What does temperature measure at the molecular level?	Average kinetic energy of particles
Does temperature measure total energy?	No — it measures average kinetic energy only
Does electronegativity apply to isolated atoms?	No — it applies only within bonds
For a first-order reaction, how does half-life change with concentration?	It is constant (independent of concentration)
For zero-order reactions, does half-life remain constant?	No — it changes with concentration
Rank intermolecular forces from weakest to strongest	London dispersion < dipole–dipole < hydrogen bonding < ion–dipole
Are hydrogen bonds covalent bonds?	No — they are intermolecular attractions
What atoms must hydrogen be bonded to for hydrogen bonding to occur?	Nitrogen, oxygen, or fluorine (N, O, F)
Do catalysts change ΔG or equilibrium position?	No — they change reaction rate only
What does a negative ΔG indicate?	The process is thermodynamically spontaneous
Does spontaneous mean fast?	No — spontaneity does not imply speed
What happens to temperature during a phase change?	It remains constant
During a phase change, what does added energy go toward?	Breaking or forming intermolecular forces
Does a double bond count as two electron domains in VSEPR?	No — it counts as one electron domain
Do lone pairs occupy more or less space than bonding pairs?	More space
Across a period (left → right), what happens to ionization energy?	It increases
Down a group (top → bottom), what happens to atomic radius?	It increases
What intermolecular force is present in all molecules?	London dispersion forces
At the same temperature, do heavier gas particles have lower average kinetic energy?	No — average kinetic energy is the same
Is the transition state a stable reaction intermediate?	No — it is unstable and fleeting
What does ionization energy measure?	How difficult it is to remove a valence electron
Across a period, why does ionization energy increase?	Nuclear charge increases with little added shielding
Down a group, why does ionization energy decrease?	Increased distance and electron shielding
What does atomic radius reflect physically?	How tightly valence electrons are held
What happens to electronegativity across a period?	It increases
What happens to electronegativity down a group?	It decreases
What two factors primarily determine bond polarity?	Electronegativity difference and bond presence
Does bond polarity automatically mean molecular polarity?	No — geometry can cancel dipoles
What determines molecular polarity?	Bond polarity and molecular geometry
What type of bond forms with a large electronegativity difference?	Ionic bond
What holds an ionic lattice together?	Electrostatic attraction between ions
Why are stronger bonds generally shorter?	Greater electrostatic attraction pulls nuclei closer
What happens to bond length as bond strength increases?	Bond length decreases
What determines electron geometry in VSEPR?	Number of electron domains

What determines molecular geometry in VSEPR?	Electron geometry plus lone pairs
Do triple bonds count as three electron domains?	No — they count as one
What happens to bond angles when lone pairs are added?	Bond angles decrease (are compressed)
Why do lone pairs repel more strongly than bonding pairs?	They occupy more space
What intermolecular force requires permanent molecular polarity?	Dipole–dipole interactions
What intermolecular force explains salt dissolving in water?	Ion–dipole interactions
What property primarily strengthens London dispersion forces?	Increased molecular size / polarizability
Are London dispersion forces present in polar molecules?	Yes — they are present in all molecules
What intermolecular force is strongest for similarly sized polar molecules?	Hydrogen bonding (if possible)
What intermolecular force dominates between an ion and a polar solvent?	Ion–dipole interaction
Why does water have an unusually high boiling point?	Strong hydrogen bonding network
What does “like dissolves like” mean mechanistically?	Similar intermolecular forces can replace each other
What phase has the strongest intermolecular interactions?	Solid
What phase has the weakest intermolecular interactions?	Gas
During melting, what happens to intermolecular forces?	They are partially overcome
Is melting an endothermic or exothermic process?	Endothermic
Is freezing an endothermic or exothermic process?	Exothermic
What happens to kinetic energy during a phase change?	It remains constant
What does latent heat represent?	Energy required to break or form intermolecular forces
What does the triple point represent on a phase diagram?	All three phases coexist
What happens at the critical point?	Liquid–gas distinction disappears
Increasing pressure favors which phase for gases?	Liquid (or solid)
Increasing temperature favors which phase?	Gas
What does temperature measure in kinetic molecular theory?	Average kinetic energy
What happens to gas pressure if temperature increases at constant volume?	Pressure increases
What happens to gas volume if temperature increases at constant pressure?	Volume increases
What does gas pressure physically result from?	Collisions of gas particles with container walls
At the same temperature, do lighter gas particles move faster than heavier ones?	Yes
At constant temperature, what happens to pressure when volume decreases?	Pressure increases
At constant pressure, what happens to volume when temperature increases?	Volume increases
At constant volume, what happens to pressure when temperature increases?	Pressure increases
At constant temperature and pressure, what happens to volume when moles increase?	Volume increases
Under what conditions do real gases deviate most from ideal behavior?	High pressure and low temperature
Why do gases deviate from ideal behavior at high pressure?	Particle volume becomes significant

Why do gases deviate from ideal behavior at low temperature?	Intermolecular forces become significant		
What does internal energy (U) include?	Total microscopic kinetic and potential energy		
Is internal energy a state function?	Yes		
What defines heat (q)?	Energy transferred due to temperature difference		
Is heat a property of a system?	No — it exists only during transfer		
What defines work (w) in thermodynamics?	Energy transferred when force acts over distance		
When is work positive (w > 0)?	When work is done on the system		
When is work negative (w < 0)?	When work is done by the system		
What happens to internal energy during gas expansion without heat input?	It decreases		
Does energy conservation ever fail in biological systems?	No		
How do cells make unfavorable processes occur?	By coupling them to favorable reactions		
Does ATP hydrolysis create energy?	No — it redistributes energy		
What does entropy (S) fundamentally measure?	Energy dispersal / number of accessible microstates		
Does entropy literally mean “disorder”?	No — disorder is a metaphor		
What happens to entropy when substances mix?	Entropy increases		
What happens to entropy during diffusion?	Entropy increases		
What happens to entropy when a solid melts?	Entropy increases		
What happens to entropy when a gas condenses?	Entropy decreases		
Can the entropy of a system decrease spontaneously?	Yes, if surroundings’ entropy increases more		
What must always increase in a spontaneous process?	Total entropy of the universe		
Are living organisms violations of the Second Law?	No		
How do living systems obey the Second Law?	They export entropy to their surroundings		
What does Gibbs free energy (ΔG) predict?	Spontaneity of a process		
What does ΔG = 0 indicate?	Equilibrium		
What does equilibrium mean dynamically?	Forward and reverse rates are equal		
Does equilibrium mean reactions stop?	No		
In ΔG = ΔH − TΔS, what does temperature weight?	The entropy term		
At high temperature, which term dominates ΔG?	Entropy (TΔS)		
Which ΔH / ΔS combination is always spontaneous?	ΔH < 0 and ΔS > 0		
Which ΔH / ΔS combination is never spontaneous?	ΔH > 0 and ΔS < 0		
When is a process with ΔH < 0 and ΔS < 0 spontaneous?	At low temperature		
When is a process with ΔH > 0 and ΔS > 0 spontaneous?	At high temperature		
What does reaction rate measure?	How fast reactants are converted to products		
What two factors primarily determine reaction rate at the molecular level?	Collision frequency and collision energy		

What is activation energy (E_a)?	Minimum energy required to reach the transition state
Can a reaction with $\Delta G < 0$ still be slow?	Yes
What does the transition state represent on an energy diagram?	The peak of the energy barrier
Is the transition state a stable intermediate?	No
What effect do catalysts have on activation energy?	They lower it
Do catalysts change ΔG or equilibrium position?	No
What happens to reaction rate when temperature increases?	It increases
Why does increasing temperature increase reaction rate?	More molecules exceed E_a
How does increasing reactant concentration usually affect rate?	It increases rate
What does reaction order describe?	Sensitivity of rate to reactant concentration
Is reaction order determined by stoichiometry?	No
How is reaction order determined?	Experimentally
What does zero-order kinetics imply about rate vs concentration?	Rate is independent of concentration
What does first-order kinetics imply about rate vs concentration?	Rate is directly proportional
What does second-order kinetics imply about rate vs concentration?	Rate is highly concentration-dependent
Which reaction order has a constant half-life?	First-order
Does half-life change in zero-order reactions?	Yes
What feature strongly suggests first-order kinetics on the MCAT?	Constant half-life
Pressure — SI unit	Pascal (Pa)
Pressure — common MCAT equivalents	1 atm = 760 mmHg ≈ 101 kPa
Energy — SI unit	Joule (J)
Power — definition and unit	Rate of energy use; Watt (W = J/s)
Electric potential (voltage) — unit meaning	Volt (V) = J/C
Electric current — SI unit	Ampere (A) = C/s
Electrical resistance — unit meaning	Ohm (Ω) = V/A
Charge — SI unit	Coulomb (C)
Density — unit logic	Mass/volume (e.g., kg/m³ or g/mL)
Work — unit equivalence	N·m = J
Frequency — SI unit	Hertz (Hz) = s^{-1}
Speed — dimensional form	Distance/time (m/s)
Acceleration — dimensional form	m/s^2
Force — dimensional form	N = kg·m/s²
Energy–frequency relationship (light) — unit check	E = hf → J = (J·s)(s^{-1})
Dimensional analysis — MCAT purpose	Check equation consistency and eliminate wrong answers
Common MCAT unit trap	Forgetting to convert prefixes (milli, micro, kilo)
Order-of-magnitude estimation — MCAT use	Approximate answers when exact math is unnecessary

Graph slope — unit meaning	(y-units)/(x-units)
Area under a curve — unit meaning	(y-units) × (x-units)
Oxidation — definition	Loss of electrons
Reduction — definition	Gain of electrons
Anode — what occurs there	Oxidation
Cathode — what occurs there	Reduction
Galvanic (voltaic) cell — defining feature	Spontaneous redox reaction
Electrolytic cell — defining feature	Nonspontaneous reaction driven by external power
Electron flow — direction	From anode to cathode
Conventional current — direction	From cathode to anode
Galvanic cell — sign of E°cell	Positive
Electrolytic cell — sign of E°cell	Negative
Relationship between ΔG° and E°cell	$\Delta G^\circ = -nFE^\circ_{cell}$
Spontaneous reaction — thermodynamic condition	$\Delta G^\circ < 0$
Stronger reducing agent	Species more easily oxidized
Stronger oxidizing agent	Species more easily reduced
Salt bridge — primary function	Maintains charge neutrality
Oxidation half-reaction — electron placement	Electrons on product side
Reduction half-reaction — electron placement	Electrons on reactant side
Cell potential — conceptual meaning	Driving force for electron flow
Wave — defining feature	Transfer of energy without net transfer of matter
Wavelength (λ) — definition	Distance between identical points on a wave
Frequency (f) — definition	Number of cycles per second
Wave speed relationship	$v = f\lambda$
Amplitude — physical meaning	Maximum displacement from equilibrium
Sound intensity — depends on	Amplitude (energy of the wave)
Loudness — perceptual correlate of	Intensity
Pitch — perceptual correlate of	Frequency
Doppler effect — approaching source	Observed frequency increases
Doppler effect — receding source	Observed frequency decreases
Speed of sound — depends on	Medium properties (density, elasticity)
Sound travels fastest in	Solids
Sound cannot travel through	Vacuum
Mechanical waves — requirement	Require a medium

Electromagnetic waves — requirement	Do not require a medium
Light — wave type	Electromagnetic
Energy of a photon — relationship	E = hf
Increasing frequency — effect on wavelength	Decreases wavelength (if speed constant)
Wave interference — constructive condition	Waves in phase
Wave interference — destructive condition	Waves out of phase
	OCHEM
What defines a nucleophile?	An electron pair donor
What defines an electrophile?	An electron pair acceptor
Are nucleophiles typically electron-rich or electron-poor?	Electron-rich
Are electrophiles typically electron-rich or electron-poor?	Electron-poor
What type of charge do strong nucleophiles usually have?	Negative charge or lone pairs
What structural feature increases nucleophilicity?	Higher electron density
What structural feature increases electrophilicity?	Partial or full positive charge
What does resonance do to charge?	Delocalizes it
Does resonance stabilization increase or decrease reactivity?	Decrease
What does inductive effect describe?	Electron withdrawal or donation through sigma bonds
Do electronegative atoms exert inductive effects?	Yes — they withdraw electron density
What hybridization state is most stable for carbocations?	sp^2
Which carbocation is more stable: primary or tertiary?	Tertiary
What stabilizes carbocations?	Alkyl substitution and resonance
What destabilizes carbocations?	Electron-withdrawing groups
Which carbocation rearrangements commonly occur?	Hydride and methyl shifts
Do carbocation rearrangements occur before or after nucleophile attack?	Before
What hybridization state is most stable for carbanions?	sp
What stabilizes carbanions?	Electron-withdrawing groups
Are carbanions nucleophiles?	Yes
What does pKa measure?	Strength of an acid
Does a lower pKa indicate a stronger or weaker acid?	Stronger acid
What is the relationship between acid strength and conjugate base stability?	Stronger acid → more stable conjugate base
What factors stabilize a conjugate base?	Resonance, electronegativity, induction, hybridization
Which is more acidic: an alcohol or a carboxylic acid?	Carboxylic acid
Why are carboxylic acids more acidic than alcohols?	Resonance-stabilized conjugate base
Which is more acidic: phenol or cyclohexanol?	Phenol

