



PARAMEDIC CARE • PRINCIPLES & PRACTICE, 6E

Disease & the Chemical Level

Chapter 19, Sections 1-2 — A 4.5-Hour Deep Dive



4 hours 30 minutes • 2 scheduled breaks

SESSION ROADMAP

How Today Breaks Down

0:00–0:15	Welcome, Hook & Learning Objectives
0:15–1:15	Part 1: Disease Vocabulary, risk factors, and classification — the language of pathophysiology.
1:15–1:30	BREAK
1:30–2:45	Part 2A: Chemistry of Life Atoms, bonds, and the four biological molecule classes.
2:45–3:00	BREAK
3:00–4:00	Part 2B: Acids, Bases & pH Balance The buffer systems and disorders you'll manage in the field.
4:00–4:20	Case Applications & Final Knowledge Check
4:20–4:30	Wrap-Up & Preview of Next Session

What You're Accountable For Today



EMS Systems Standard

“Pathophysiology” — today builds the vocabulary and chemistry foundation everything later in this chapter depends on.



Competency

Integrates comprehensive knowledge of pathophysiology to form the foundation for the assessment and management of emergency patients of all ages.

Every Assessment You'll Ever Run Starts Here

You will never see “pathophysiology” written on a run sheet



But every sign, every symptom, every treatment decision you make is downstream of what you learn today.

This isn't memorization for a test



It's the reason a patient in DKA breathes the way they do, why a septic patient's blood pressure crashes, and why glucagon doesn't work on an empty tank.

By the end of today, you'll be able to explain the “why” behind the “what”



That's the difference between following a protocol and understanding your patient.

Zooming Out, One Level at a Time



Cell

The smallest unit of life, built from molecules, which are built from atoms.



Tissue

A group of similar cells performing a common function.



Organ

A group of tissues working together toward a shared function.



Organ System

A group of organs working together — humans have 11 of them.



PART 1 • 60 MINUTES

Disease

The vocabulary every clinician needs before anything else makes sense.

01

Five Words That Run This Chapter

Homeostasis

- The body's steady internal balance — everything in this chapter is a story about it being disrupted or restored.

Pathology

- The medical science that deals with all aspects of disease.

Pathophysiology

- Specifically, the study of how disease disrupts normal function.

Pathologist

- A physician who specializes in pathology.

Disease

- An abnormal structural or functional change within the body.

Predisposing Factors



Age



Gender



Genetics



Lifestyle



Environment

Risk Analysis: What You Can and Can't Control



Can't Control

Genetics



Gender



Age



Can Control

Lifestyle choices



Environment



Minimizing these can slow the effects of age



Risk analysis looks at a person's whole life, not one factor in isolation



Obesity: A Modifiable Risk Factor

- Obesity contributes to cardiovascular disease, diabetes, and joint disease — but it's a lifestyle-linked, modifiable factor.
- It's also a practical field consideration — airway management, extrication, and moving patients safely.
- This is risk analysis in action: you can't change a patient's genetics, but prevention and management target what's controllable.



Figure 19-1: Obesity is one of many risk factors for cardiovascular disease.

The Vocabulary of a Disease Course



How It's Described

- Pathogenesis — the sequence of events leading to disease
- Etiology — the occurrences, reasons, and variables behind it
- Idiopathic — predisposing factors can't be identified
- Clinical presentation — how the disease manifests



How It's Assessed

- Symptom — what the patient tells you (subjective)
- Sign — what you find on exam (objective)
- Syndrome — a specific constellation of signs & symptoms
- Diagnosis — the assumption the disease follows a known course

Acute, Chronic, and What Comes After

Acute

- Sudden onset.

Chronic (insidious)

- A slower, creeping onset.

Complications

- Abnormalities that result from the original problem.

Sequelae

- Complications that are common or expected.

Prognosis

- The expected outcome.

Classifying Disease (1 of 2)



Infectious

Caused by pathogens invading the body.



Immunologic

Overreactions of the immune system, like anaphylaxis.



Inflammatory

Inflamed secondary to another disease process.



Ischemic

Diminished blood flow, lack of oxygen.



Metabolic

Like diabetes — a breakdown in body chemistry.



Nutritional

Caused by a vitamin or nutrient deficiency.



Genetic

Inherited, like hemophilia or color blindness.

Classifying Disease (2 of 2)



Congenital

Present at birth — developed in the fetus.



Neoplastic

Cancers — uncontrolled cell growth.



Trauma

Caused by external forces.



Physical Agents

Chemicals and poisons.



Iatrogenic

Caused by medical treatment itself — e.g. a pneumothorax from central line placement.



Idiopathic

Unknown cause.

Congenital Disease, Up Close



- Down syndrome develops in the fetus — it's present from birth, making it congenital by definition.
- Congenital doesn't mean genetic in every case — some congenital conditions come from in-utero exposures, not inherited genes.
- As a paramedic, you'll care for congenital-disease patients across their entire lifespan, not just as infants.

Figure 19-2: Down syndrome is a congenital disease. (© Daniel Limmer)

How Cancer Grows

- Genetic predisposition, smoking, pollution, and UV or radiation exposure can all trigger abnormal cell growth.
- Normal cells accumulate changes over time — becoming progressively more deformed and disorganized.
- This is neoplastic disease from Part 1's classification list, made visual — we'll return to this process in far more depth in a later session.

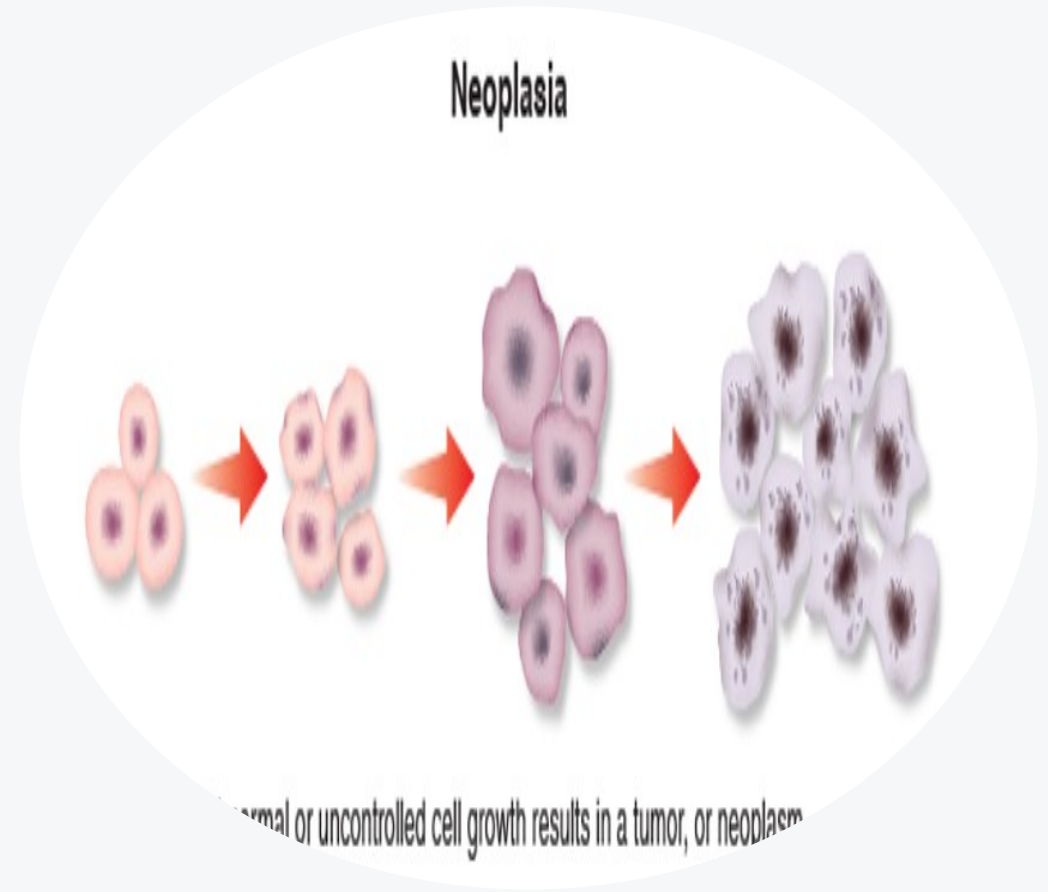


Figure 19-3: Abnormal or uncontrolled cell growth results in a tumor, or neoplasm.



CASE IN POINT

The Patient Who “Just Has Bad Luck”

You respond to a 58-year-old with chest pain. He tells you his father died young of a heart attack, he's smoked for 30 years, and he was just diagnosed with type 2 diabetes. He says, “I guess it's just bad luck — nothing I can do about it.”

