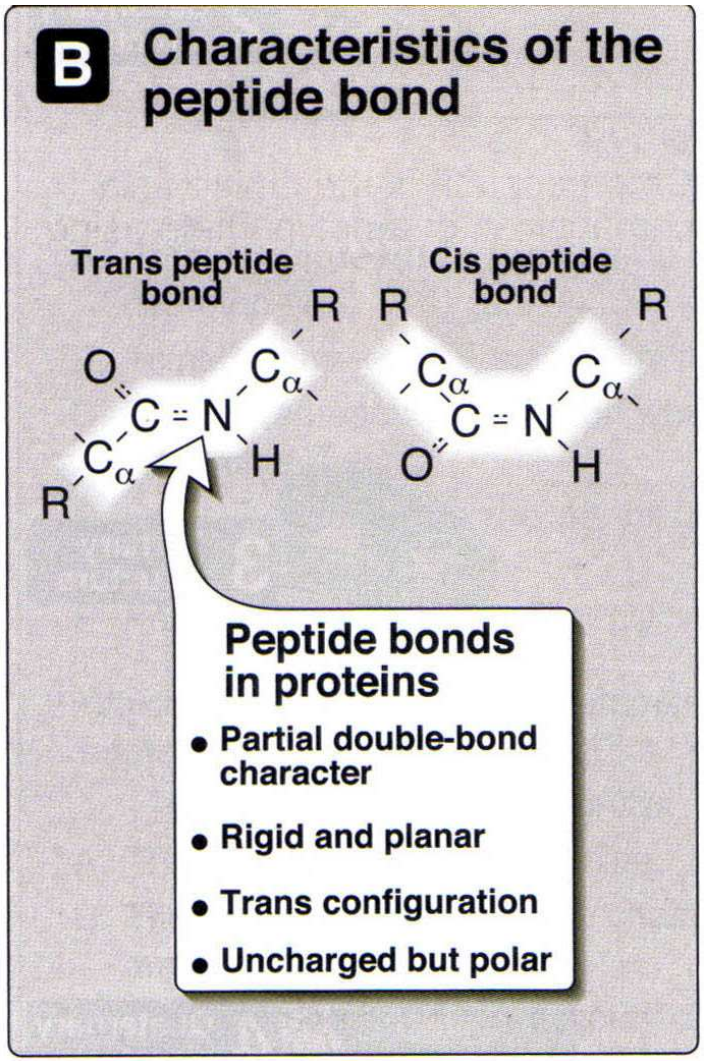
- COOH behaves as a proton donor

The amphoteric nature of amino acids; dipolar or Zwitterion
Isoelectric pH, where the net charge is zero

(Nayak S, 2010)

The Peptide Bond





Harvey R and Ferrier D. 2011. Lippincott's Illustrated Reviews-Biochemistry, 5th ed. LW&W, PA, USA

The four orders of protein structure

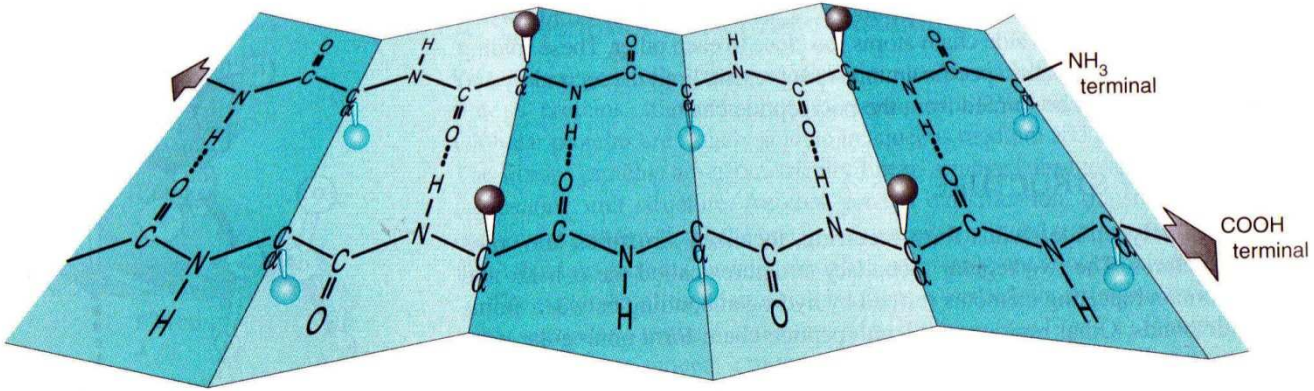
Primary structure: the sequence of the amino acids in a polypeptide chain