Why is phenol more acidic than cyclohexanol?	Resonance stabilization				
Which hybridization gives the most acidic C–H bond: sp, sp^2, or sp^3?	sp				
Why are sp-hybridized C–H bonds more acidic?	Greater s-character stabilizes the conjugate base				
How does electronegativity affect acidity?	More electronegative atom stabilizes negative charge				
How do electron-withdrawing groups affect acidity?	Increase acidity				
How do electron-donating groups affect acidity?	Decrease acidity				
What solvent property increases nucleophilicity of anions?	Aprotic solvent				
Do polar protic solvents stabilize anions?	Yes				
In polar protic solvents, how does nucleophilicity change down a group?	It increases				
In polar aprotic solvents, how does nucleophilicity change across a period?	It increases				
Which solvent type favors SN2 reactions?	Polar aprotic				
Which solvent type stabilizes carbocations?	Polar protic				
Which solvent type favors SN1 reactions?	Polar protic				
What is the rate law for an SN1 reaction?	Rate depends on substrate concentration only				
What is the rate law for an SN2 reaction?	Rate depends on substrate and nucleophile				
What is the key intermediate in an SN1 reaction?	Carbocation				
Does an SN2 reaction form a carbocation?	No				
Which substrates favor SN1 reactions?	Tertiary (and some secondary)				
Which substrates favor SN2 reactions?	Primary and methyl				
Which reaction proceeds via backside attack?	SN2				
What stereochemical outcome results from SN2?	Inversion of configuration				
What stereochemical outcome results from SN1?	Racemization (mixture)				
Why does SN1 lead to racemization?	Planar carbocation intermediate				
What solvent type favors SN1 reactions?	Polar protic				
What solvent type favors SN2 reactions?	Polar aprotic				
Do strong nucleophiles favor SN1 or SN2?	SN2				
Do weak nucleophiles favor SN1 or SN2?	SN1				
What type of nucleophile is required for SN2?	Strong nucleophile				
Is steric hindrance favorable or unfavorable for SN2?	Unfavorable				
Does steric hindrance favor SN1?	Yes				
When do carbocation rearrangements occur in SN1?	Before nucleophile attack				
Can SN1 reactions undergo rearrangements?	Yes				
Can SN2 reactions undergo rearrangements?	No				
What is the rate law for an E1 reaction?	Rate depends on substrate concentration only				

What is the rate law for an E2 reaction?	Rate depends on substrate and base				
What key intermediate forms in an E1 reaction?	Carbocation				
Does E2 form a carbocation intermediate?	No				
Which substrates favor E1 reactions?	Tertiary (and some secondary)				
Which substrates favor E2 reactions?	Secondary and tertiary				
Which elimination reaction is concerted?	E2				
Which elimination reaction involves rearrangements?	E1				
Does E2 allow carbocation rearrangements?	No				
What stereochemical requirement does E2 have?	Anti-periplanar H and leaving group				
Which reaction favors Zaitsev products?	E1 and E2 with small bases				
What is the Zaitsev product?	More substituted alkene				
Which reaction favors Hofmann products?	E2 with bulky base				
What is the Hofmann product?	Less substituted alkene				
What type of base favors E2 reactions?	Strong base				
Does weak base favor E1 or E2?	E1				
Do polar protic solvents favor E1 or E2?	E1				
Do polar aprotic solvents favor E2?	Yes				
Can E1 and SN1 compete under similar conditions?	Yes				
Can E2 and SN2 compete under similar conditions?	Yes				
What reaction converts an alkene to an alkane?	Hydrogenation				
What reagent is used for catalytic hydrogenation?	H_2 with Pd, Pt, or Ni				
Does catalytic hydrogenation produce syn or anti addition?	Syn				
What reaction adds halogens (Br_2 or Cl_2) across a double bond?	Halogenation				
What intermediate forms during halogenation of alkenes?	Halonium ion				
Does halogenation result in syn or anti addition?	Anti				
What reaction adds HX across an alkene?	Hydrohalogenation				
What regioselectivity rule applies to hydrohalogenation?	Markovnikov’s rule				
What does Markovnikov’s rule state?	H adds to carbon with more hydrogens				
Why does Markovnikov addition occur?	Formation of more stable carbocation				
What reagent leads to anti-Markovnikov addition of HBr?	Peroxides (ROOR)				
Is the peroxide effect seen with HCl or HI?	No — HBr only				
What reaction adds water across an alkene under acidic conditions?	Acid-catalyzed hydration				
Is acid-catalyzed hydration Markovnikov or anti-Markovnikov?	Markovnikov				
What rearrangement risk exists in acid-catalyzed hydration?	Carbocation rearrangements				
What hydration method avoids rearrangements?	Oxymercuration–demercuration				

What regioselectivity does oxymercuration produce?	Markovnikov
Does oxymercuration involve carbocation rearrangements?	No
What hydration method gives anti-Markovnikov alcohols?	Hydroboration–oxidation
Is hydroboration–oxidation syn or anti addition?	Syn
What does oxidation mean in organic chemistry?	Loss of electrons / increase in bonds to O or heteroatoms
What does reduction mean in organic chemistry?	Gain of electrons / increase in bonds to H
Which alcohols can be oxidized to aldehydes?	Primary alcohols
Which alcohols can be oxidized to ketones?	Secondary alcohols
Can tertiary alcohols be oxidized under normal conditions?	No
What oxidizing agent converts primary alcohols to aldehydes without overoxidation?	PCC
What oxidizing agents convert primary alcohols to carboxylic acids?	Jones reagent, $KMnO_4$
What oxidizing agents convert secondary alcohols to ketones?	PCC, Jones reagent
What functional group defines an aldehyde?	Carbonyl at end of carbon chain
What functional group defines a ketone?	Carbonyl within carbon chain
Which carbonyl compound is more electrophilic: aldehyde or ketone?	Aldehyde
Why are aldehydes more reactive than ketones?	Less steric hindrance and weaker electron donation
What reagent reduces aldehydes and ketones to alcohols?	$NaBH_4$ or $LiAlH_4$
Does $NaBH_4$ reduce carboxylic acids?	No
Does $LiAlH_4$ reduce carboxylic acids?	Yes
What product results from reducing an aldehyde?	Primary alcohol
What product results from reducing a ketone?	Secondary alcohol
What functional group results from oxidizing an aldehyde?	Carboxylic acid
Are oxidation–reduction reactions reversible on the MCAT?	Context-dependent
What is the key MCAT cue for oxidation level?	Number of bonds to O vs H
What type of reaction do aldehydes and ketones most commonly undergo?	Nucleophilic addition
Why are carbonyl carbons electrophilic?	Polar C=O bond creates partial positive charge
Does nucleophilic addition increase or decrease saturation?	Decrease (π bond is broken)
What functional group forms when NH_3 or a primary amine reacts with a carbonyl?	Imine
What functional group forms when a secondary amine reacts with a carbonyl?	Enamine
Is imine formation reversible?	Yes
What condition generally promotes imine formation?	Mildly acidic conditions
What is reduced during imine formation?	Nothing (condensation reaction)
What functional group forms when an alcohol adds to a carbonyl?	Hemiacetal
What is a hemiacetal?	Carbon bonded to both –OH and –OR

What functional group forms when a second alcohol adds to a hemiacetal?	Acetal				
What is an acetal?	Carbon bonded to two –OR groups				
Are acetals stable in acidic or basic conditions?	Basic conditions				
What condition hydrolyzes acetals back to carbonyls?	Acidic conditions				
Why are acetals useful in synthesis?	They protect carbonyl groups				
Do ketones form acetals more slowly than aldehydes?	Yes				
Why are aldehydes more reactive in nucleophilic addition?	Less steric hindrance				
What happens to hybridization at the carbonyl carbon after nucleophilic addition?	$sp^2 \rightarrow sp^3$				
Does nucleophilic addition require a good leaving group?	No				
What is the key MCAT cue for carbonyl reactivity?	Aldehyde vs ketone distinction				
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What functional group defines a carboxylic acid?	Carbonyl attached to –OH
Why are carboxylic acids acidic?	Resonance-stabilized conjugate base
What type of reaction do carboxylic acid derivatives undergo?	Nucleophilic acyl substitution
What must leave during nucleophilic acyl substitution?	A leaving group
Which derivative is most reactive toward nucleophilic attack?	Acid chloride
Which derivative is least reactive?	Amide
Rank carboxylic acid derivatives from most to least reactive	Acid chloride > anhydride > ester > amide
What determines derivative reactivity?	Leaving group basicity
Which leaving groups are best?	Weak bases
Can an amide be converted directly to an ester without activation?	No
Can acid chlorides react with weak nucleophiles?	Yes
What product forms when an acid chloride reacts with an alcohol?	Ester
What product forms when an acid chloride reacts with an amine?	Amide
What reaction converts a carboxylic acid to an acid chloride?	$SOCl_2$
Are carboxylic acids good electrophiles?	No
Why are carboxylic acids poor electrophiles?	–OH is a poor leaving group
What must often be done to activate carboxylic acids?	Convert to a more reactive derivative
Do esters undergo nucleophilic acyl substitution readily?	Moderately
Why are amides the least reactive derivatives?	Strong resonance donation from N

What is the key MCAT cue for acyl substitution?	Identify leaving group quality			
What does IR spectroscopy primarily detect?	Functional groups			
What IR region corresponds to O–H stretch (alcohols/acids)?	~3200–3600 cm^{-1}			
What IR peak indicates an N–H stretch?	~3300 cm^{-1}			
What IR peak indicates a C=O stretch?	~1700 cm^{-1}			
What IR region corresponds to C–H stretches?	~2850–3000 cm^{-1}			
Do carboxylic acids show a broad O–H peak in IR?	Yes			
What does ^1H NMR spectroscopy detect?	Hydrogen environments			
What does chemical shift measure in NMR?	Degree of shielding			
Downfield shifts indicate what?	Deshielding			
What NMR feature indicates number of neighboring hydrogens?	Splitting pattern			
What is the n+1 rule?	Number of peaks = neighbors + 1			
What does integration in ^1H NMR represent?	Relative number of hydrogens			
Where do aromatic hydrogens typically appear in ^1H NMR?	~7–8 ppm			
Where do aldehyde hydrogens appear in ^1H NMR?	~9–10 ppm			
What does mass spectrometry measure?	Mass-to-charge ratio			
What does the molecular ion peak represent?	Intact molecule mass			
What does the base peak represent?	Most abundant fragment			
Does MS give structural connectivity directly?	No			
Which spectroscopy is best for determining molecular weight?	Mass spectrometry			
Which spectroscopy is best for identifying functional groups?	IR spectroscopy			
What does chromatography separate compounds based on?	Differences in affinity between stationary and mobile phases			
In TLC, which compounds travel farther up the plate?	Less polar compounds			
What does a higher Rf value indicate?	Greater movement / lower polarity			
What is the stationary phase in TLC?	Polar silica gel			
What is the mobile phase in TLC?	Solvent			
In column chromatography, which compounds elute first?	Less polar compounds			
What does increasing solvent polarity do in column chromatography?	Increases elution speed			
What does distillation separate compounds based on?	Boiling point differences			
When is simple distillation effective?	Large boiling point differences			
When is fractional distillation required?	Similar boiling points			
What does extraction separate compounds based on?	Differential solubility			
In acid–base extraction, what happens to charged species?	They become water-soluble			
What does recrystallization purify compounds based on?	Solubility vs temperature			