DISCUSS

- Which of his risk factors are predisposing (uncontrollable) vs. modifiable (controllable)?
- Is his diabetes better classified as metabolic, genetic, or both — and does that classification change how you'd counsel him?
- How would you explain risk analysis to this patient in a way that's honest but not dismissive of his family history?



QUICK CHECK

A patient tells you, “My chest feels tight.” You then observe he is diaphoretic and his heart rate is 128. Which term describes the diaphoresis and heart rate?

A

Symptom — a subjective complaint

B

Sign — an objective finding

C

Syndrome — a constellation of findings

D

Sequela — an expected complication

Before We Move On...

Disease is any abnormal structural or functional change in the body

- And it's shaped by predisposing factors you can and can't control.
- You now have a shared vocabulary for describing any disease course

- Pathogenesis, etiology, signs, symptoms, syndromes, and diagnosis.

And a working classification system

- 13 categories, from infectious to idiopathic — you'll use this framework for the rest of your career.



BREAK

15 minutes

Grab water, stretch, and get ready — next up: the chemistry that runs every cell in the body.

Back at 1:30



PART 2A • 75 MINUTES

Disease at the Chemical Level

02

Every clinical process you'll ever manage starts with atoms, bonds, and molecules.

From the Big Bang to the First Cell

- The Big Bang theory: the universe began with the explosion of a primeval atom.
- Chemical evolution: simple chemicals in the primordial atmosphere and ocean combined to form larger, more complex chemicals.
- Eventually, a self-replicating chemical surrounded by a membrane appeared — and cellular life began.

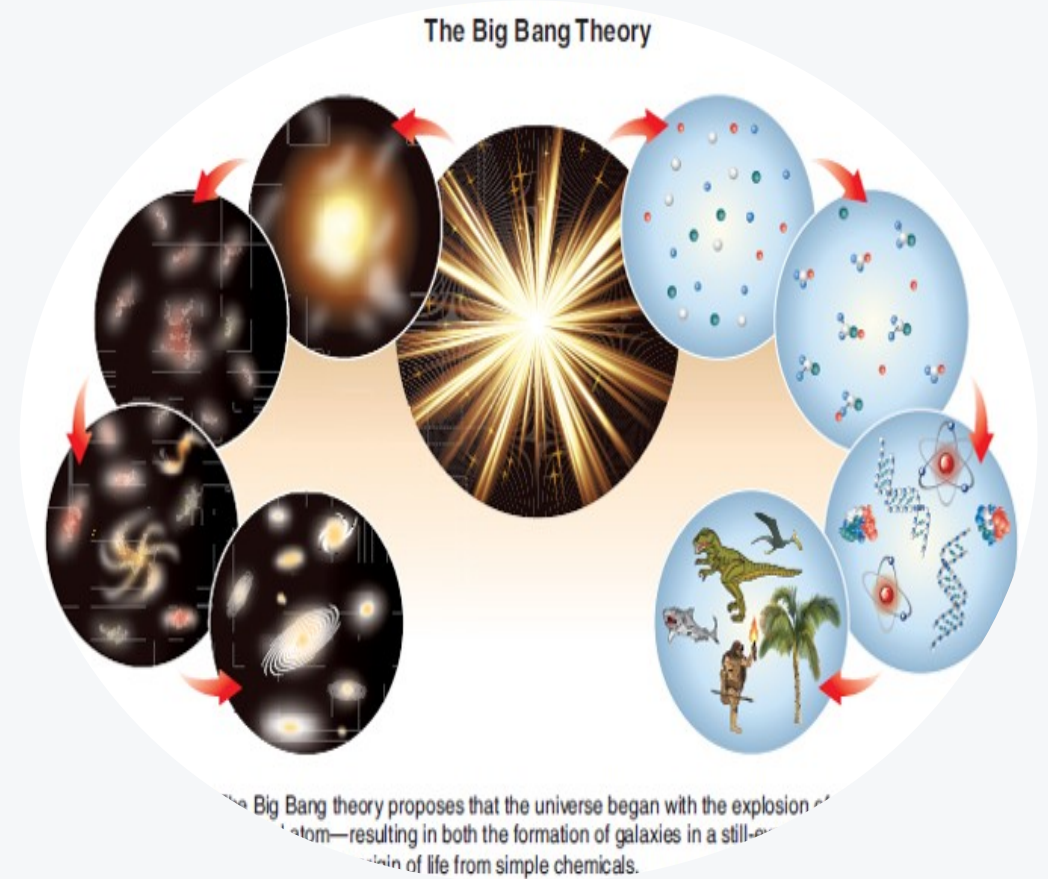
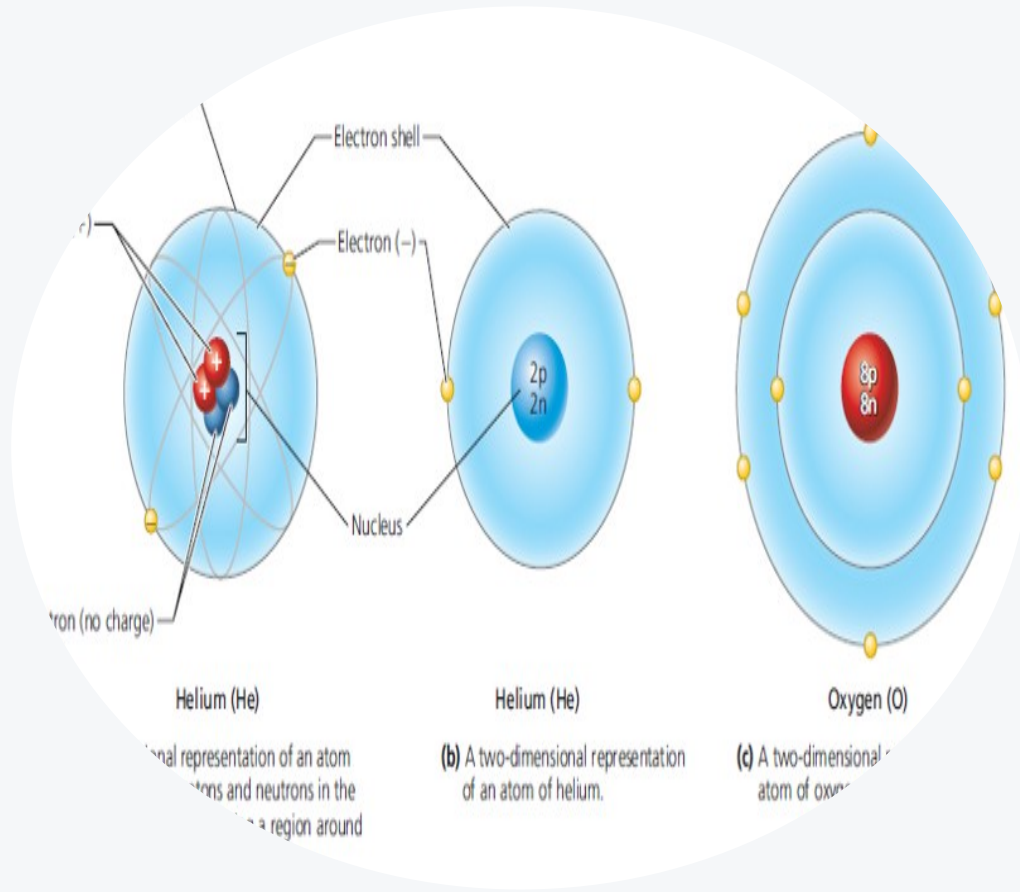


Figure 19-4: The Big Bang theory — from primeval atom to galaxies, and from simple chemicals to life.

Rebuilding the Atom



- Atom — the fundamental chemical unit.
- Protons and neutrons sit in the nucleus; protons carry a positive charge, neutrons are neutral.
- Electrons are smaller particles that orbit the nucleus — negatively charged.

Figure 19-5: Atoms can be represented in various ways — helium and oxygen shown here.

Elements, the Periodic Table & Isotopes

- Element — a substance that cannot be separated into simpler substances.
- Atomic number — the number of protons in the nucleus; this defines the element.
- Isotopes — atoms of the same element with the same number of protons but a different number of neutrons.

Mass number
(number of protons + neutrons)

Atomic number
(number of protons)

¹ ₁ H							⁴ ₂ He
⁷ ₃ Li	⁹ ₄ Be	¹¹ ₅ B	¹² ₆ C	¹⁴ ₇ N	¹⁶ ₈ O	¹⁹ ₉ F	²⁰ ₁₀ Ne
	²⁴ ₁₂ Mg	²⁷ ₁₃ Al	²⁸ ₁₄ Si	³¹ ₁₅ P	³² ₁₆ S	³⁵ ₁₇ Cl	

Figure 19-6: A portion of the periodic table — atomic number, mass number, and symbol for each element.