Secondary structure: the folding of short (3- to 30-residue), contiguous segments of polypeptide into geometrically ordered units

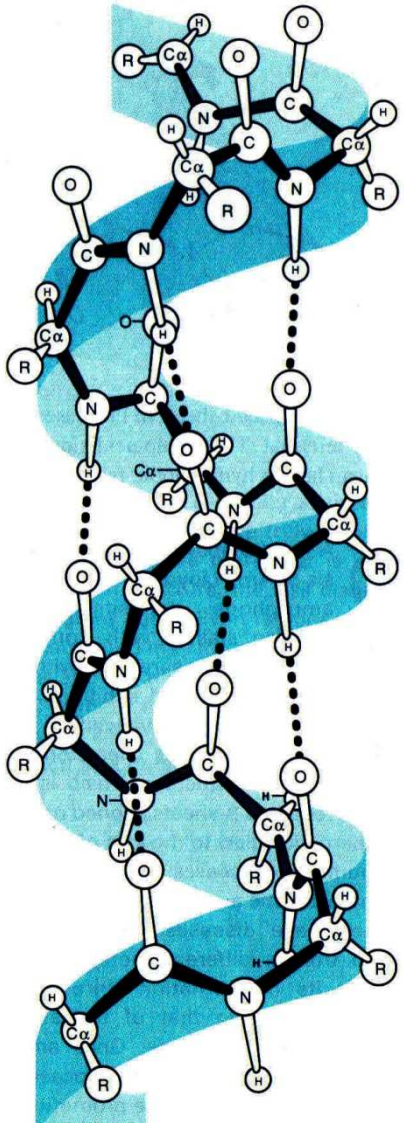
Tertiary structure: the three-dimensional assembly of secondary structural units to form larger functional units such as the mature polypeptide and its component domains

Quaternary structure: the number and types of polypeptide units of oligomeric proteins and their spatial arrangement.

Secondary structure



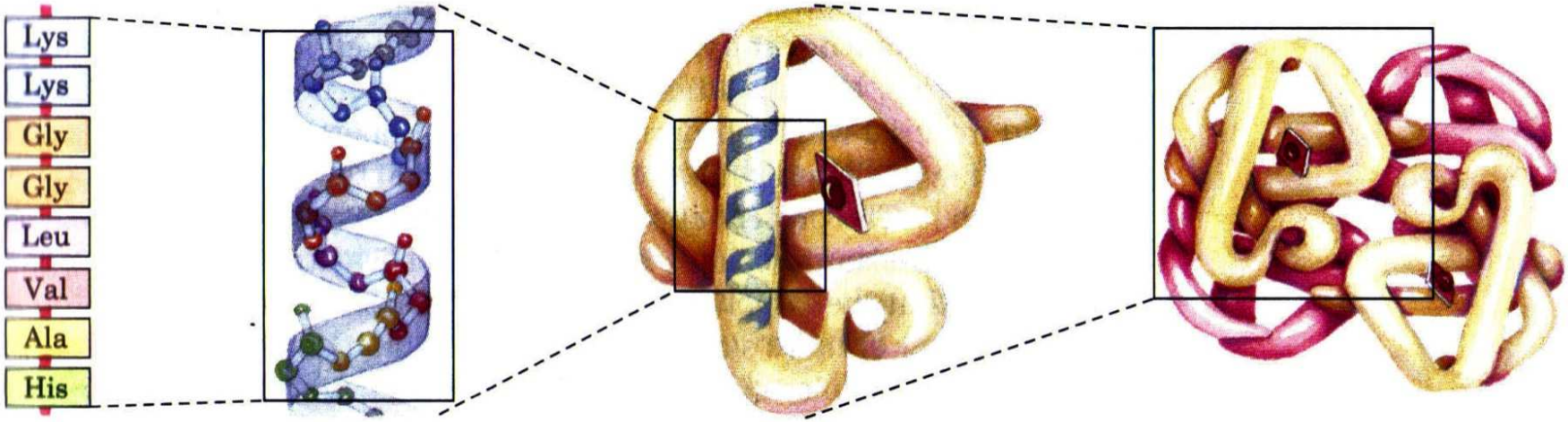
A β-pleated sheet



An α-helix

Smith C, Marks AD, Lieberman M. 2005. Marks Basic Medical Biochemistry, A clinical Approach. LW&W, USA