Why should recrystallization solvent dissolve compound when hot but not cold?	Allows crystal formation upon cooling				
What does SDS-PAGE separate proteins based on?	Molecular weight				
What lab technique separates proteins by charge?	Isoelectric focusing				
What does dialysis separate molecules based on?	Size				
What bond links amino acids together?	Peptide (amide) bond				
What reaction forms peptide bonds?	Condensation (dehydration)				
What organic functional group is present in peptide bonds?	Amide				
		Biochemistry Basics			
What structural feature is shared by all standard amino acids?	α-carbon bonded to amino group, carboxyl group, hydrogen, and R group				
What part of an amino acid determines its chemical behavior?	Side chain (R group)				
Does the peptide backbone largely determine protein function?	No				
What chemical roles can amino acid side chains play?	Acids/bases, H-bonding, charge, hydrophobic interactions				
What property primarily drives protein folding in water?	Hydrophobic side chains avoiding water				
Which class of amino acids tends to cluster in protein interiors?	Nonpolar (hydrophobic)				
Which class of amino acids commonly forms hydrogen bonds?	Polar, uncharged				
Which amino acids participate in ionic interactions at physiological pH?	Charged side chains				
What determines the charge state of an amino acid side chain?	pH relative to its pKa				
Can amino acid side chains gain or lose protons?	Yes				
Why are proteins sensitive to pH?	Side chain protonation states change				
Which amino acid is achiral?	Glycine				
Which amino acid configuration is used in biological proteins?	L-amino acids				
Does chirality mainly affect memorization or structure?	Structure				
Do amino acids behave the same in proteins as when free in solution?	No				
What constrains amino acid behavior inside proteins?	Local environment and neighboring residues				
Can the same amino acid behave differently in different proteins?	Yes				
What MCAT emphasis replaces memorizing amino acid names?	Chemical properties and functional grouping				
What is the most common MCAT trap about amino acids?	Assuming properties are fixed regardless of context				
Core MCAT takeaway: why can proteins do chemistry?	Side chains act as chemical tools in 3D space				
What is a zwitterion?	A molecule with both positive and negative charges				
At physiological pH, are free amino acids typically zwitterions?	Yes				
What two groups on all amino acids can be ionized?	Amino group and carboxyl group				
When pH < pKa, is a group protonated or deprotonated?	Protonated				
When pH > pKa, is a group protonated or deprotonated?	Deprotonated				
At very low pH, what is the net charge of an amino acid?	Positive				

At very high pH, what is the net charge of an amino acid?	Negative
What is the isoelectric point (pI)?	pH at which net charge is zero
At the pI, does an amino acid migrate in an electric field?	No
If pH < pI, what is the net charge of the amino acid?	Positive
If pH > pI, what is the net charge of the amino acid?	Negative
Which amino acid side chains are commonly ionizable on the MCAT?	Asp, Glu, His, Lys, Arg, Tyr, Cys
Which amino acid side chains are negatively charged at physiological pH?	Aspartate, Glutamate
Which amino acid side chains are positively charged at physiological pH?	Lysine, Arginine
Which amino acid has a side-chain pKa near physiological pH?	Histidine
Why is histidine especially important in enzyme active sites?	It can gain or lose protons near pH 7
Do peptide bonds ionize under physiological conditions?	No
In proteins, which groups usually contribute to net charge?	Side chains, N-terminus, C-terminus
Does changing pH alter protein charge distribution?	Yes
Key MCAT trap: are amino acid charges fixed?	No — they depend on pH and environment
What defines a protein’s primary structure?	Amino acid sequence
What type of bond links amino acids in primary structure?	Peptide (amide) bond
Does denaturation break peptide bonds?	No
What interactions stabilize secondary structure?	Backbone hydrogen bonds
Which two secondary structures are most common?	α-helices and β-sheets
Do side chains create secondary structure?	No
What determines where secondary structures form?	Amino acid sequence and environment
What defines tertiary structure?	Overall 3D shape of a single polypeptide
What is the dominant force driving tertiary structure in water?	Hydrophobic interactions
Which interactions can stabilize tertiary structure?	Hydrophobic, H-bonds, ionic, disulfide
What type of bond is a disulfide bond?	Covalent
Where do disulfide bonds most often form?	Oxidizing environments (e.g., extracellular)
What defines quaternary structure?	Association of multiple polypeptide chains
Do all proteins have quaternary structure?	No
What forces stabilize quaternary structure?	Same as tertiary structure
What is hydrophobic collapse?	Nonpolar residues clustering inward
Why does hydrophobic collapse occur?	To minimize free energy in water
What does denaturation disrupt first?	Secondary, tertiary, quaternary structure
What common factors cause denaturation?	Heat, extreme pH, chemicals
Key MCAT trap: does loss of structure mean loss of sequence?	No — sequence remains intact

Is protein folding thermodynamically favorable?	Yes (ΔG < 0)
What does it mean that protein folding is spontaneous?	It occurs without energy input
What primarily guides protein folding?	Amino acid sequence
Do proteins require external instructions to fold correctly?	No
What cellular problem do chaperone proteins prevent?	Misfolding and aggregation
Do chaperones encode the final protein structure?	No
When are chaperone proteins especially important?	Crowded or stressful cellular conditions
Can a protein refold after denaturation?	Sometimes, if primary structure is intact
What type of interactions are disrupted during denaturation?	Noncovalent interactions
What happens to protein function upon denaturation?	It is lost
What does misfolding often lead to?	Aggregation or loss of function
What biological consequence can protein aggregation have?	Disease
Does folding aim to maximize symmetry?	No
What is the true goal of protein folding?	Lowest free energy state
Do folding pathways vary between proteins?	Yes
What environment promotes hydrophobic collapse?	Aqueous environment
What happens to hydrophobic residues during folding?	They move to the protein interior
Are folding intermediates usually stable?	No
Does incorrect folding always result in permanent damage?	No
Key MCAT trap: do chaperones make folding energetically favorable?	No — they assist, not drive
What is the defining feature of an enzyme?	It is a biological catalyst
Do enzymes change the ΔG of a reaction?	No
How do enzymes increase reaction rate?	By lowering activation energy
What part of the enzyme carries out catalysis?	Active site
Is the active site a continuous sequence of amino acids?	No
What forms the active site chemically?	Amino acids brought together by folding
What two properties define enzyme specificity?	Shape and chemical complementarity
What does the lock-and-key model assume?	Pre-formed rigid active site
What does the induced-fit model propose?	Binding induces conformational change
Which model better explains transition-state stabilization?	Induced fit
What do enzymes stabilize more than substrates?	Transition state
Do enzymes add energy to reactions?	No
Can enzymes change equilibrium position?	No
What structural feature limits maximum enzyme rate?	Finite number of active sites
What does enzyme saturation mean?	All active sites are occupied

What happens to reaction rate at saturation?	It plateaus
What property of enzymes explains saturation?	Structural binding limitation
What environmental factors can reduce enzyme activity?	Temperature, pH, ionic strength
Does enzyme inactivation usually involve bond breakage?	No
Key MCAT trap: do enzymes force reactions forward?	No — they reshape the pathway
What reaction scheme underlies Michaelis–Menten kinetics?	$E + S \rightleftharpoons ES \rightarrow E + P$
What does Vmax represent?	Maximum reaction rate
When is Vmax reached?	When all enzyme active sites are occupied
Does Vmax depend on substrate concentration?	No
What does Vmax depend on?	Enzyme concentration and catalytic capacity
What happens to Vmax if enzyme concentration doubles?	Vmax doubles
What is Km defined as?	Substrate concentration at ½ Vmax
What does a low Km indicate?	Effective binding at low substrate
What does a high Km indicate?	Poor binding / higher substrate needed
Is Km a pure binding affinity constant?	No
What processes contribute to Km?	Binding, unbinding, and catalysis
At low substrate concentration ([S] ≪ Km), how does rate depend on [S]?	Approximately linear
At high substrate concentration ([S] ≫ Km), how does rate depend on [S]?	Independent of [S]
What does enzyme saturation mean structurally?	All active sites are occupied
What shape does a Michaelis–Menten curve have?	Hyperbolic
Does the MM curve ever become linear at high [S]?	No
What biological advantage comes from enzymes operating near Km?	Sensitivity to substrate changes
Does increasing substrate always increase rate?	No
What limits reaction rate at saturation?	Enzyme availability
Key MCAT trap: does Km equal affinity?	No — only approximates it under specific conditions
At very low substrate concentration, what limits reaction rate?	Substrate availability
At very high substrate concentration, what limits reaction rate?	Enzyme availability
When [S] ≪ Km, how does reaction rate change with [S]?	Increases nearly linearly
When [S] ≫ Km, how does reaction rate change with [S]?	It plateaus
What does the plateau of the MM curve represent?	Vmax
What does a steeper initial slope of the MM curve indicate?	Lower Km
What does a right-shifted MM curve suggest?	Higher Km
Does changing substrate concentration change Vmax?	No
What parameter change most directly reflects enzyme loss or mutation?	Decreased Vmax

What parameter change reflects altered substrate binding?	Km				
Why do cells often keep enzyme activity near Km?	Allows regulation by small [S] changes				
What happens to rate if substrate increases when enzyme is saturated?	No change				
Does the MM curve reflect reaction inefficiency at high [S]?	No				
What structural reality explains MM curve shape?	Finite active sites				
Can two enzymes have the same Vmax but different Km?	Yes				
Can two enzymes have the same Km but different Vmax?	Yes				
What happens to MM curve if enzyme concentration decreases?	Vmax decreases				
What happens to MM curve if enzyme concentration increases?	Vmax increases				
Key MCAT cue: flat curve at high [S] means what?	Saturation				
Key MCAT trap: does plateau mean reaction stopped?	No — r				
What is the defining feature of enzyme inhibition?	Reduced reaction rate due to interference				
What two strategies do all inhibitors use?	Compete for binding or reduce catalytic capacity				
What type of inhibitor competes with substrate for the active site?	Competitive inhibitor				
What happens to Km in competitive inhibition?	Km increases				
What happens to Vmax in competitive inhibition?	Unchanged				
Can competitive inhibition be overcome by increasing substrate?	Yes				
Where does a noncompetitive inhibitor bind?	Site other than active site				
What happens to Vmax in noncompetitive inhibition?	Vmax decreases				
What happens to Km in noncompetitive inhibition?	Unchanged				
Can noncompetitive inhibition be overcome by substrate?	No				
What happens to both Km and Vmax in mixed inhibition?	Vmax decreases; Km changes				
Where does a mixed inhibitor bind?	Allosteric site				
What type of inhibitor binds only to ES complex?	Uncompetitive inhibitor				
What happens to Vmax in uncompetitive inhibition?	Vmax decreases				
What happens to Km in uncompetitive inhibition?	Km decreases				
Why does Km decrease in uncompetitive inhibition?	ES is stabilized				
Which inhibition type preserves substrate binding?	Noncompetitive				
Which inhibition type reduces apparent affinity?	Competitive				
Which inhibition type cannot be overcome by substrate?	Noncompetitive				
Key MCAT cue: Vmax decreases, Km unchanged → what inhibition?	Noncompetitive				
What defines an allosteric site?	A regulatory binding site distinct from the active site				
Does allosteric regulation block the active site directly?	No				
How does allosteric binding alter enzyme activity?	By changing enzyme conformation				

Can allosteric effectors activate enzymes?	Yes
Can allosteric effectors inhibit enzymes?	Yes
Are allosteric interactions reversible?	Yes
What type of enzymes most often show allosteric regulation?	Multisubunit enzymes
What is cooperative binding?	Binding at one site alters affinity at other sites
What kinetic curve shape indicates cooperativity?	Sigmoidal (S-shaped)
How does cooperativity affect sensitivity to substrate concentration?	It increases sensitivity
Does cooperativity follow Michaelis–Menten kinetics?	No
What parameter replaces Km conceptually in cooperative enzymes?	$K_{0.5}$ (or apparent Km)
What happens to enzyme activity when an allosteric activator binds?	Activity increases
What happens to enzyme activity when an allosteric inhibitor binds?	Activity decreases
What is feedback inhibition?	End product inhibits an early pathway enzyme
What type of regulation is feedback inhibition?	Allosteric
What problem does feedback inhibition prevent?	Overproduction of products
Why is allosteric regulation fast?	It does not require gene expression
What cellular signals commonly act as allosteric regulators?	ATP, ADP, AMP, metabolites
Key MCAT trap: is allosteric regulation permanent?	No — it is reversible
What is metabolic control?	Regulation of pathway flux through enzyme activity
What does pathway “flux” describe?	Rate of product formation through a pathway
Do cells primarily regulate metabolism by changing enzymes or activity?	Activity
What type of regulation is fastest?	Allosteric regulation
What type of regulation is slowest?	Gene expression
Why is gene expression slow as a regulatory mechanism?	Requires transcription and translation
What is the key advantage of allosteric regulation?	Fast and reversible control
What type of enzyme is most commonly regulated in pathways?	Early or rate-limiting enzymes
What property makes early pathway enzymes ideal control points?	They influence downstream flux
What happens to pathway flux if a rate-limiting enzyme is inhibited?	Flux decreases
Does inhibiting a non-rate-limiting enzyme always affect flux?	No
What is feedback inhibition sensing?	End-product concentration
What happens to enzyme shape during allosteric regulation?	Conformation changes
Can enzyme activity change without changing enzyme amount?	Yes
What cellular condition often triggers regulatory responses?	Energy imbalance
What nucleotide signals low-energy state?	AMP
What nucleotide signals high-energy state?	ATP
What is the MCAT trap about enzyme quantity and activity?	They are not equivalent