Radioactive Decay & Half-Life

Mass number

- The total number of neutrons and protons in an atom.

Radioactive isotopes

- Unstable combinations of neutrons and protons in the nucleus.

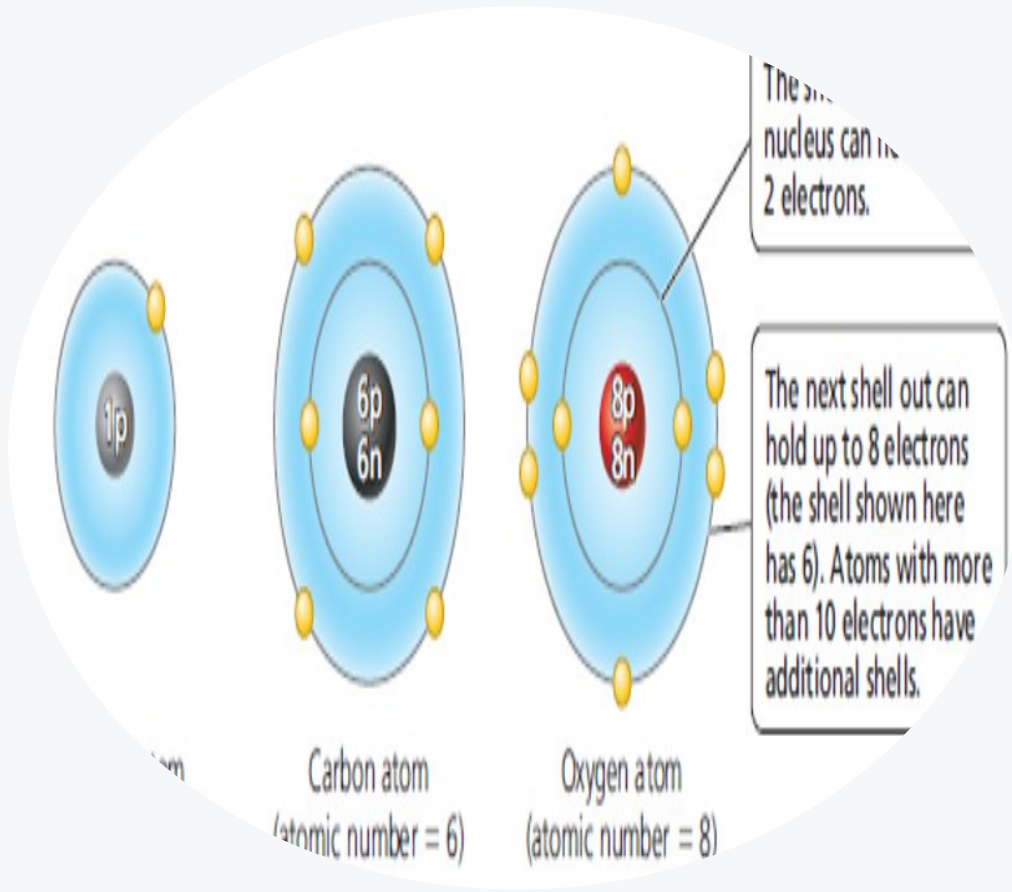
Radioactive decay

- The nucleus breaks down and emits radiation (alpha, beta, gamma) until the atom regains stability.

Half-life

- The time it takes for a parent isotope to decrease by one-half — the same concept used clinically for drug elimination.

Electron Shells & the Valence Shell



- Orbital — a specific shape that can hold two or more electrons.
- Electron shells — numbered starting with the shell closest to the nucleus.
- Valence shell — the outermost shell; its electrons (valence electrons) determine how an atom bonds.
- Noble gases (helium, neon, argon, krypton, xenon, radon) have full valence shells — which is why they don't bond.

Figure 19-8: Hydrogen, carbon, and oxygen atoms — each ring is an electron shell.

Covalent Bonds: Sharing Electrons

- Atoms become stable by bonding to other atoms.
- Covalent bond — an equal sharing of electrons between atoms.
- Molecule — a substance made of atoms held together by covalent bonds.
- Ion — an atom or molecule that has acquired an electrical charge.

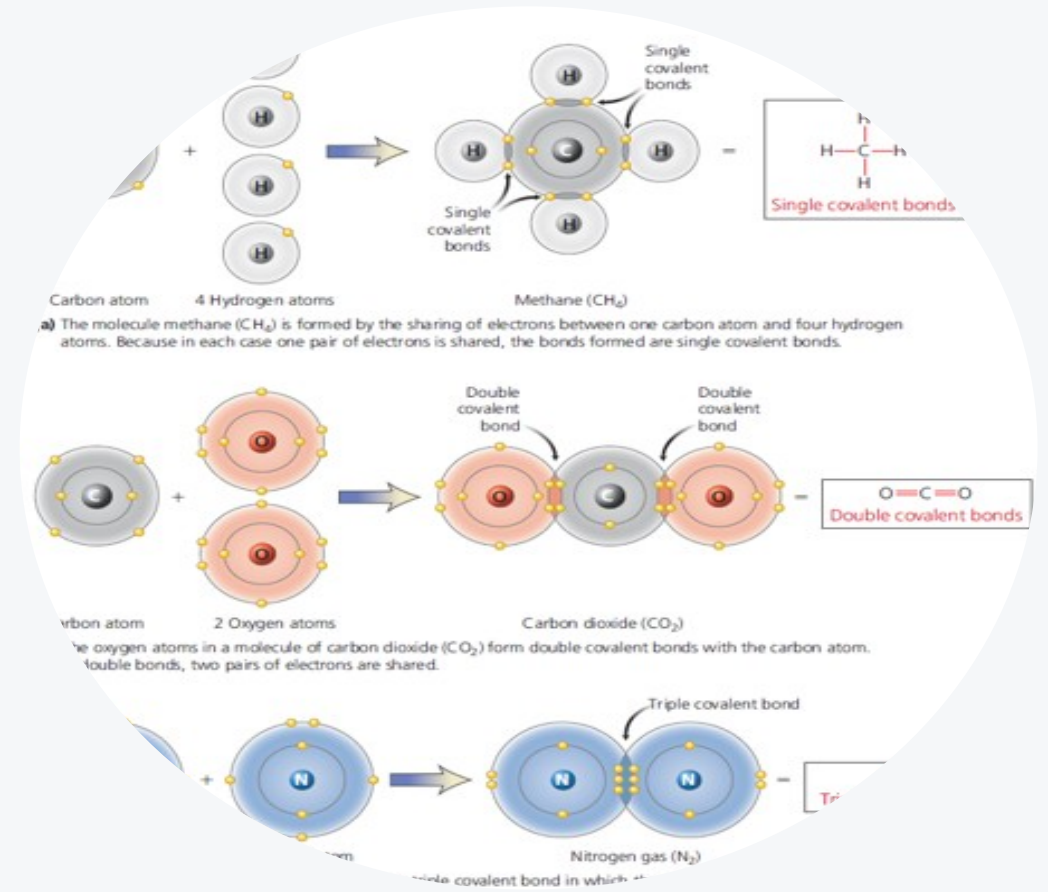
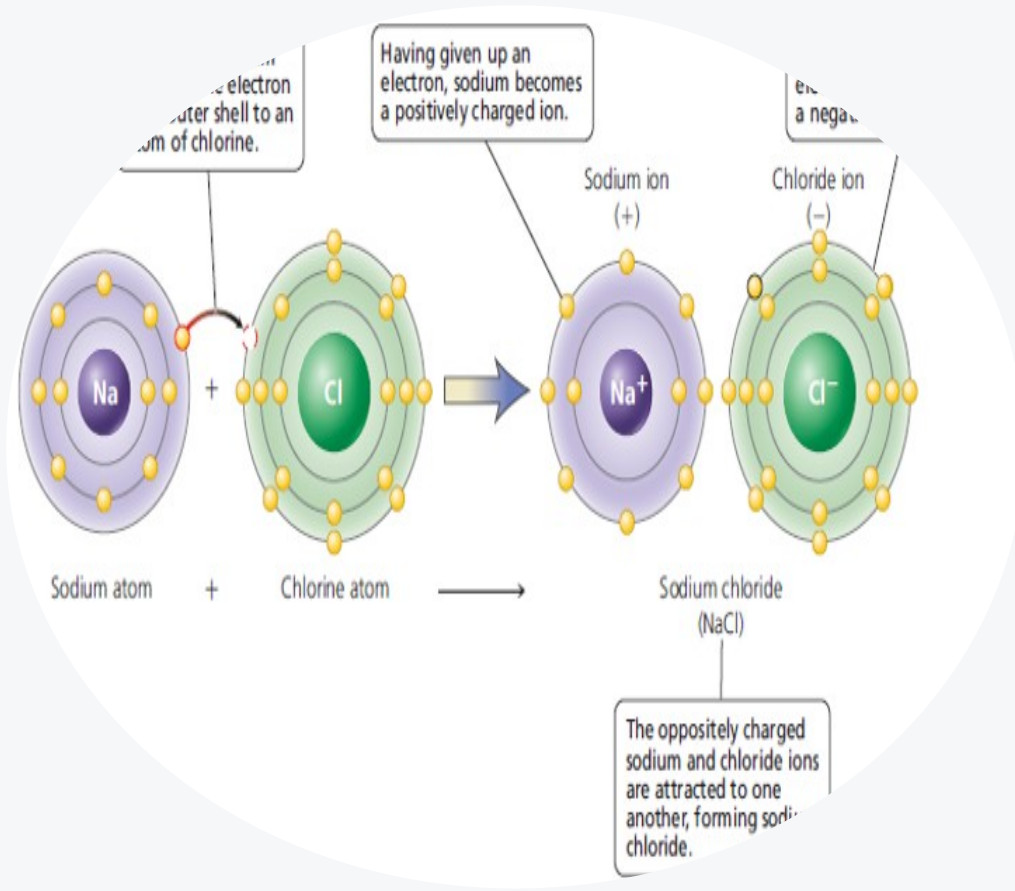