The four orders of protein structure



Primary Secondary Tertiary Quaternary

Levels of structure in proteins

Adapted from :Nelson DL and Cox MM. 2008.Lehninger Principles of Biochemistry. Worth Publishers, NY, USA)

Peptides

Dipeptide:
Anserine - found in skeletal muscle; activates myosin ATPase activity
Aspartame – L-aspartylphenylalanyl methyl ester; artificial sweetener, Nutra Sweet

Pentapeptide:
Enkephalins – a hypothamic hormone

Nonapeptides:
Oxytocin and vasopressin

Tripeptide:
Glutathione – glutamic acid, cysteine and glycine; in RBCs; redox reactions, decopmposed H_2O_2 and maintains cells integrity; keeps hemoglobin in a reduced state
Thyrotropin – a hypothalamic hormone

Forces controlling protein structure

Hydrogen bonding: within polypeptide chains and with the surrounding medium

Hydrophobic : hydrophobic R-groups drive their amino acids into the interior of protein; this restricts the available conformations into which a protein may fold

Electrostatic : Charge-charge (oppositely charged R-groups), charge-dipole (ionised R-groups and water), and dipole-dipole (between polar R-groups);

Van der Waals : attraction or repulsion between uncharged non-bonded atoms;

Disulphide bridges : oxidation of two cysteine residues (-S-S-); strong high energy covalent bonds

Classification of proteins

Based on solubility

Table 4.3: Proteins of different soluble property

Class	*Soluble in*	*Example*
Albumins	Water	Serum albumin, egg albumin
Globulins	Dilute salt solutions	Serum globulins
Histones (Basic proteins)	Dilute acids	Nucleoproteins, histones
Scleroproteins	Insoluble in H_2O	Collagen, elastin

Based on shape

- Gobular (compactly folded and coiled)
- Fibrous (elongated)
- DNA-binding
- Transmembrane

Based on composition

- Simple
- Conjugated proteins
- Derived proteins

Table 4.4: Different conjugated proteins

Example for conjugated proteins	*Nonprotein part present + protein*
1. Hemoglobin (Hb)	Heme + globin
2. Nucleoprotein	DNA + histone
3. Lipoprotein	Lipids + apolipoprotein
4. Phosphoprotein (Casein)	Phosphate + protein
5. Glycoprotein (egg albumin)	Carbohydrate + protein
6. Rhodopsin	11-cis retinal + opsin (protein)
7. Ferritin	Iron + apoferritin

(Nayak S, 2010)

Essential and Nonessential Amino Acids

Our cells can synthesize them

Nonessential	Essential
Alanine	Arginine*
Asparagine	Histidine
Aspartate	Isoleucine
Cysteine	Leucine
Glutamate	Lysine
Glutamine	Methionine*

Our cells cannot synthesize them

(Nayak S, 2010)