Does pathway regulation usually involve irreversible changes?	No				
Core MCAT takeaway: how do cells control metabolism?	By controlling enzyme shape and activity				
		Acids, Buffers, Redox			
What is the only acid–base definition that matters for biology?	Brønsted–Lowry				
What is a Brønsted–Lowry acid?	Proton donor				
What is a Brønsted–Lowry base?	Proton acceptor				
Are biological acid–base reactions proton transfer reactions?	Yes				
What forms when an acid donates a proton?	Conjugate base				
What forms when a base accepts a proton?	Conjugate acid				
Are acid–base reactions one-way or reversible?	Reversible				
What does acid strength reflect?	Willingness to donate a proton				
What does base strength reflect?	Willingness to accept a proton				
What is the relationship between acid strength and conjugate base strength?	Inversely related				
Do strong acids have strong or weak conjugate bases?	Weak				
What does pKa represent conceptually?	Proton tipping point				
At pH = pKa, what fraction is protonated?	50%				
If pH < pKa, which form dominates?	Protonated				
If pH > pKa, which form dominates?	Deprotonated				
Does pKa require memorization of Ka values on the MCAT?	No				
What does comparing pH to pKa allow you to predict?	Charge state				
Why does pH affect enzyme activity?	Side-chain protonation changes				
Where do most biological acid–base reactions occur?	Within proteins				
Core MCAT takeaway: what is acid–base chemistry in biology?	Proton bookkeeping				
What is a buffer?	A solution with a weak acid and its conjugate base				
What is the core function of a buffer?	Resist changes in pH				
Do buffers keep pH perfectly constant?	No				
How does a buffer respond when acid (H^+) is added?	Conjugate base binds excess protons				
How does a buffer respond when base (OH^-) is added?	Weak acid donates protons				
What two components must a buffer contain?	Weak acid and conjugate base				
Do strong acids make good buffers?	No				
Why must buffer acids be weak?	They partially dissociate				
When is buffer capacity highest?	When pH ≈ pKa				
Why is buffer capacity highest at pH ≈ pKa?	Acid and base forms are balanced				
What happens to buffer effectiveness far from pKa?	It decreases				

Can buffer capacity be exceeded?	Yes
What does the Henderson–Hasselbalch relationship link?	pH, pKa, and acid/base ratio
Conceptually, what increases pH in a buffer?	More conjugate base
Conceptually, what decreases pH in a buffer?	More weak acid
Does Henderson–Hasselbalch require calculation on the MCAT?	Rarely
What does Henderson–Hasselbalch primarily tell you?	Which form dominates
Does a buffer “fix” pH?	No — it slows pH change
Where does biological buffering occur?	Blood, cytosol, active sites
Key MCAT trap: do buffers prevent pH shifts?	No — they resist them
Why do enzymes have an optimal pH?	Correct protonation of key side chains
What happens to enzyme activity outside its optimal pH range?	Activity decreases or stops
What molecular change most directly causes pH-dependent loss of activity?	Altered side-chain charges
Can pH changes disrupt ionic interactions in proteins?	Yes
Can pH changes disrupt hydrogen bonds in proteins?	Yes
Does extreme pH affect protein tertiary structure?	Yes
Does pH change usually break peptide bonds?	No
What aspect of enzyme function is most sensitive to pH?	Active-site chemistry
Why can small pH changes have large effects on enzymes?	Side chains are near their pKa values
Do all enzymes share the same optimal pH?	No
What determines an enzyme’s optimal pH?	Local chemical environment
Is enzyme pH sensitivity mainly a global or local effect?	Local
What does “local pH” mean in enzymology?	pH within the active-site microenvironment
Can active sites experience pH different from bulk solution?	Yes
Why is buffering important for enzyme function?	Maintains proper protonation states
Do buffers act uniformly throughout the cell?	No
What happens to enzyme activity if buffering capacity is exceeded?	Activity can collapse
Does buffering guarantee enzyme activity?	No — it only stabilizes conditions
Key MCAT trap: does optimal pH mean strongest binding?	No — it means proper catalysis
Core MCAT takeaway: why does pH control biology?	It controls proton location in proteins
What defines an oxidation–reduction (redox) reaction?	Transfer of electrons
What does oxidation mean?	Loss of electrons
What does reduction mean?	Gain of electrons
In biology, what often accompanies oxidation?	Loss of hydrogen
In biology, what often accompanies reduction?	Gain of hydrogen

Can oxidation and reduction occur separately?	No — they are coupled			
What is the reducing agent?	The electron donor			
What is the oxidizing agent?	The electron acceptor			
When a molecule is oxidized, what happens to the other reactant?	It is reduced			
What carries energy in biological redox reactions?	Electrons			
Why are electrons considered “high-energy” when reduced?	They can be transferred to do work			
Do redox reactions create energy?	No — they transfer it			
What happens to potential energy as electrons fall to lower-energy states?	Energy is released			
What type of reactions power metabolism?	Redox reactions			
Are most metabolic pathways overall oxidative or reductive?	Oxidative (catabolic)			
Are anabolic pathways more oxidative or reductive?	Reductive			
Why must cells carefully control redox reactions?	Uncontrolled energy release is harmful			
What cellular process is fundamentally a redox cascade?	Electron transport			
Does oxidation always involve oxygen?	No			
Core MCAT trap: does redox equal bond breaking?	No — it equals electron transfer			
What is the primary role of NAD^+ in metabolism?	Electron carrier			
What does NAD^+ become when it is reduced?	NADH			
How many electrons does NAD^+ accept when reduced?	Two electrons			
How many protons are transferred with NAD^+ reduction?	One proton (second proton released to solution)			
Is NADH the oxidized or reduced form?	Reduced			
Does NAD^+ primarily participate in catabolic or anabolic pathways?	Catabolic			
What happens to NADH in the electron transport chain?	It is oxidized			
What is the primary role of FAD?	Electron carrier			
What does FAD become when it is reduced?	$FADH_2$			
How many electrons does FAD accept when reduced?	Two electrons			
How many protons does $FADH_2$ carry?	Two protons			
How does FAD binding differ from NAD^+ binding?	FAD is enzyme-bound			
Does $FADH_2$ generally produce more or less ATP than NADH?	Less			
Why does $FADH_2$ yield less ATP than NADH?	It enters ETC at a lower energy level			
Are NAD^+/NADH consumed in reactions?	No — they are recycled			
What does a high NADH/NAD^+ ratio indicate?	Reduced cellular state			
What does a high NAD^+/NADH ratio indicate?	Oxidized cellular state			
What happens to metabolism if NAD^+ is depleted?	Oxidation reactions stall			
Why are redox carriers essential for metabolism?	They shuttle electrons safely			
Core MCAT trap: do NADH and $FADH_2$ store ATP?	No — they store electrons			

What ultimately determines the direction of redox reactions?	Relative electron affinity / energy levels
Do electrons spontaneously move to higher-energy states?	No
What does a favorable redox reaction accomplish biologically?	Releases usable energy
How is energy from redox reactions captured in cells?	Via electron carriers and proton gradients
Why must redox reactions be coupled to other processes?	To harness released energy
What happens if electrons are transferred directly to oxygen?	Energy is released uncontrollably
How do cells prevent uncontrolled redox reactions?	Stepwise electron transfer
What role does buffering play during redox reactions?	Stabilizes proton concentrations
Why are protons important in redox reactions?	Electron transfer often moves protons
What happens to pH if redox-generated protons are not buffered?	pH changes dramatically
Why is redox chemistry inseparable from acid–base chemistry?	Electrons and protons move together
What happens to NADH after it donates electrons?	It becomes NAD^+
What happens to $FADH_2$ after it donates electrons?	It becomes FAD
Are redox carriers consumed during metabolism?	No
What determines whether NAD^+ or FAD is used in a reaction?	Enzyme active-site chemistry
What cellular condition favors oxidation reactions?	High NAD^+/NADH ratio
What cellular condition favors reduction reactions?	High NADH/NAD^+ ratio
What happens to metabolism if redox balance is disrupted?	Pathways stall or reverse
Key MCAT trap: does buffering affect redox direction?	No — it affects proton handling
Core MCAT takeaway: how do cells safely extract energy?	Controlled electron and proton flow
	Metabolism
What is the primary goal of metabolism?	Extract usable energy from nutrients
Are metabolic pathways isolated or interconnected?	Interconnected
What type of pathway is glycolysis overall?	Catabolic
Does glycolysis require oxygen?	No
Where does glycolysis occur?	Cytosol
What is the net ATP yield of glycolysis per glucose?	2 ATP
What is the net NADH yield of glycolysis per glucose?	2 NADH
What molecule is the end product of glycolysis?	Pyruvate
What type of reactions define irreversible steps in metabolism?	Large negative ΔG steps
Why are irreversible steps important?	They are regulatory control points
Which glycolytic steps are irreversible?	Hexokinase, PFK-1, pyruvate kinase
Which glycolytic enzyme is the primary rate-limiting enzyme?	Phosphofructokinase-1 (PFK-1)

What does ATP generally signal in metabolism?	High-energy state			
What does AMP generally signal in metabolism?	Low-energy state			
Does increasing substrate always increase pathway flux?	No			
What determines pathway flux most strongly?	Regulation of key enzymes			
What happens to pathways when energy is abundant?	Catabolic pathways slow			
What happens to pathways when energy is low?	Catabolic pathways accelerate			
What is substrate-level phosphorylation?	Direct ATP formation from a substrate			
Core MCAT takeaway: how is metabolism regulated?	By controlling irreversible steps			
- (Question / Prompt)	**-**			
What are the two phases of glycolysis?	Energy investment and energy payoff			
How many ATP are invested in glycolysis per glucose?	2 ATP			
At what step is the first ATP invested?	Hexokinase			
At what step is the second ATP invested?	Phosphofructokinase-1			
How many ATP are produced in the payoff phase?	4 ATP			
What is the net ATP gain from glycolysis?	2 ATP			
At what steps is ATP generated in glycolysis?	Phosphoglycerate kinase and pyruvate kinase			
How many NADH are produced per glucose in glycolysis?	2 NADH			
At what step is NADH produced in glycolysis?	Glyceraldehyde-3-phosphate dehydrogenase			
Why does glycolysis yield 2 NADH?	One glucose forms two G3P molecules			
Does glycolysis require mitochondria?	No			
What happens to glycolysis when oxygen is absent?	It continues			
Why must NAD^+ be regenerated for glycolysis to continue?	GAPDH requires NAD^+			
What process regenerates NAD^+ anaerobically?	Fermentation			
What is the purpose of fermentation?	Regenerate NAD^+			
Does fermentation produce additional ATP?	No			
What are the two common fermentation end products in humans?	Lactate			
What happens to pyruvate during fermentation?	It is reduced			
What happens to NADH during fermentation?	It is oxidized to NAD^+			
Core MCAT trap: does fermentation increase ATP yield?	No			
- (Question / Prompt)	**-**			
Which enzyme is the primary regulatory enzyme of glycolysis?	Phosphofructokinase-1 (PFK-1)			
Why is PFK-1 the key control point of glycolysis?	It catalyzes the committed step			
What molecule allosterically inhibits PFK-1?	ATP			
What molecule allosterically activates PFK-1?	AMP			
How does ATP inhibit PFK-1 mechanistically?	Signals high-energy state			
Why is AMP a strong activator of PFK-1?	Signals low-energy state			

Does ADP activate or inhibit PFK-1?	Activates (less strongly than AMP)
What metabolite inhibits PFK-1 in the liver?	Citrate
What does citrate inhibition indicate?	TCA cycle is saturated
What hormone generally promotes glycolysis?	Insulin
What hormone generally inhibits glycolysis?	Glucagon
In which tissue is hormonal regulation of glycolysis most important?	Liver
Why is liver glycolysis hormonally regulated?	To maintain blood glucose levels
Does muscle glycolysis respond strongly to glucagon?	No
What enzyme catalyzes the first step of glycolysis?	Hexokinase (glucokinase in liver)
Why is hexokinase considered regulatory?	It traps glucose in the cell
How does glucokinase differ from hexokinase?	Lower affinity, liver-specific
Why does the liver use glucokinase instead of hexokinase?	Prevents trapping glucose at low levels
What enzyme catalyzes the final step of glycolysis?	Pyruvate kinase
Core MCAT trap: is glycolysis regulated by every step?	No — mainly irreversible steps
- (Question / Prompt)	**-**
What are the three main fates of pyruvate in human cells?	Oxidation to acetyl-CoA, fermentation, carboxylation
Where does pyruvate oxidation occur?	Mitochondrial matrix
What enzyme complex converts pyruvate to acetyl-CoA?	Pyruvate dehydrogenase (PDH)
Is pyruvate dehydrogenase a single enzyme or complex?	Multi-enzyme complex
What type of reaction does PDH catalyze?	Oxidative decarboxylation
What carbon product is released during PDH reaction?	CO_2
What electron carrier is reduced during PDH?	$NAD^+ \rightarrow NADH$
What metabolic product links glycolysis to the TCA cycle?	Acetyl-CoA
Is the PDH reaction reversible?	No
Why is PDH considered a key regulatory point?	It commits carbon to oxidation
What energy signals inhibit PDH?	ATP, NADH, acetyl-CoA
What energy signals activate PDH?	ADP, NAD^+
What vitamin-derived cofactor is essential for PDH?	Thiamine (B_1)
What happens to acetyl-CoA if the TCA cycle is saturated?	It accumulates or is diverted
Can acetyl-CoA be converted back to glucose in humans?	No
Why can’t acetyl-CoA be used for net glucose synthesis?	Carbon is lost as CO_2
What pathway uses acetyl-CoA to store energy?	Fatty acid synthesis
What happens to pyruvate during anaerobic conditions?	It is reduced to lactate
What is the purpose of lactate formation?	Regenerate NAD^+
Core MCAT trap: is PDH part of the TCA cycle?	No — it is a link reaction
- (Question / Prompt)	**-**