Figure 19-9: Single, double, and triple covalent bonds — methane, carbon dioxide, and nitrogen gas.

Ionic Bonds: Transferring Electrons



- Cation — an atom or molecule missing electrons; net positive charge.
- Anion — an atom or molecule with extra electrons; net negative charge.
- Ionic bond — opposite charges attract, forming a bond between a cation and an anion.
- This is the same chemistry behind the electrolytes (Na⁺, K⁺, Cl⁻) you'll monitor in every IV fluid decision.

Figure 19-10: An ionic bond — sodium transfers an electron to chlorine, forming sodium chloride.

Hydrogen Bonds & Why Water Is Special

- Polar bond — an unequal covalent bond, creating a polar molecule.
- Hydrogen bond — attraction between a slightly positive hydrogen atom and a slightly negative atom (often oxygen).
- This weak attraction gives water its special physical properties — properties every fluid and electrolyte decision you make depends on.

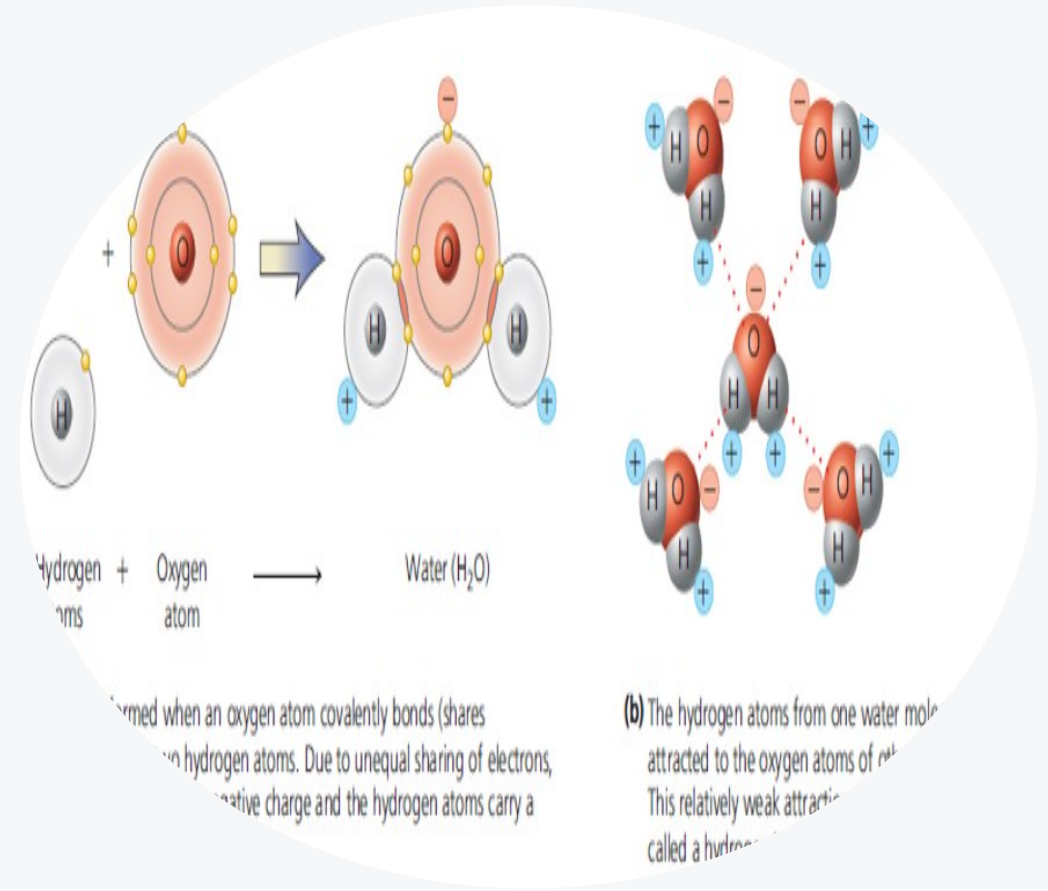


Figure 19-11: Hydrogen bonds of water — a weak attraction with an outsized effect.

Compounds: More Than the Sum of Their Elements



- Inorganic chemicals don't contain carbon; organic chemicals do (about 90% of all known chemicals).
- The major elements of living systems: carbon, hydrogen, oxygen, and nitrogen.
- Compound — the chemical union of two or more elements. The major compounds of living systems: carbohydrates, proteins, nucleic acids, and lipids.

Figure 19-12: Table salt (NaCl) — neither a silvery metal nor a yellow gas, but something entirely new.

Four Classes of Biological Chemicals



Carbohydrates

Sugars & starches — the body's primary calorie source (glucose, glycogen).



Proteins

Built from amino acids; enzymes, antibodies, structure, and transport.



Nucleic Acids

DNA and RNA — the genetic instructions for life.



Lipids

Triglycerides, phospholipids, and steroids — energy storage and membranes.

Sugars, Starches & Stored Energy

- Monosaccharides — simple sugars: glucose, fructose, galactose.
- Disaccharides — two simple sugars joined: sucrose, lactose, maltose.
- Polysaccharides — starches, cellulose, and glycogen.