Proteins- Sources

TABLE 4–5
CLASSIFICATION OF SOME COMMON PROTEINS

Type	Chemical Properties	General Comments
Simple proteins:		
Albuminoids (scleroproteins)	Insoluble in water; highly resistant to enzymatic digestion; some become gelatinous upon boiling in water or dilute acids or bases.	Includes collagen, elastin, and keratin; common in supporting tissues; sometimes referred to as fibrous protein.
Albumins	Readily soluble in water; coagulate upon heating.	Present in egg, milk, and serum.
Globulins	Low solubility in water; solubility increases with the addition of neutral salts; coagulates upon heating.	Abundant in nature; examples are serum globulins, muscle globulins, and numerous plant globulins.
Glutelins	Insoluble in water; soluble in dilute acids or bases.	Abundant in cereal grains; an example is wheat gluten.
Prolamins	Insoluble in water, absolute alcohol, or neutral solvents; soluble in 80% ethanol.	Zein in corn and gliadin in wheat are prolamins.
Conjugated proteins:		
Chromoproteins	Combination of a protein and a pigmented (colored) substance.	Common example is hemoglobin—hematin and protein.
Lecithoproteins	Combination of protein and lecithin.	Found in fiber of clotted blood and vitellin of egg.
Lipoproteins	Water-soluble combination of fat and protein.	A vehicle for the transport of fat in the blood; all contain triglycerides, cholesterol, and phospholipids in varying proportions.
Metalloproteins	Proteins that are complexed with metals.	One example is transferrin, a metalloprotein that can bind with copper, iron, and zinc. Various enzymes contain minerals.
Mucoproteins or glycoproteins	Contain carbohydrates such as mannose and galactose.	Examples are mucin from the mucous secretions which act as protectants and lubricants in many parts of the body.
Nucleoproteins	Combination of proteins and nucleic acids.	Present in germs of seeds and glandular tissue.
Phosphoproteins	Compounds containing protein and phosphorus in a form other than phospholipid or nucleic acid.	Casein in milk and ovovitellin in eggs, are examples.

Lipids

Lipids

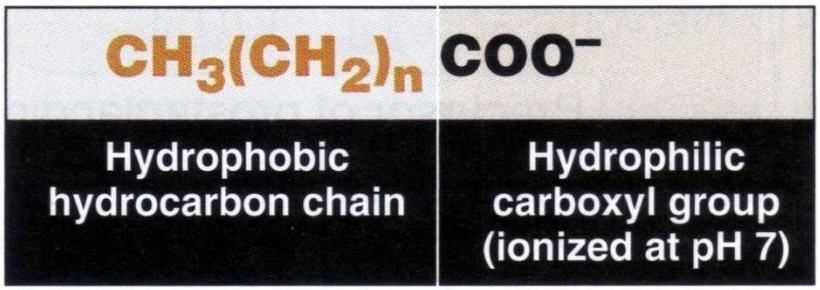
- Biomolecules
- Amphipathic (polar and nonpolar)
- Low solubility in water; high solubility on non polar solvents
- highly reduced forms of carbon; yield large amount of energy upon oxidation in metabolism;

Lipids are fatty acids and their derivatives, and substances related biosynthetically or functionally to these compounds.
(http://lipidlibrary.aocs.org/index.html)