What is the primary purpose of the TCA cycle?	Oxidize acetyl-CoA to harvest high-energy electrons				
Where does the TCA cycle occur?	Mitochondrial matrix				
What molecule enters the TCA cycle?	Acetyl-CoA				
How many carbons enter the TCA cycle per turn?	Two				
How many carbons are released per turn of the TCA cycle?	Two (as CO_2)				
Are the carbons released in the first turn from acetyl-CoA?	No				
How many NADH are produced per turn of the TCA cycle?	3 NADH				
How many $FADH_2$ are produced per turn of the TCA cycle?	1 $FADH_2$				
How many GTP (or ATP) are produced per turn?	1				
What type of phosphorylation produces GTP in the TCA cycle?	Substrate-level phosphorylation				
What molecule is regenerated at the end of the cycle?	Oxaloacetate				
Why is the TCA cycle considered amphibolic?	Serves catabolic and anabolic roles				
What happens to the TCA cycle when NADH accumulates?	It slows				
What energy signals inhibit the TCA cycle?	ATP, NADH				
What energy signals activate the TCA cycle?	ADP, NAD^+				
What is the rate-limiting enzyme of the TCA cycle?	Isocitrate dehydrogenase				
Why are irreversible steps important in the TCA cycle?	They are control points				
Does the TCA cycle run without oxygen?	No (indirectly requires O_2)				
Why is oxygen required for the TCA cycle to continue?	To regenerate NAD^+ and FAD				
Core MCAT trap: does the TCA cycle directly use oxygen?	No				
- (Question / Prompt)	**-**				
Where is the electron transport chain located?	Inner mitochondrial membrane				
What is the primary purpose of the ETC?	Convert electron energy into a proton gradient				
What molecules donate electrons to the ETC?	NADH and $FADH_2$				
Which complex receives electrons from NADH?	Complex I				
Which complex receives electrons from $FADH_2$?	Complex II				
Why does $FADH_2$ yield less ATP than NADH?	Enters at Complex II (bypasses Complex I)				
What molecule is the final electron acceptor in the ETC?	Oxygen				
What forms when oxygen accepts electrons?	Water				
What happens to the ETC if oxygen is absent?	It stops				
Why does lack of oxygen halt the TCA cycle?	NAD^+ is not regenerated				
What drives proton pumping in the ETC?	Energy released from electron transfer				
Which complexes pump protons?	Complexes I, III, and IV				
Where are protons pumped to?	Intermembrane space				
What gradient is created by the ETC?	Electrochemical proton gradient				
What is the proton-motive force?	Energy stored in the proton gradient				

What enzyme uses the proton gradient to make ATP?	ATP synthase				
What type of phosphorylation occurs at ATP synthase?	Oxidative phosphorylation				
Does electron flow directly make ATP?	No				
What directly drives ATP synthase?	Proton flow back into the matrix				
Core MCAT trap: does oxygen make ATP directly?	No				
- (Question / Prompt)	**-**				
What is the approximate ATP yield per NADH in oxidative phosphorylation?	~2.5 ATP				
What is the approximate ATP yield per $FADH_2$?	~1.5 ATP				
Why are ATP yields “approximate” on the MCAT?	Proton leak and shuttle variability				
What is coupling in oxidative phosphorylation?	Linking electron transport to ATP synthesis				
What happens when the ETC is uncoupled?	Electron transport continues, ATP synthesis decreases				
What happens to oxygen consumption during uncoupling?	It increases				
What happens to heat production during uncoupling?	It increases				
What protein physiologically uncouples the ETC in brown fat?	Thermogenin (UCP1)				
What is the purpose of brown fat uncoupling?	Heat generation				
What happens to proton gradient during uncoupling?	It is dissipated				
What type of molecule is cyanide?	ETC inhibitor				
What does cyanide inhibit?	Complex IV				
What happens to ATP production with cyanide poisoning?	It stops				
What happens to electron flow with cyanide poisoning?	It stops				
What happens to oxygen consumption with cyanide poisoning?	It decreases				
What is the effect of oligomycin?	Inhibits ATP synthase				
What happens to proton gradient with oligomycin?	It increases				
What happens to electron flow with oligomycin?	It slows or stops				
What is the effect of an uncoupler on proton gradient?	Decreases gradient				
Core MCAT trap: does more oxygen always mean more ATP?	No				
- (Question / Prompt)	**-**				
What three things should you always track in metabolism?	Carbon, electrons, and usable energy				
Why is tracking carbon important in metabolic pathways?	It tells you what molecules can be made next				
Why is tracking electrons critical in metabolism?	Electron flow determines energy capture				
What primarily stores usable energy during metabolism?	Reduced electron carriers and gradients				
Is ATP the main long-term energy store in cells?	No				
What is ATP best described as?	A local energy transfer molecule				
Where is most metabolic energy stored before ATP synthesis?	NADH, $FADH_2$, and proton gradients				
Why don’t cells convert all energy directly into ATP immediately?	ATP is unstable and inefficient for long-term storage				
What happens to electrons before ATP is made?	They are transferred stepwise				

Why are metabolic pathways broken into many steps?	To control energy release
What happens if electrons fall to oxygen all at once?	Energy is released uncontrollably
What principle explains why oxygen is the final electron acceptor?	Lowest energy electron state
What is metabolic flux?	Rate of material flow through a pathway
What primarily controls metabolic flux?	Enzyme regulation, not substrate amount
Why do cells regulate irreversible steps?	They commit substrates directionally
What is a futile cycle?	Opposing pathways running simultaneously
Why are futile cycles avoided?	They waste energy
How do cells prevent futile cycles?	Reciprocal regulation
Why are branch points major regulatory targets?	They determine pathway direction
Core MCAT rule: how do you reason through metabolism questions?	Follow carbon, electrons, then energy
Amino acids that absorb UV light (~280 nm)	Tryptophan, Tyrosine (Phenylalanine weakly)
Primary amino acid used for UV protein quantification	Tryptophan
Amino acids commonly phosphorylated	Serine, Threonine, Tyrosine
Amino acid capable of forming disulfide bonds	Cysteine
Amino acid with thiol (-SH) side chain	Cysteine
Most basic amino acid	Arginine
Amino acid with side-chain pKa closest to physiological pH	Histidine
Amino acid commonly acting as a biological buffer	Histidine
Amino acids with aromatic side chains	Phenylalanine, Tyrosine, Tryptophan
Amino acids with branched side chains	Leucine, Isoleucine, Valine
Amino acid that introduces kinks in protein structure	Proline
Amino acid with secondary amine	Proline
Amino acids that are negatively charged at physiological pH	Aspartate, Glutamate
Amino acids that are positively charged at physiological pH	Lysine, Arginine
Amino acid side chain most likely to participate in acid–base catalysis	Histidine
Amino acids commonly acetylated or methylated	Lysine, Arginine
Amino acid with phenolic hydroxyl group	Tyrosine
Amino acid with highest tendency to form hydrogen bonds	Serine, Threonine
Amino acid most sensitive to oxidation	Cysteine
Amino acid classification of glycine	Nonpolar, achiral
-	**Back**
Metabolism — MCAT framing	Network of chemical reactions that manage energy and resources
Catabolic pathways — definition	Break down molecules to release energy
Anabolic pathways — definition	Build molecules using energy
Glycolysis — cellular location	Cytosol

Glycolysis — input molecule	Glucose				
Glycolysis — end product	Pyruvate				
Glycolysis — net ATP yield per glucose	2 ATP				
Glycolysis — net reducing equivalents produced	2 NADH				
Pyruvate oxidation — cellular location	Mitochondrial matrix				
Pyruvate oxidation — key conversion	Pyruvate → acetyl-CoA				
Pyruvate oxidation — reducing equivalents produced	NADH				
Citric acid (TCA) cycle — cellular location	Mitochondrial matrix				
TCA cycle — input molecule	Acetyl-CoA				
TCA cycle — main purpose	Oxidize acetyl-CoA to CO_2				
TCA cycle — reducing equivalents per turn	3 NADH, 1 $FADH_2$				
TCA cycle — ATP (or equivalent) per turn	1 GTP (≈ ATP)				
Electron transport chain — cellular location	Inner mitochondrial membrane				
Electron transport chain — main function	Create proton gradient				
Oxidative phosphorylation — definition	ATP synthesis driven by proton gradient				
ATP synthase — energy source	Proton-motive force				
Final electron acceptor in ETC	Oxygen				
Result of ETC electron transfer to oxygen	Water				
Fermentation — when it occurs	Absence of oxygen				
Fermentation — primary purpose	Regenerate NAD^+				
Lactic acid fermentation — product	Lactate				
Alcohol fermentation — products	Ethanol and CO_2				
NADH — primary role	Electron carrier for ATP production				
$FADH_2$ — primary role	Electron carrier (enters ETC downstream of NADH)				
Pentose phosphate pathway — key purpose	Produce NADPH and ribose-5-phosphate				
NADPH — primary biological role	Reductive biosynthesis and antioxidant defense				
		Physiological Mechanics			
What form of energy is stored in charge separation?	Electrical potential energy				
What is an electrochemical gradient composed of?	Chemical force + electrical force				
Does concentration alone determine ion movement?	No				
What determines the direction of ion movement across membranes?	Net electrochemical force				
Why does charge separation across a membrane store energy?	It creates electrical potential				
What physical structure is required to maintain electrical potential?	A membrane				
If ions could move freely, would a membrane potential persist?	No				

What does oxidation mean in electrochemistry?	Loss of electrons			
What does reduction mean in electrochemistry?	Gain of electrons			
Why do electrons move spontaneously between substances?	Differences in reduction tendency			
What does reduction potential represent conceptually?	Tendency to accept electrons			
Do electrons flow from higher or lower reduction potential?	Lower → higher			
Why is oxygen a powerful terminal electron acceptor?	High reduction tendency			
What happens when electrons move to lower-energy states?	Energy is released			
How can energy from electron flow be used biologically?	To create gradients or do work			
In biology, what replaces wires and batteries?	Membranes and gradients			
What two forces act on ions across membranes?	Chemical and electrical			
Can ions move against concentration gradients?	Yes, if electrical force dominates			
What MCAT trap assumes concentration alone determines movement?	Ignoring electrical force			
Core MCAT takeaway: what is electrochemistry really about?	Energy stored in gradients			
- (Question / Prompt)	**-**			
What is an equilibrium potential for an ion?	Membrane voltage that prevents net ion movement			
When an ion is at equilibrium, is it still moving?	Yes, but net movement is zero			
What two forces are balanced at equilibrium potential?	Electrical and chemical forces			
What does the Nernst equation conceptually calculate?	Equilibrium potential for one ion			
Does the Nernst equation apply to multiple ions at once?	No			
What happens to equilibrium potential if ion concentration gradient increases?	It becomes more extreme			
For a cation, what does a more positive equilibrium potential indicate?	Stronger outward chemical force			
For an anion, how does charge affect equilibrium direction?	Electrical force reverses direction			
Does equilibrium potential depend on membrane permeability?	No			
What determines whether an ion will actually move?	Difference between Vm and Eion			
If membrane potential equals equilibrium potential, what is net flux?	Zero			
If membrane potential differs from equilibrium potential, what happens?	Net ion movement occurs			
What is the driving force on an ion?	Vm − Eion			
Does equilibrium mean equal concentrations on both sides?	No			
Why can ions be at equilibrium without equal concentrations?	Electrical force balances chemical force			
Which ions typically have very negative equilibrium potentials?	K^+			
Which ions typically have very positive equilibrium potentials?	Na^+, Ca^{2+}			
Why is Ca^{2+} equilibrium potential extremely positive?	Very low intracellular concentration			
What MCAT trap confuses equilibrium with uniformity?	Assuming equal concentrations			
Core MCAT takeaway: what does Nernst tell you?	Where an ion “wants” to go			
What is resting membrane potential (Vm)?	Voltage difference across membrane at rest			