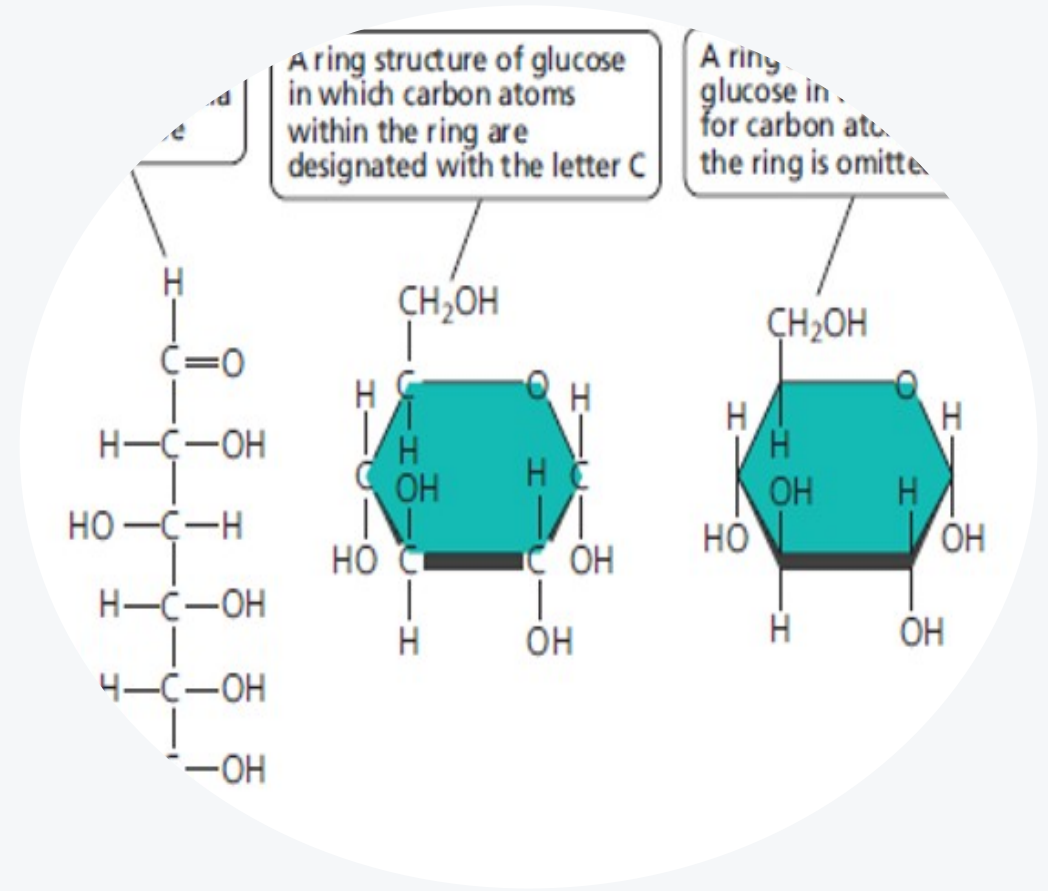
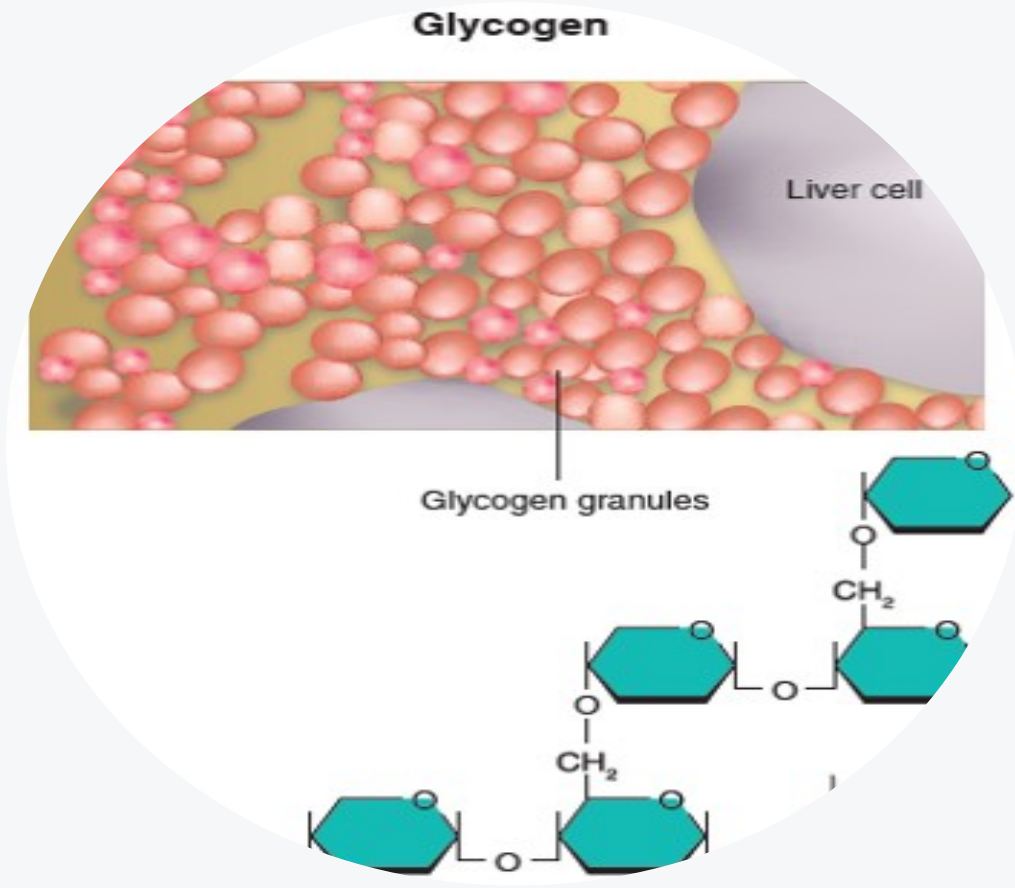


Figure 19-13: Glucose — a six-carbon sugar and the principal energy source for the human body.

Glycogen: The Body's Sugar Reserve



- Glycogen — the important storage polysaccharide in animals.
- Stored primarily in the liver and skeletal muscle.
- Glycogenolysis — the breakdown of glycogen into glucose, controlled by the hormones glucagon and epinephrine.

Figure 19-15: Glycogen is stored primarily in the liver and skeletal muscle.

Why Glucagon Doesn't Always Work

- Glucagon can only release glucose that's already stored as glycogen.
- In patients with limited glycogen stores — chronic alcoholics, liver disease, malnutrition — glucagon can be ineffective.
- If you suspect limited glycogen stores, give glucose directly to raise blood glucose levels.



© Dr. Bryan E. Bledsoe — glucagon administration in the field.



QUICK CHECK

Your patient is a known alcoholic found unresponsive with a blood glucose of 32. You administer glucagon IM with no effect. What's the most likely explanation?

A

Glucagon was given at the wrong dose

B

The patient has depleted glycogen stores, so there's nothing for glucagon to mobilize

C

Glucagon only works in pediatric patients

D

The patient's blood pH is too alkalotic for glucagon to function

Proteins Do Almost Everything



Built Up From

- Amino acids, joined by peptide bonds
- Peptide: chain under 10 amino acids
- Polypeptide: chain over 10 amino acids
- Four levels of structure: primary → secondary → tertiary → quaternary



What They Do

- Enzymes speed up chemical reactions by binding a substrate
- Antibodies and complement proteins defend the body
- Receptor and transport proteins move signals and substances
- Structural proteins support cells and tissues

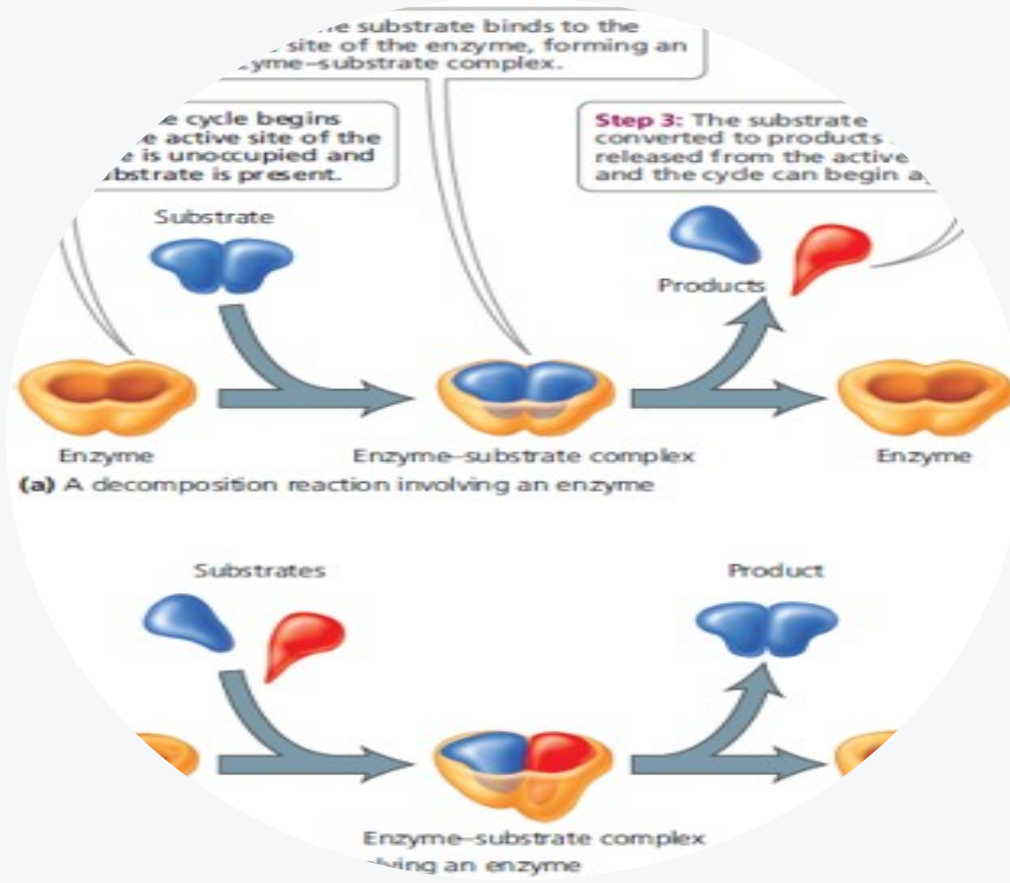
Four Levels of Protein Structure

- Primary — the sequence of amino acids, held by peptide bonds.
- Secondary — alpha helices and beta sheets, stabilized by hydrogen bonding.
- Tertiary — the overall 3D shape of one polypeptide.
- Quaternary — the shape formed by multiple polypeptide subunits together, like hemoglobin's four subunits.