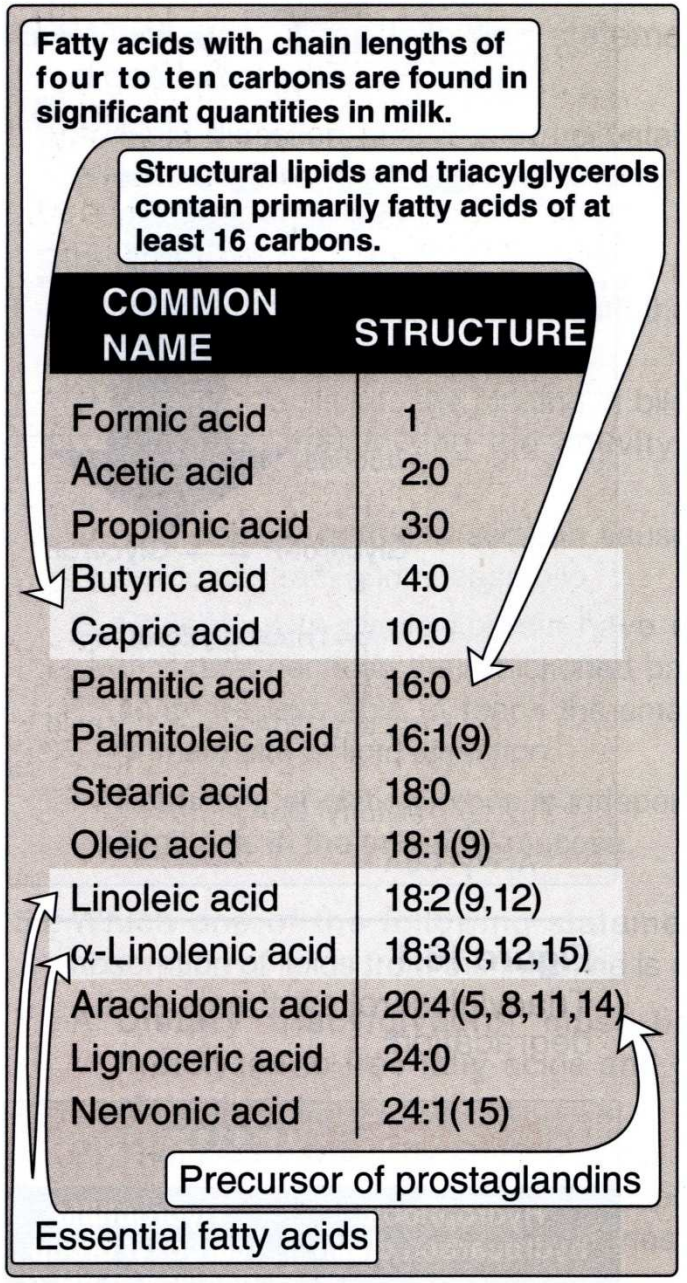
Biological Functions of Lipids

- Structural elements (phospholipids, cholesterol)
- Energy storage (fatty acids, triacylglycerols)
- Hormones (estrogen, testosterone)
- Enzyme cofactors (coenzyme A)
- Electron carriers (coenzyme Q)
- Light-absorbing pigments (carotenoids)
- Emulsifying agents (bile salts)
- Intracellular messengers (phosphatidyl inositol)