Is Vm an equilibrium potential?	No
What determines Vm?	Relative permeability of ions
Which ion contributes most to Vm at rest?	K^+
Why does K^+ dominate Vm?	Highest resting membrane permeability
Why is Vm close to EK but not equal?	Other ions contribute
Which ions contribute secondarily to Vm?	Na^+ and Cl^-
Does ion concentration alone determine Vm?	No
What equation conceptually combines multiple ions?	Goldman equation
Does Goldman require exact calculation on the MCAT?	Rarely
What does increased Na^+ permeability do to Vm?	Depolarizes membrane
What does increased K^+ permeability do to Vm?	Hyperpolarizes membrane
What does increased Cl^- permeability usually do?	Stabilizes Vm
Why does Cl^- often stabilize Vm?	ECl near Vm
Is Vm static?	No
What cellular structures set up ion gradients?	Pumps and transporters
Does the Na^+/K^+ pump directly create Vm?	No (minor direct effect)
What is the Na^+/K^+ pump's main role?	Maintain gradients
What happens to Vm if gradients collapse?	Vm disappears
Core MCAT trap: is Vm set by pumps alone?	No — permeability matters
What is simple diffusion?	Passive movement down a gradient
Does simple diffusion require a protein?	No
What limits simple diffusion across membranes?	Size and polarity
What is facilitated diffusion?	Passive transport via a protein
Does facilitated diffusion require ATP?	No
Can facilitated diffusion become saturated?	Yes
Why does facilitated diffusion saturate?	Limited number of transporters
What determines direction of passive transport?	Electrochemical gradient
What is primary active transport?	Transport directly using ATP
What is an example of primary active transport?	Na^+/K^+ ATPase
What is secondary active transport?	Transport driven by ion gradients
Does secondary active transport use ATP directly?	No
What provides energy for secondary active transport?	Stored gradient energy
What is symport?	Two solutes move in same direction
What is antiport?	Two solutes move in opposite directions
What determines whether transport is active or passive?	Direction relative to gradient

Can a solute move uphill overall without ATP?	Yes (secondary active transport)
What establishes gradients used in secondary transport?	Primary active transport
What MCAT trap confuses transport type?	Equating protein use with ATP use
Core MCAT takeaway: what powers transport?	Gradients, not proteins alone
What is osmosis?	Movement of water across a semipermeable membrane
What determines the direction of water movement?	Effective solute concentration
Do permeant solutes contribute to tonicity long-term?	No
What defines tonicity?	Effect of solution on cell volume
What type of solutes determine tonicity?	Impermeant solutes
What happens to a cell in a hypotonic solution?	It swells
What happens to a cell in a hypertonic solution?	It shrinks
What happens to a cell in an isotonic solution?	No net volume change
Does osmolarity always equal tonicity?	No
Why can two solutions with same osmolarity have different tonicities?	Different solute permeability
What membrane protein facilitates water movement?	Aquaporin
Do aquaporins require ATP?	No
What happens if aquaporins are blocked?	Slower water movement
Does water move to equalize volume or solute concentration?	Solute concentration
What drives osmotic pressure?	Solute particles
What happens to water movement at equilibrium?	Net movement stops
Does osmosis require ion movement?	No
Why are cells vulnerable to osmotic stress?	Water moves freely
What MCAT trap confuses osmosis logic?	Counting permeant solutes
Core MCAT takeaway: what determines cell volume?	Impermeant solutes
What defines epithelial tissue functionally?	Directional transport across a barrier
What feature allows epithelia to be directional?	Cell polarity
What are the two membrane sides of epithelial cells?	Apical and basolateral
What separates apical and basolateral domains?	Tight junctions
What is transcellular transport?	Movement through cells
What is paracellular transport?	Movement between cells
Which route is more selective: transcellular or paracellular?	Transcellular
What determines paracellular permeability?	Tight junction properties
What type of transport dominates nutrient absorption?	Transcellular
What type of transport dominates ion/water bulk movement?	Paracellular (often)

What is bulk flow?	Movement driven by pressure gradients
Is bulk flow selective?	No
Where is bulk flow most important physiologically?	Capillaries
What forces drive bulk flow across capillaries?	Hydrostatic and oncotic pressures
Does bulk flow require transport proteins?	No
What establishes gradients that drive epithelial transport?	Active transporters
Why is Na^+ transport central to epithelial physiology?	Drives secondary transport and water movement
What happens to water when Na^+ is absorbed?	It follows osmotically
Why is epithelial transport considered integrated?	Multiple transporters work together
Core MCAT trap: is epithelial transport one protein at a time?	No — it's coordinated
What determines whether an ion moves across a membrane?	Difference between Vm and the ion's equilibrium potential
What does "driving force" represent conceptually?	How strongly an ion wants to move
If Vm = Eion, what is the driving force?	Zero
For a cation, if Vm is more positive than Eion, which way does it move?	Out of the cell
For a cation, if Vm is more negative than Eion, which way does it move?	Into the cell
Why must charge be considered in driving force questions?	Electrical force can override concentration
MCAT trap: why is "down the concentration gradient" incomplete?	Electrical force also acts
What are leak channels?	Channels that are always open
Which ion's leak channels dominate resting Vm?	K^+
Why does Vm remain stable at rest?	Constant leak permeability
What are gated channels?	Channels that open in response to stimuli
What stimuli can gate channels?	Voltage, ligands, mechanical forces
Do gated channels determine resting Vm?	No
MCAT trap: are all channels normally closed?	No — leak channels are open
What is electrogenic transport?	Transport that changes Vm
Is the Na^+/K^+ ATPase electrogenic?	Yes
Why is the Na^+/K^+ pump electrogenic?	Moves unequal charges
Can transport occur without changing Vm?	Yes
What determines whether transport is electrogenic?	Net charge movement
MCAT trap: does ion movement always change Vm?	No
	Metabolism Continued

What is the biggest misconception about metabolism?	That cells choose pathways independently			
How does the body actually regulate metabolism?	Through global metabolic states			
What defines a metabolic state?	Hormone levels, blood nutrients, organ responses			
Are metabolic states local or systemic?	Systemic			
What are the two dominant metabolic states?	Fed and fasted			
Are fed and fasted states systemically compatible?	No			
What is the priority of the fed state?	Uptake, storage, and growth			
What is the priority of the fasted state?	Maintain blood glucose			
What variable is most tightly protected system-wide?	Blood glucose			
Why is blood glucose non-negotiable?	Certain tissues depend on it			
Which tissues absolutely require glucose?	Brain, RBCs, renal medulla			
Why is ATP demand alone insufficient to define state?	Glucose availability dominates			
What medium carries metabolic state information?	Blood			
Do hormones fine-tune individual enzymes?	No			
What do hormones actually do?	Flip system operating modes			
Why don’t opposing pathways run together systemically?	Hormonal enforcement			
What is prevented by state-based control?	Futile cycling			
Why does pathway memorization fail on the MCAT here?	State logic overrides pathways			
What question solves most MCAT metabolism passages?	“What state is the body in?”			
Core MCAT rule: what decides metabolic direction?	State, not pathway availability			
- (Question / Prompt)	**-**			
What is the primary role of the pancreas in metabolism?	Sense blood nutrient levels			
Does the pancreas respond to cellular ATP levels directly?	No			
What blood variable most strongly stimulates insulin release?	Blood glucose			
What blood variable most strongly stimulates glucagon release?	Low blood glucose			
Are insulin and glucagon ever high at the same time?	No			
Why must insulin and glucagon be opposing hormones?	To enforce a single metabolic state			
What matters more: absolute hormone level or hormone ratio?	Hormone ratio			
What does a high insulin-to-glucagon ratio indicate?	Fed state			
What does a low insulin-to-glucagon ratio indicate?	Fasted state			
Do hormones regulate individual reactions directly?	No			
What do hormones primarily regulate?	Pathway directionality			
How do hormones communicate state to tissues?	Via bloodstream			
Why is endocrine signaling slow compared to neural signaling?	It is systemic			
Which organ sets the pace for systemic metabolism?	Liver			
Why is the liver hormonally sensitive?	It buffers blood nutrients			

Does muscle respond strongly to glucagon?	No				
Why is liver metabolism prioritized over muscle?	Blood homeostasis				
What happens if hormone signaling is contradictory?	Metabolic chaos				
Why does the MCAT emphasize hormone ratios?	They define metabolic mode				
Core MCAT trap: does insulin mean “make ATP”?	No — it means abundance				
- (Question / Prompt)	**-**				
What does insulin fundamentally signal to the body?	Nutrient abundance				
Does insulin primarily signal “high ATP demand”?	No				
What systemic goal does insulin enforce?	Uptake and storage				
What happens to blood glucose in the fed state?	It rises				
Why must excess glucose be removed from blood?	To maintain homeostasis				
What is the liver’s primary role under insulin signaling?	Buffer excess nutrients				
What happens to glucose uptake in muscle under insulin?	It increases				
What transporter mediates insulin-stimulated glucose uptake in muscle and adipose?	GLUT4				
Does insulin increase glucose uptake in the brain?	No				
Why is brain glucose uptake insulin-independent?	Continuous energy requirement				
What happens to glycolysis under insulin signaling?	It is upregulated				
What happens to glycogen synthesis under insulin?	It is upregulated				
What happens to gluconeogenesis under insulin?	It is suppressed				
What happens to fatty acid synthesis under insulin?	It is promoted				
What happens to fatty acid oxidation under insulin?	It is suppressed				
Why does insulin favor storage over immediate oxidation?	Excess fuel is available				
What happens to protein synthesis under insulin?	It increases				
What happens to protein breakdown under insulin?	It decreases				
Why is insulin considered an anabolic hormone?	It promotes biosynthesis				
Core MCAT trap: does insulin mean “use glucose now”?	No — it means “store abundance”				
- (Question / Prompt)	**-**				
What does glucagon fundamentally signal to the body?	Nutrient scarcity				
When is glucagon secretion highest?	During fasting				
What systemic goal does glucagon enforce?	Maintain blood glucose				
Why is maintaining blood glucose critical in fasting?	Glucose-dependent tissues				
Which organ is the primary target of glucagon?	Liver				
Does skeletal muscle respond directly to glucagon?	No				
What happens to glycogen breakdown under glucagon?	It increases				
What happens to glycogen synthesis under glucagon?	It decreases				
What happens to gluconeogenesis under glucagon?	It increases				

What happens to glycolysis in the liver under glucagon?	It decreases				
Why is liver glycolysis suppressed during fasting?	Preserve glucose for blood				
What happens to fatty acid oxidation under glucagon?	It increases				
What happens to fatty acid synthesis under glucagon?	It decreases				
Why does fat become a major fuel during fasting?	Glucose must be spared				
What happens to protein breakdown during prolonged fasting?	It increases				
Why are amino acids mobilized during fasting?	Substrates for gluconeogenesis				
What happens to ketone body production under glucagon?	It increases				
Why are ketone bodies produced during fasting?	Alternative fuel for brain				
Why is glucagon considered a catabolic hormone?	Promotes breakdown pathways				
Core MCAT trap: does glucagon mean “low ATP”?	No — it means low glucose				
- (Question / Prompt)	**-**				
Why is the liver considered the metabolic buffer of the body?	It stabilizes blood nutrient levels				
Does the liver primarily meet its own energy needs?	No				
What variable does the liver prioritize regulating?	Blood glucose				
Why is the liver uniquely positioned to buffer nutrients?	Direct portal blood supply				
What does the portal circulation deliver to the liver?	Nutrients absorbed from the gut				
Under insulin, what is the liver’s main glucose-related role?	Uptake and storage				
Under glucagon, what is the liver’s main glucose-related role?	Glucose release				
Why does the liver store glycogen after meals?	To buffer postprandial glucose				
Why does the liver break down glycogen during fasting?	To maintain blood glucose				
Does the liver use GLUT4 for glucose uptake?	No				
Why is liver glucose uptake insulin-independent?	To always buffer blood glucose				
What happens to hepatic glycolysis in the fed state?	It increases				
What happens to hepatic glycolysis in the fasted state?	It decreases				
Why is liver metabolism state-dependent?	It serves systemic needs				
What happens to fatty acid synthesis in the liver under insulin?	It increases				
What happens to fatty acid oxidation in the liver under glucagon?	It increases				
Why does the liver export fuels instead of consuming them?	Other tissues have priority				
What happens if liver buffering fails?	Blood nutrient instability				
Why does the MCAT emphasize liver metabolism?	It integrates hormonal signals				
Core MCAT trap: is the liver just another consumer tissue?	No — it is a regulator				
- (Question / Prompt)	**-**				
What is the primary short-term glucose reserve in the body?	Glycogen				
Where is glycogen stored?	Liver and muscle				
Why is liver glycogen prioritized over muscle glycogen systemically?	Liver can release glucose to blood				