Level	Description	Stabilized by	Example: Hemoglobin
Primary	Linear sequence of amino acids in a polypeptide	Peptide bonds	
Secondary	Formation of alpha helices and beta-pleated sheets in a polypeptide	Hydrogen bonding between groups along the peptide-bonded backbone; thus, depends on primary structure	 One α -helix
Tertiary	Overall three-dimensional shape of a polypeptide (includes contribution from secondary structures)	Bonds and other interactions between side chains or between side chains and the peptide-bonded backbone; thus, depends on primary structure	 One of hemoglobin's subunits
Quaternary	Shape produced by combinations of polypeptides (thus, combinations of tertiary structures)	Bonds and other interactions between side chains and between peptide backbones of different polypeptides; thus, depends on primary structure	 Hemoglobin which consists of four polypeptide subunits

Table 19-2: Primary, secondary, tertiary, and quaternary protein structure, using hemoglobin as the example.

Enzymes: The Body's Reaction Accelerators



- Enzymes are proteins that speed up chemical reactions without being consumed.
- A substrate binds to the enzyme, forming an enzyme-substrate complex.
- Cofactors are nonprotein substances that help convert substrate to product; coenzymes are organic cofactors.

Figure 19-18: The working cycle of an enzyme — substrate binds, reacts, and releases as product.

DNA: The Genetic Instructions for Life

- DNA carries the genetic instructions for life, built from two long polymer chains (nucleotides) joined by paired nucleobases.
- The genetic code: four nucleobases — adenine (A), thymine (T), cytosine (C), guanine (G).
- The sequence of these bases encodes all the information needed to build and run the body.

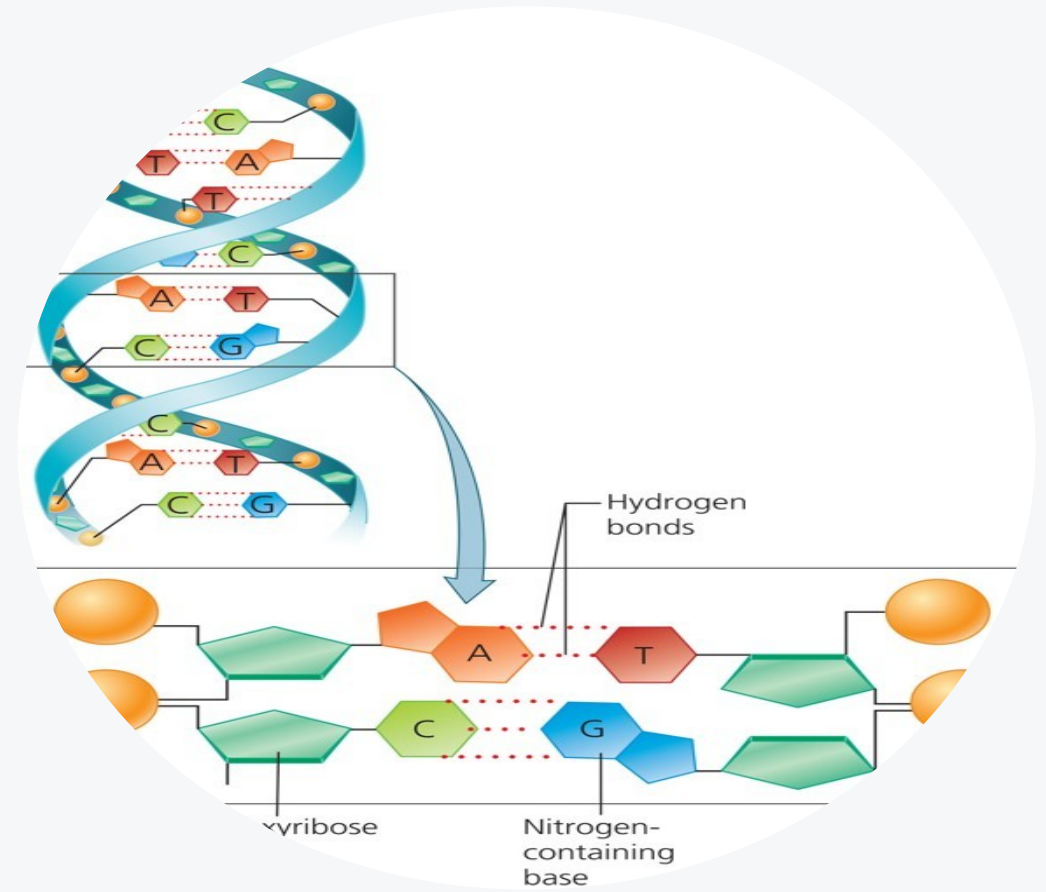
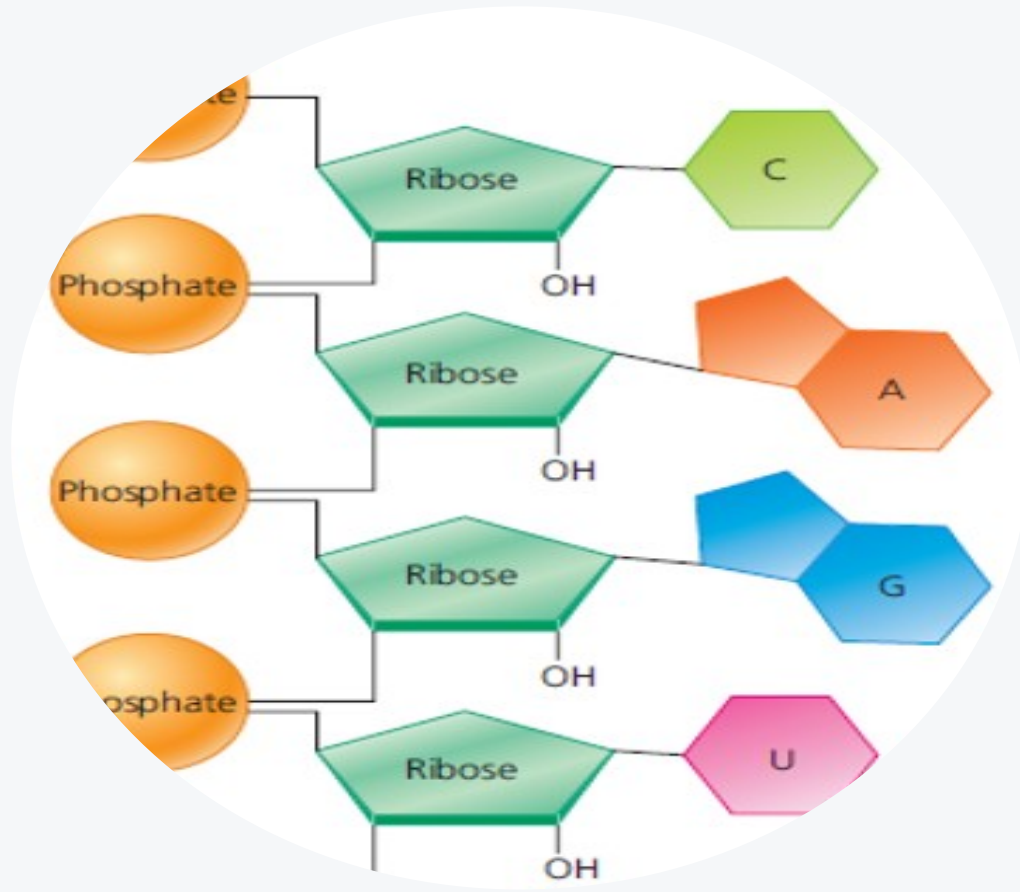


Figure 19-20: DNA — two chains of nucleotides twisted into a double helix.

RNA: Turning Code Into Protein



- RNA is chemically similar to DNA, but single-stranded, and plays the major role in protein synthesis.
- Its nucleobases: adenine (A), cytosine (C), guanine (G), and uracil (U) — no thymine.

Figure 19-21: RNA — single-stranded, using uracil (U) in place of thymine.

Nucleotides: The Shared Building Block

- Genes — sequences that code for a specific amino acid sequence, which becomes a specific protein.
- The number of chromosomes in a cell's nucleus varies by organism — humans have 46.