Fatty acids



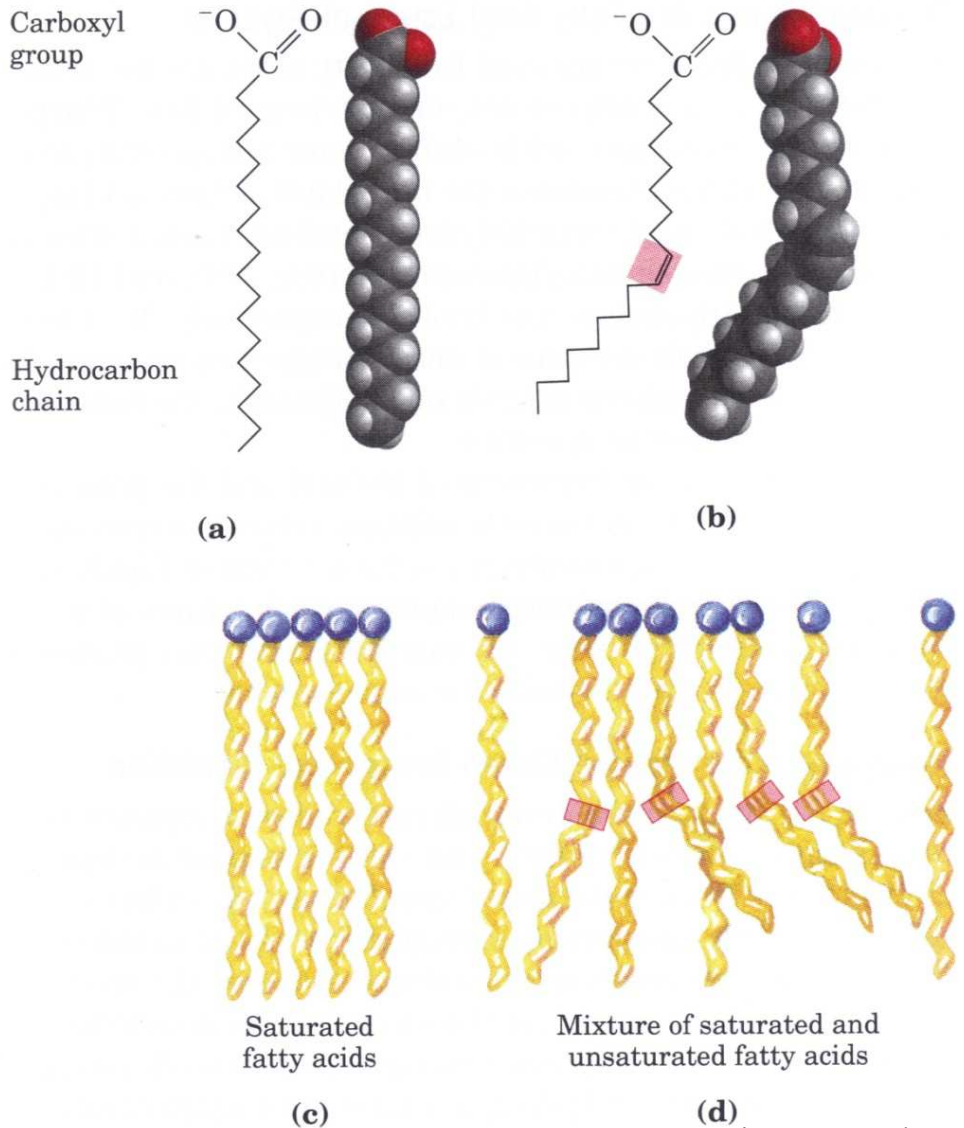
Structure of a fatty acid



Some fatty acids of physiological importance

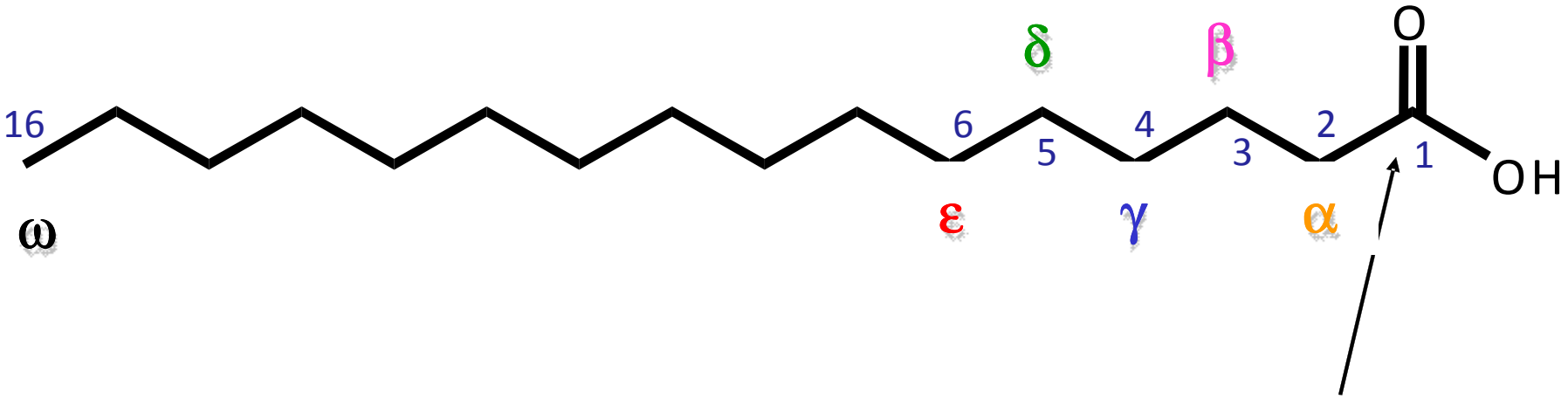
Harvey R and Ferrier D. 2011. Lippincott's Illustrated Reviews-Biochemistry, 5th ed. LW&W, PA, USA

Fatty acids - saturation



Nelson DL and Cox MM. 2008.Lehninger Principles of Biochemistry. Worth Publishers, NY, USA

Palmitic Acid

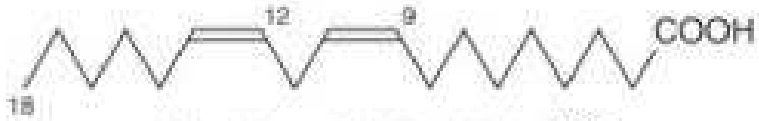


ω	omega, always the last alkyl carbon
ε	epsilon, fifth carbon after the carbonyl
δ	delta, fourth carbon after the carbonyl
γ	gamma, third carbon after the carbonyl
β	beta, second carbon after the carbonyl
α	alpha, first carbon after the carbonyl