Can muscle glycogen directly maintain blood glucose?	No				
How long do liver glycogen stores typically last during fasting?	~24 hours				
What fuel dominates after glycogen depletion?	Fatty acids				
Why are fatty acids ideal long-term fuels?	High energy density				
Can fatty acids be converted to glucose in humans?	No				
Why can't fatty acids support blood glucose directly?	No net glucose production				
What pathway provides glucose after glycogen is depleted?	Gluconeogenesis				
What substrates feed gluconeogenesis during fasting?	Amino acids, glycerol, lactate				
Why is protein breakdown not a long-term solution?	Loss of functional tissue				
What metabolic shift protects protein during prolonged fasting?	Ketone body production				
Where are ketone bodies produced?	Liver				
What is the purpose of ketone bodies?	Alternative fuel for brain				
Can the liver use ketone bodies itself?	No				
Why can ketones reduce glucose demand?	Brain can oxidize them				
What happens to glucose utilization in prolonged fasting?	It decreases				
Why is fat the dominant long-term fuel strategy?	Spares glucose and protein				
Core MCAT rule: what determines fuel choice?	Metabolic state and time scale				
- (Question / Prompt)	**-**				
What type of signal is epinephrine?	Acute stress signal				
Does epinephrine indicate fed or fasted state?	Neither				
What is the primary goal of epinephrine signaling?	Rapid fuel mobilization				
How does epinephrine affect blood glucose?	Increases it				
Which organs respond strongly to epinephrine?	Liver and muscle				
Why can muscle respond to epinephrine but not glucagon?	Different receptor expression				
What happens to glycogen under epinephrine?	Rapid breakdown				
Core MCAT trap: is epinephrine a long-term metabolic regulator?	No				
- (Question / Prompt)	**-**				
What is another name for the fed state?	Absorptive state				
What is another name for the fasted state?	Postabsorptive state				
Does "postabsorptive" mean starving?	No				
Why does the MCAT use absorptive/postabsorptive language?	To test state recognition				
- (Question / Prompt)	**-**				
Which tissue absolutely requires glucose at all times?	Red blood cells				
Why can't RBCs use fatty acids or ketones?	No mitochondria				
What is the brain's primary fuel under normal conditions?	Glucose				
What alternative fuel can the brain use during prolonged fasting?	Ketone bodies				

Can skeletal muscle use fatty acids?	Yes				
Core MCAT rule: what matters more than tissue preference?	Systemic metabolic state				
		Neurophysiology and Muscles			
- (Question / Prompt)	**-**				
What core problem does the nervous system solve?	Rapid, targeted information transfer				
How does neural signaling differ from endocrine signaling?	Faster, more precise, short-lived				
What is being transmitted in neural signaling: matter or information?	Information				
What form of energy underlies neural signaling?	Electrochemical potential energy				
What is the resting membrane potential (RMP)?	Stable negative membrane voltage				
Is the resting membrane potential a state of inactivity?	No — it is stored energy				
What three factors generate the resting membrane potential?	Ion gradients, permeability, pumps				
Which ion has the greatest influence on resting membrane potential?	Potassium (K^+)				
Why does K^+ dominate the resting potential?	Highest permeability at rest				
Are ion gradients created during each action potential?	No				
What maintains ion gradients long-term?	Na^+/K^+ ATPase				
Do ion pumps generate action potentials directly?	No				
What type of electrical signals occur continuously in neurons?	Graded potentials				
Are graded potentials all-or-none?	No				
Do graded potentials decay with distance?	Yes				
What determines the direction of ion movement?	Electrochemical gradient				
Why are neurons considered polarized cells?	Structure enforces signal direction				
What does “selective permeability” mean?	Membrane favors certain ions				
Why is resting potential considered readiness?	Energy is stored for rapid signaling				
Core MCAT trap: does a negative membrane potential mean the neuron is inactive?	No				
What is an action potential?	Rapid, all-or-none change in membrane voltage				
What triggers an action potential?	Reaching threshold				
What does threshold represent?	Critical level of depolarization				
Are action potentials graded in size?	No				
What ion’s movement causes the rapid depolarization phase?	Na^+				
What causes voltage-gated Na^+ channels to open?	Membrane depolarization				
Why does Na^+ rush into the neuron?	Strong electrochemical gradient				
What phase follows peak depolarization?	Repolarization				
What ion’s movement drives repolarization?	K^+				

Why do voltage-gated K^+ channels open later than Na^+ channels?	Slower activation kinetics				
What causes hyperpolarization after repolarization?	Continued K^+ efflux				
What is the absolute refractory period?	No second AP possible				
What causes the absolute refractory period?	Na^+ channel inactivation				
What is the relative refractory period?	Stronger stimulus needed				
What causes the relative refractory period?	K^+ channels still open				
Does action potential amplitude encode stimulus strength?	No				
What encodes stimulus strength in neurons?	Action potential frequency				
Why is the action potential considered regenerative?	Na^+ influx opens more Na^+ channels				
Can action potentials summate?	No				
Core MCAT trap: does stronger stimulus make a bigger AP?	No				
How does an action potential propagate along an axon?	Local current depolarizes adjacent membrane				
Why don’t action potentials travel backward?	Refractory period				
What determines the speed of action potential conduction?	Axon diameter and myelination				
How does increased axon diameter affect conduction?	Increases speed				
How does myelin increase conduction velocity?	Reduces ion leakage				
What is saltatory conduction?	APs jump between nodes				
What structure enables saltatory conduction?	Nodes of Ranvier				
Where are voltage-gated Na^+ channels concentrated?	Nodes of Ranvier				
What happens if myelin is lost?	Slower conduction				
Do action potentials decay as they propagate?	No				
How is stimulus intensity encoded in neurons?	Firing frequency				
Can action potential amplitude encode intensity?	No				
What is temporal coding?	Information via firing rate				
What is spatial coding?	Information via number of neurons activated				
What is the role of graded potentials in coding?	Summation at axon hillock				
What determines whether threshold is reached?	Net graded input				
Where is the trigger zone for action potentials?	Axon hillock				
Why is the axon hillock highly excitable?	High Na^+ channel density				
What MCAT trap confuses coding mechanisms?	AP size vs frequency				
Core MCAT rule: what carries information?	Frequency and pattern				
What is a synapse?	Junction where neurons communicate				
What type of signal crosses most synapses?	Chemical				
What triggers neurotransmitter release?	Ca^{2+} influx				

Through what channels does Ca^{2+} enter the presynaptic terminal?	Voltage-gated Ca^{2+} channels			
What causes voltage-gated Ca^{2+} channels to open?	Arrival of an action potential			
Why is Ca^{2+} critical for neurotransmitter release?	Triggers vesicle fusion			
How are neurotransmitters released into the synapse?	Exocytosis			
What separates presynaptic and postsynaptic cells?	Synaptic cleft			
Do neurotransmitters cross membranes directly?	No			
What determines postsynaptic response?	Receptor type			
What are ionotropic receptors?	Ligand-gated ion channels			
What are metabotropic receptors?	G-protein–coupled receptors			
Which receptor type is faster?	Ionotropic			
Which receptor type produces longer-lasting effects?	Metabotropic			
Are all neurotransmitters excitatory?	No			
What determines whether a neurotransmitter is excitatory or inhibitory?	Postsynaptic receptor			
What is an EPSP?	Excitatory postsynaptic potential			
What is an IPSP?	Inhibitory postsynaptic potential			
What ion movement commonly causes inhibition?	Cl^- influx or K^+ efflux			
Core MCAT trap: is neurotransmitter identity enough to predict effect?	No			
Why must neurotransmitter signaling be terminated?	To prevent continuous activation			
What are the three main mechanisms of signal termination?	Reuptake, degradation, diffusion			
What is neurotransmitter reuptake?	Presynaptic reabsorption			
What proteins mediate reuptake?	Transporters			
What is enzymatic degradation?	Breakdown by enzymes			
What is an example of enzymatic degradation?	Acetylcholinesterase			
What happens if neurotransmitter breakdown is inhibited?	Prolonged signaling			
What is synaptic summation?	Integration of multiple inputs			
What is temporal summation?	Rapid repeated signals from one synapse			
What is spatial summation?	Simultaneous signals from multiple synapses			
Where does summation primarily occur?	Axon hillock			
What determines whether summation reaches threshold?	Net EPSPs vs IPSPs			
Are EPSPs and IPSPs all-or-none?	No			
Why are graded potentials necessary for integration?	They vary in size			
Can IPSPs cancel EPSPs?	Yes			
What happens if inhibitory input dominates?	No action potential			
How do neurons integrate thousands of inputs?	Electrical summation			
What role does distance play in summation?	Signals decay with distance			

What MCAT trap confuses synaptic logic?	Assuming one EPSP causes an AP				
Core MCAT rule: what determines neuronal output?	Integrated input				
What is the fundamental function of muscle tissue?	Convert chemical energy into mechanical work				
What molecule directly powers muscle contraction?	ATP				
What ion links electrical signals to muscle contraction?	Ca^{2+}				
What does excitation–contraction coupling describe?	Electrical signal → mechanical contraction				
Does muscle contraction require an action potential?	Yes				
What cellular event initiates contraction in muscle?	Rise in intracellular Ca^{2+}				
Where does Ca^{2+} come from in muscle cells?	Sarcoplasmic reticulum				
What happens to muscle when Ca^{2+} levels fall?	Relaxation				
Is Ca^{2+} used up during contraction?	No				
What removes Ca^{2+} from the cytosol during relaxation?	Ca^{2+} pumps				
What protein interaction generates force in muscle?	Actin–myosin interaction				
Does ATP cause contraction or relaxation?	Both				
Why is ATP required for relaxation?	To detach myosin from actin				
What happens if ATP is absent?	Rigor (persistent contraction)				
What structure organizes actin and myosin in muscle?	Sarcomere				
Are sarcomeres present in all muscle types?	No				
Which muscle types have sarcomeres?	Skeletal and cardiac				
What determines the strength of contraction?	Number of cross-bridges				
What determines contraction timing?	Ca^{2+} dynamics				
Core MCAT trap: does Ca^{2+} directly provide energy?	No				
What is the sarcomere?	Basic contractile unit of striated muscle				
What structures define the boundaries of a sarcomere?	Z lines				
What protein makes up thin filaments?	Actin				
What protein makes up thick filaments?	Myosin				
What band contains only thick filaments?	H zone				
What band contains only thin filaments?	I band				
What band contains overlap of actin and myosin?	A band				
Which band remains constant during contraction?	A band				
Which bands shorten during contraction?	I band and H zone				
What happens to sarcomere length during contraction?	It shortens				
Does actin shorten during contraction?	No				
Does myosin shorten during contraction?	No				

What actually moves during contraction?	Actin slides over myosin			
What is the sliding filament model?	Filaments slide, not shrink			
What structural change increases force generation?	Increased cross-bridge overlap			
What sarcomere length produces maximal force?	Optimal overlap			
Why does overstretching reduce force?	Decreased overlap			
Why does excessive shortening reduce force?	Filament interference			
Are sarcomeres present in smooth muscle?	No			
Core MCAT trap: does contraction shorten filaments?	No			
What is a cross-bridge in muscle contraction?	Myosin head bound to actin			
What molecule must bind myosin to detach it from actin?	ATP			
What happens if ATP is unavailable?	Rigor state			
What provides the energy for the power stroke?	Release of Pi and ADP			
What primes the myosin head for binding?	ATP hydrolysis			
What event exposes myosin-binding sites on actin?	Ca^{2+} binding to troponin			
What protein blocks actin–myosin interaction at rest?	Tropomyosin			
What protein complex regulates tropomyosin position?	Troponin			
What happens when Ca^{2+} binds troponin?	Tropomyosin shifts			
Does Ca^{2+} provide energy for contraction?	No			
What directly determines contraction force at the molecular level?	Number of cross-bridges			
Can cross-bridge cycling occur without Ca^{2+}?	No			
Can cross-bridge cycling occur without ATP?	No			
What happens to contraction if Ca^{2+} remains elevated?	Sustained contraction			
What removes Ca^{2+} from the cytosol to end contraction?	SERCA pumps			
Is ATP used more during contraction or relaxation?	Both			
Why does rigor mortis occur after death?	ATP depletion			
Does faster ATP hydrolysis always mean more force?	No			
What primarily determines contraction speed?	Myosin ATPase activity			
Core MCAT trap: does Ca^{2+} replace ATP's role?	No			
Which muscle types are striated?	Skeletal and cardiac			
Which muscle type is non-striated?	Smooth			
Which muscle types have sarcomeres?	Skeletal and cardiac			
Which muscle type lacks sarcomeres?	Smooth			
What initiates Ca^{2+} release in skeletal muscle?	Action potential in T-tubules			
Is extracellular Ca^{2+} required for skeletal contraction?	No			