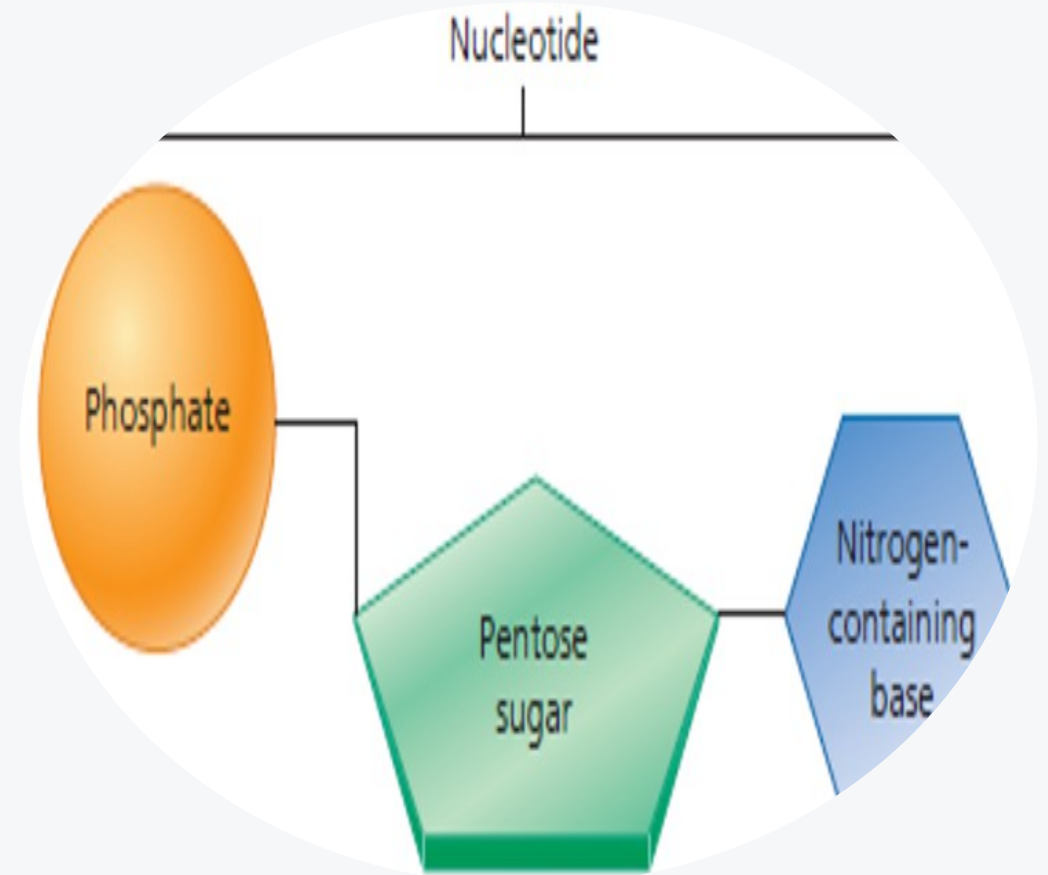
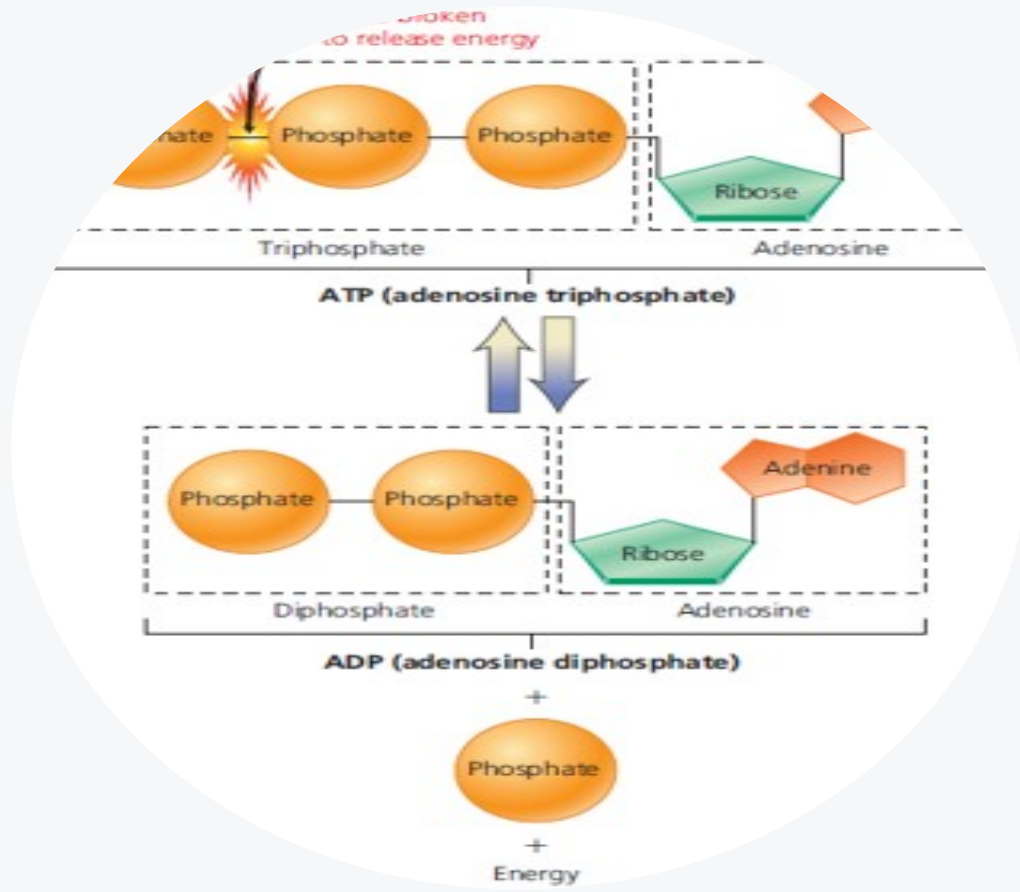


Figure 19-22: A nucleotide — a five-carbon sugar, a phosphate group, and a nitrogen-containing base.

ATP: The Energy Currency of the Cell



- Adenosine triphosphate (ATP) — a nucleotide and the principal energy source for nearly every cellular activity.
- Its phosphate bonds are highly unstable — breaking the last one releases usable energy, yielding ADP plus a free phosphate.

Figure 19-23: ATP breaks its last phosphate bond to release energy, becoming ADP.

Fats: Energy Storage, Insulation & Structure

- Lipids don't dissolve in water (nonpolar) and function in long-term energy storage, insulation, structure, and control.
- Triglycerides — rich energy sources, saturated or unsaturated.
- Phospholipids form the membrane that surrounds every cell.
- Steroids — built on a cholesterol backbone; includes HDL (“good”), LDL (“bad”), and VLDL (mainly carries triglycerides).