Fatty acids

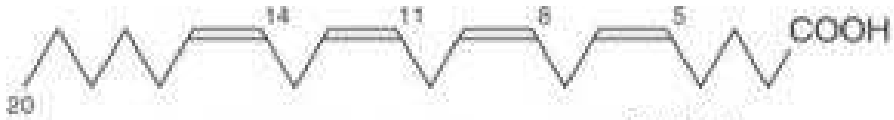
Palmitoleic acid (ω7, 16:1, Δ^9)

Oleic acid (ω9, 18:1, Δ^9)

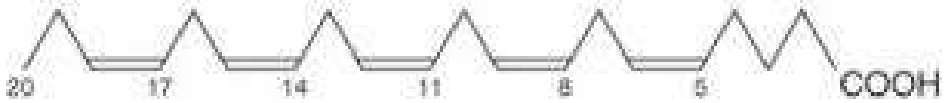


*Linoleic acid (ω6, 18:2, $\Delta^{9,12}$)

*α-Linolenic acid (ω3, 18:3, $\Delta^{9,12,15}$)



*Arachidonic acid (ω6, 20:4, $\Delta^{5,8,11,14}$)



Eicosapentaenoic acid (ω3, 20:5, $\Delta^{5,8,11,14,17}$)

Lipids - Sources

TABLE 4–3
CLASSIFICATION OF LIPIDS

Type of Lipid	Example	Chemistry	General Comments
Simple lipids:			
Neutral fats	Triglycerides (triacylglycerols).	Esters of fatty acids with glycerol; ratio of 3 fatty acids to 1 glycerol.	Most abundant lipids in nature. Mixed triglycerides (those in which at least 2 fatty acids are different) account for 98% of the fats in feeds and over 90% of fat in the body.
Waxes	Beeswax.	Esters of fatty acids with high-molecular-weight alcohols other than glycerol. This group includes the esters of cholesterol, vitamin A, and vitamin D.	More important in commerce than in animal nutrition; occur widely in cuticle of leaves and fruit.
Compound lipids:			
Phospholipids	Lecithins. Cephalins. Lipositols.	Compounds of neutral fat, a phosphoric acid, and a nitrogenous base (choline, ethanolamine, or serine); water-soluble.	Lecithins are largest group of phospholipids. Lecithin may be obtained from egg yolks or soybeans.
Glycolipids	Cerebrosides. Gangliosides.	Sugar-(carbohydrate)-containing fatty acids plus nitrogen.	Sugar can be glucose or galactose; found in nervous tissue; component of cell membrane.
Lipoproteins	Chylomicrons. Very low density lipoproteins (VLDL). Low density lipoproteins (LDL). High density lipoproteins (HDL).	They all contain protein, triglycerides, phospholipids, and cholesterol; but in varying amounts.	The lipoproteins, synthesized in the liver, are composed of about ¼ to ⅓ protein, with the remainder lipids. Means of transporting lipids in the blood.
Derived lipids:			
Fatty acids	Palmitic acid. Oleic acid. Stearic acid. Linoleic acid.	Generally have one acid group (COOH); may be saturated, or unsaturated—contain 1 or more double bonds.	In most cases, there is an even number of carbon atoms in the naturally-occurring fatty acids. There are few odd-numbered carbon atom fatty acids in nature. Release of fatty acids from triglyceride releases glycerol.
Steroids	Cholesterol. Ergosterol. Cortisol. Bile acids. Vitamin D. Androgens, estrogens, and progesterone.	Derivatives of the perhydrocyclopentan-o-penanthrene nucleus (chemical structure is a series of rings).	One of the most studied classes of lipids. Collectively many of these are referred to as steriod hormones—hormones of the adrenal gland, testes, and ovaries.
Hydrocarbons	Terpenes.	Compounds of hydrogen and carbon only.	Includes a series of oils (such as camphor), resin acids, and plant pigments. Beta-carotene is an example of an important terpene.

Ensminger ME, Oldfield JE, Heinemann WW. 1990. Feeds and Nutrition. The Ensminger Publ. Com. CA, US