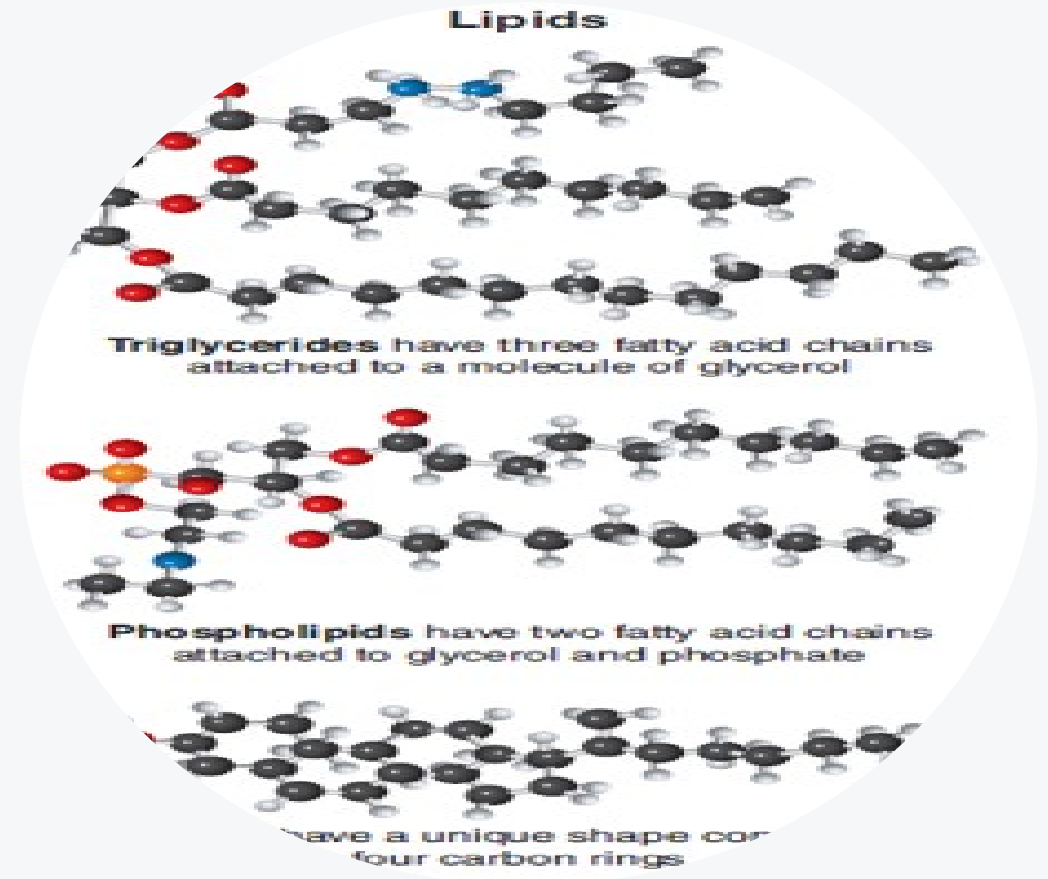
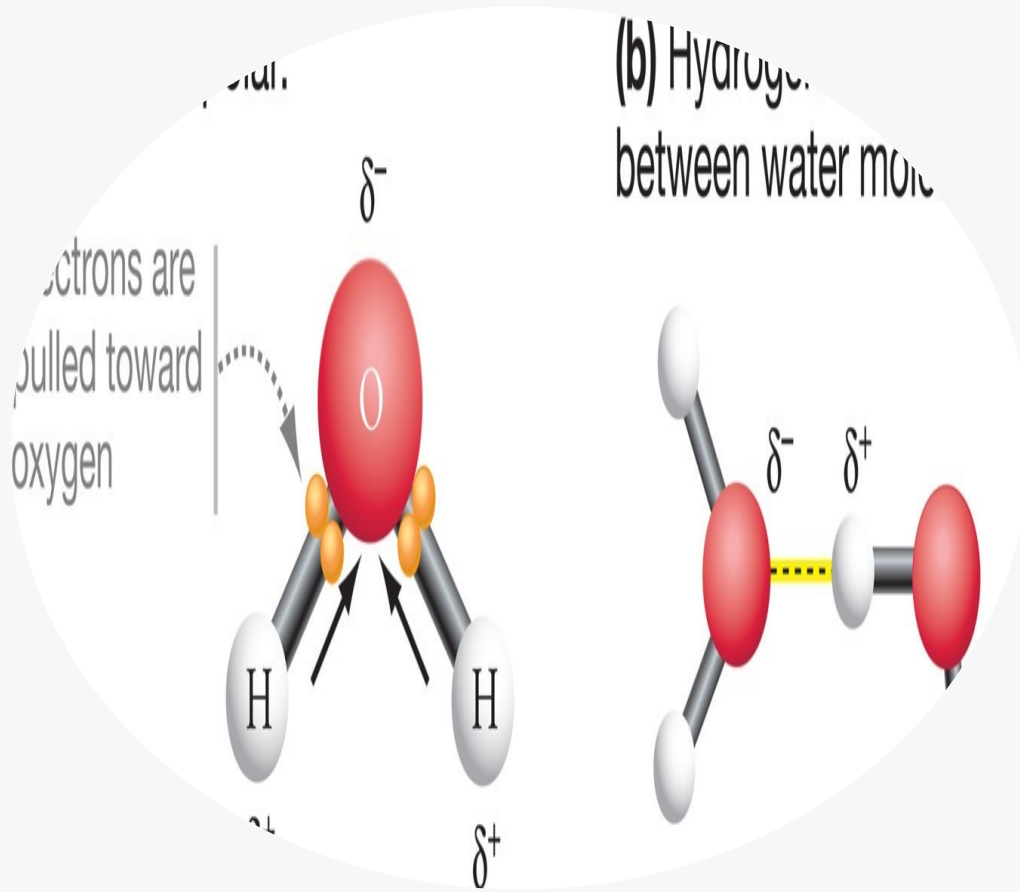


Figure 19-24: Triglycerides, phospholipids, and steroids — the three lipid types relevant to pathophysiology.

The Universal Solvent



- Water is a polar molecule and the universal solvent — it transports substances throughout the body.
- It also helps maintain a constant body temperature.
- Every buffer system, every IV fluid decision, and every cell in the body depends on water's unique chemistry.

Figure 19-31: Water is polar and participates in hydrogen bonds.



CASE IN POINT

Reading the Chemistry Behind the Chart

A 45-year-old with a history of chronic alcohol use presents confused, tachycardic, and hypoglycemic (BGL 38). His partner says he hasn't eaten in three days. You give glucagon 1mg IM with no improvement in mental status or blood glucose after 10 minutes.

DISCUSS

- Using what you just learned about glycogen and glycogenolysis, why might glucagon have failed here?
- What's your next chemistry-informed treatment step?
- How would you explain to a new EMT why 'just give glucagon' isn't always the right answer?

Before We Move On...

Atoms bond in three main ways

- Covalent (sharing), ionic (transferring), and hydrogen bonds (weak attraction) — and these bonds explain everything from electrolytes to why water behaves the way it does.

Four classes of biological chemicals run the body

- Carbohydrates for fuel, proteins for structure and function, nucleic acids for genetic instruction, lipids for storage and membranes.

ATP is the energy currency behind every one of your interventions

- And glycogen is the fuel tank it draws from — which is exactly why an empty tank means glucagon won't help.



BREAK

15 minutes

Next up: acids, bases, and the pH balance behind every blood gas you'll ever read.

Back at 3:00



PART 2B • 60 MINUTES

Acids, Bases & pH Balance

The narrowest window in the whole body — and the one you'll manage constantly.

03

It All Comes Down to Protons

Dissociation reaction

- A compound or molecule breaks apart into separate components.

Acids

- Substances that give up protons during chemical reactions.

Bases

- Substances that acquire protons during chemical reactions.

Acid-base reaction

- At its core, simply a transfer of protons.

0 to 14: Where Common Substances Fall



0 — Hydrochloric
acid



2 — Lemon juice



4 — White wine



6 — Coffee, urine,
saliva



7 — Distilled water
(neutral)



7.4 — Blood
(normal)



9 — Bile

The Body's First Line Against pH Swings



Carbonic Acid–Bicarbonate

Regulates blood pH; buffers organic and fixed acids, but only works while respiration is normal and bicarbonate is available.



Protein Buffer

Amino acids in the protein chain react to pH shifts — hemoglobin is the key player here.



Phosphate Buffer

Limited role in ECF, but a major stabilizer of urine pH.

Four Systems, Four Speeds



Immediate

Buffer pairs — carbonic acid/bicarbonate, proteins/hemoglobin, phosphate — release or absorb hydrogen ions instantly



Slower, but Powerful

- Respiratory system — retains or removes CO_2 within minutes to hours
- Electrolyte shifts — exchange Na^+/K^+ for H^+ in the ECF, minutes to hours
- Renal system — secretes or absorbs H^+ , HCO_3^- , phosphate, and ammonia, over hours to days

Acidosis vs. Alkalosis



Acidosis

An excess of acids in the body



pH deviates below the normal range of 7.35–7.45



Can be respiratory or metabolic in origin



Alkalosis

An excess of base in the body



pH deviates above the normal range of 7.35–7.45



Can also be respiratory or metabolic in origin



When the Lungs Are the Problem



Respiratory Acidosis

The lungs can't clear enough CO_2 — pH falls, hypercapnia develops. Caused by decreased rate, tidal volume, or both.



Respiratory Alkalosis

Hyperventilation clears too much CO_2 — hypocapnia develops. Often triggered by anxiety, a metabolic disorder, or environmental factors.

When the Kidneys Are the Problem



Metabolic Acidosis

A deficiency of bicarbonate in the body — the kidneys play the major role in maintaining stable pH here.



Metabolic Alkalosis

Uncommon — due to an increase in bicarbonate levels or a decrease in circulating acids.



QUICK CHECK

A COPD patient's ABG shows pH 7.30, CO₂ 60 mmHg. Which acid-base disorder does this represent?

A

Metabolic acidosis

B

Metabolic alkalosis

C

Respiratory acidosis

D

Respiratory alkalosis



CASE IN POINT

The Fruity-Smelling Breath

You're called for a 19-year-old type 1 diabetic who is confused, tachypneic with deep, rapid respirations, and has a fruity odor to his breath. His blood glucose is 480. His family says he ran out of insulin four days ago.

DISCUSS

- What acid-base disorder is this patient's breathing pattern compensating for?
- Is this a respiratory or a metabolic problem at its root — and how can you tell from the presentation alone?
- Which buffer and organ systems are being overwhelmed here?

The Throughline

- 1 Disease is any abnormal structural or functional change — shaped by factors you can and can't control.
- 2 You now have a shared vocabulary: pathogenesis, etiology, signs, symptoms, syndromes, and 13 categories of classification.
- 3 Every cell in the body runs on chemistry — atoms, bonds, and four classes of biological molecules.
- 4 ATP is the energy currency; glycogen is the fuel tank behind it — and an empty tank changes your treatment plan.
- 5 pH balance is one of the narrowest windows in the body — buffered first, then corrected by the lungs and kidneys.

Where We Pick Up Next Time

Part 3: Disease at the Cellular Level



The cell, its organelles, fluid balance, and how cells adapt, get injured, and die.

Part 4: Disease at the Tissue Level



The four tissue types and how tissue growth goes wrong — neoplasia and cancer.

Part 5: Disease at the Organ Level



The circulatory system and the pathophysiology of shock.

Part 6: The Body's Defenses



Infection, inflammation, immunity, and stress.



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