What initiates Ca^{2+} influx in cardiac muscle?	Action potential
Does cardiac muscle require extracellular Ca^{2+}?	Yes
What is calcium-induced calcium release?	Ca^{2+} influx triggers SR release
Which muscle type uses CICR?	Cardiac
What initiates contraction in smooth muscle?	Ca^{2+} binding to calmodulin
Does smooth muscle use troponin?	No
What protein replaces troponin in smooth muscle?	Calmodulin
What enzyme phosphorylates myosin in smooth muscle?	Myosin light-chain kinase
Is smooth muscle contraction slower than skeletal?	Yes
Why is smooth muscle contraction slower?	Different regulatory mechanism
Can smooth muscle maintain tone with low ATP use?	Yes
Which muscle type is under voluntary control?	Skeletal
Which muscle types are involuntary?	Cardiac and smooth
Core MCAT trap: do all muscles use troponin?	No
What is a motor unit?	One motor neuron and all muscle fibers it innervates
Does one motor neuron control one muscle fiber?	No
How does the nervous system increase muscle force?	Recruit more motor units
What is motor unit recruitment?	Activating additional motor units
Are all motor units recruited simultaneously?	No
What is the size principle?	Small motor units are recruited first
Why are small motor units recruited before large ones?	Finer force control
Core MCAT trap: does muscle force increase by bigger action potentials?	No
What is frequency (temporal) summation in muscle?	Increased force via repeated stimulation
How does frequency summation increase force?	Ca^{2+} accumulates
What happens if Ca^{2+} is not fully removed between twitches?	Stronger contraction
What is incomplete tetanus?	Partial relaxation between contractions
What is complete tetanus?	No relaxation between contractions
Why does tetanus produce maximal force?	Sustained high Ca^{2+}
Is tetanus possible in cardiac muscle?	No
Why can’t cardiac muscle undergo tetanus?	Long refractory period
What is the length–tension relationship?	Force depends on sarcomere length
Why does optimal overlap maximize force?	Maximum cross-bridge formation
What happens to force at very short sarcomere lengths?	Decreases

Core MCAT rule: what determines muscle force output?	Recruitment + frequency
Insulin — source gland and cell type	Pancreas (β cells of the islets of Langerhans)
Insulin — chemical class	Peptide hormone
Insulin — receptor type	Membrane receptor (receptor tyrosine kinase)
Insulin — primary signaling mechanism	RTK → autophosphorylation → intracellular signaling cascade
Insulin — net physiological effect	Lowers blood glucose by promoting uptake and storage
Glucagon — source gland and cell type	Pancreas (α cells of the islets of Langerhans)
Glucagon — chemical class	Peptide hormone
Glucagon — receptor type	Membrane receptor (G-protein–coupled receptor)
Glucagon — primary second messenger	cAMP
Glucagon — net physiological effect	Raises blood glucose via glycogen breakdown and gluconeogenesis
Epinephrine — source gland	Adrenal medulla
Epinephrine — chemical class	Amine (catecholamine)
Epinephrine — receptor type	Membrane receptor (GPCR)
Epinephrine — primary second messenger	cAMP (β-adrenergic receptors)
Epinephrine — net physiological effect	Fight-or-flight: ↑ heart rate, ↑ blood glucose
Norepinephrine — source	Adrenal medulla and sympathetic neurons
Norepinephrine — chemical class	Amine (catecholamine)
Norepinephrine — receptor type	Membrane receptor (GPCR)
Norepinephrine — dominant physiological role	Vasoconstriction and blood pressure regulation
Cortisol — source gland	Adrenal cortex
Cortisol — chemical class	Steroid hormone
Cortisol — receptor location	Intracellular (cytosolic / nuclear receptor)
Cortisol — net physiological effect	Long-term stress response; ↑ blood glucose
Aldosterone — source gland	Adrenal cortex
Aldosterone — chemical class	Steroid hormone
Aldosterone — primary physiological target	Kidneys (distal tubules and collecting ducts)
Aldosterone — net physiological effect	↑ Na^+ reabsorption → ↑ water retention → ↑ blood volume
ADH (vasopressin) — source gland	Posterior pituitary
ADH — chemical class	Peptide hormone
ADH — receptor type	Membrane receptor (GPCR)
ADH — primary physiological effect	↑ Water reabsorption in kidneys
Oxytocin — source gland	Posterior pituitary
Oxytocin — chemical class	Peptide hormone
Oxytocin — primary physiological roles	Uterine contractions and milk ejection

Melatonin — source gland and role	Pineal gland; regulates circadian rhythm				
- (Question / Prompt)	**-**	Molecular and Cell Biology			
What explanatory gap does molecular biology fill in physiology?	How physiological capacity is implemented				
What does physiology explain versus molecular biology?	Physiology explains what; molecular biology explains how				
Do cells “choose” actions directly?	No				
How do cells determine what they can do?	By controlling protein availability				
Why don’t cells do everything their genome encodes?	Only expressed genes matter				
What is the functional currency of the cell?	Proteins				
Why is DNA not the functional unit of the cell?	It encodes potential, not action				
What determines a cell’s responsiveness to signals?	Receptors and downstream machinery				
Why can the same hormone affect different cells differently?	Different protein expression				
What does cell identity primarily depend on?	Stable gene expression patterns				
Are differences between somatic cells due to DNA sequence?	No				
What allows cells to adapt over time?	Changes in molecular machinery				
Why is molecular biology placed after physiology in this course?	It explains physiological limits				
What is the “regulated factory” metaphor emphasizing?	Dynamic control, not static output				
Why must molecular control exist at all?	Unregulated activity is dangerous				
What level of control explains chronic vs acute effects?	Molecular and gene-level control				
Why does memorizing pathways fail at this level?	Control overrides pathways				
What determines whether a physiological response is possible?	Molecular capacity				
What does molecular biology explain that physiology alone cannot?	Adaptation and long-term change				
Core MCAT rule: what limits cellular behavior?	Which proteins exist				
- (Question / Prompt)	**-**				
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Core MCAT rule: what limits cellular behavior?	Which proteins exist
- (Question / Prompt)	**-**
What is the core function of the endomembrane system?	Protein and lipid routing
Why is routing necessary inside cells?	Proteins must reach correct destinations
What is the first step in secretory protein targeting?	Ribosome binding to ER
What feature directs ribosomes to the rough ER?	Signal sequence
Does the signal sequence remain on mature proteins?	Often removed
What is the role of the rough ER?	Protein synthesis and initial folding
Why does protein folding begin in the ER?	Quality control
What happens to misfolded proteins in the ER?	Retained and degraded
What organelle modifies and sorts proteins after the ER?	Golgi apparatus
What is the Golgi’s primary role?	Post-translational modification
What kind of modifications occur in the Golgi?	Glycosylation, tagging
How does the Golgi direct proteins to destinations?	Sorting signals
What determines whether a protein is secreted or retained?	Targeting signals
What is constitutive secretion?	Continuous protein export
What is regulated secretion?	Storage then stimulus-dependent release
Why is regulated secretion useful?	Rapid response capability
What happens if protein targeting fails?	Loss of cellular function
Why does the MCAT emphasize ER stress?	Misfolding disrupts control
Does the endomembrane system control gene expression?	Indirectly
Core MCAT rule: what does the endomembrane system enforce?	Correct protein localization
- (Question / Prompt)	**-**
Why is protein degradation essential for cellular control?	Removes damaged or unneeded proteins
What happens if proteins are never degraded?	Loss of regulation
What is the proteasome?	Cytosolic protein degradation complex
What types of proteins does the proteasome degrade?	Short-lived or misfolded proteins
What molecular tag targets proteins to the proteasome?	Ubiquitin

Does ubiquitination always signal degradation?	No				
What determines whether ubiquitination leads to degradation?	Ubiquitin pattern				
Where does proteasomal degradation occur?	Cytosol				
What is the lysosome?	Acidic degradative organelle				
What types of material does the lysosome degrade?	Long-lived proteins, organelles				
Why is lysosomal pH important?	Activates degradative enzymes				
What process delivers cytosolic material to lysosomes?	Autophagy				
What is autophagy primarily used for?	Recycling cellular components				
When is autophagy especially active?	Nutrient deprivation				
How does autophagy support survival?	Provides internal nutrients				
Do proteasome and lysosome serve redundant roles?	No				
Which degradation system is more selective?	Proteasome				
Which degradation system handles bulk material?	Lysosome				
What happens if degradation pathways fail?	Accumulation of dysfunctional proteins				
Core MCAT rule: what balances protein synthesis?	Protein degradation				
- (Question / Prompt)	**-**				
Why is gene regulation considered upstream control?	It determines which proteins can exist				
What level of control has the longest-lasting effects?	Gene expression				
Does gene regulation act quickly or slowly?	Slowly				
What is transcriptional regulation?	Control of RNA synthesis				
What is the primary enzyme involved in transcription?	RNA polymerase				
What determines whether a gene is transcribed?	Regulatory signals and chromatin state				
What are transcription factors?	Proteins that regulate transcription				
Do transcription factors act alone?	No				
What is post-transcriptional regulation?	Control after RNA is made				
What processes fall under post-transcriptional control?	Splicing, stability, translation				
Why is post-transcriptional control faster than transcriptional control?	RNA already exists				
Can cells regulate protein levels without changing transcription?	Yes				
Why don’t all mRNAs get translated equally?	Differential stability and access				
What is alternative splicing?	Producing multiple proteins from one gene				
Why is alternative splicing powerful?	Increases protein diversity				
Does increased mRNA always mean increased protein?	No				
Why does the MCAT emphasize regulation over pathways?	Regulation determines outcomes				
What type of control best explains cell differentiation?	Transcriptional regulation				
What type of control best explains rapid adaptation?	Post-transcriptional regulation				
Core MCAT rule: what sets cellular capability?	Gene expression pattern				

- (Question / Prompt)	-
What does epigenetics refer to?	Heritable changes in gene expression without DNA sequence change
Do epigenetic changes alter nucleotide sequence?	No
What is the primary function of epigenetic regulation?	Maintain stable gene expression patterns
Why is epigenetics essential for multicellular organisms?	Enables cell differentiation
What is chromatin?	DNA plus associated proteins
How does chromatin structure affect gene expression?	Controls DNA accessibility
What is euchromatin?	Loosely packed, transcriptionally active chromatin
What is heterochromatin?	Tightly packed, transcriptionally inactive chromatin
What is DNA methylation generally associated with?	Gene silencing
What histone modification is commonly linked to gene activation?	Histone acetylation
How does histone acetylation affect chromatin?	Loosens structure
How do epigenetic marks influence transcription factors?	Control access to DNA
Are epigenetic marks permanent?	Potentially reversible
Can epigenetic states be copied during cell division?	Yes
What allows daughter cells to retain identity?	Epigenetic inheritance
Can environmental factors influence epigenetic state?	Yes
Why is epigenetics considered long-term regulation?	Stable across time
What MCAT trap confuses genetics and epigenetics?	Assuming sequence change
What level of control does epigenetics operate at?	Chromatin accessibility
Core MCAT rule: what does epigenetics encode?	Cellular memory
- (Question / Prompt)	**-**
Why must DNA replication be tightly controlled?	Errors propagate permanently
What is the primary goal of DNA replication?	Accurate genome duplication
Does DNA replication occur continuously?	No
During which cell-cycle phase does DNA replication occur?	S phase
Why is semiconservative replication important?	Preserves sequence fidelity
What general mechanism improves replication accuracy?	Proofreading
Why are repair mechanisms necessary even with proofreading?	Errors still occur
What types of damage do DNA repair pathways address?	Mismatches, breaks, lesions
What happens if DNA damage is not repaired?	Mutations accumulate
What is the primary purpose of the cell cycle?	Controlled cell division
Why are checkpoints essential in the cell cycle?	Prevent error propagation
What do cell-cycle checkpoints monitor?	DNA integrity and completion
What happens if checkpoint conditions are not met?	Cell-cycle arrest
Can cells permanently exit the cell cycle?	Yes

What is G_0 phase?	Non-dividing state			
Why do differentiated cells often enter G_0?	Function prioritized over division			
What balances proliferation in tissues?	Checkpoint regulation			
What happens when cell-cycle control fails?	Uncontrolled proliferation			
What MCAT trap confuses replication and transcription?	Assuming same enzymes			
Core MCAT rule: what preserves genetic stability?	Fidelity + checkpoints			
- (Question / Prompt)	**-**			
What core problem does the immune system solve?	Distinguish self from non-self			
What is an antigen?	A molecule recognized as foreign			
What determines immune specificity?	Molecular recognition			
Is immune recognition random?	No			
What type of interaction underlies antigen recognition?	Protein–protein binding			
Why is immune recognition considered a control problem?	Wrong activation is dangerous			
What does “clonal selection” mean?	Expansion of specific responders			
Why is clonal expansion slow initially?	Few specific cells exist			
What is the advantage of clonal expansion?	Targeted amplification			
What distinguishes innate from adaptive immunity?	Specificity and memory			
Which immune branch acts first?	Innate			
Which immune branch provides memory?	Adaptive			
What is immune memory at the molecular level?	Persistent altered expression			
Why does immune memory enable faster responses?	Pre-expanded specific cells			
How do immune cells communicate?	Cytokines			
What are cytokines conceptually?	Signaling molecules			
Why is immune signaling context-dependent?	Signal combinations matter			
What happens if immune regulation fails?	Autoimmunity or immunodeficiency			
Why does the MCAT emphasize immune regulation?	Balance is critical			
Core MCAT rule: what defines immune behavior?	Recognition + regulation			
- (Question / Prompt)	**-**			
If a hormone is present but a cell does not respond, what is the most likely cause?	Missing receptor or downstream machinery			
Same signal, different cells, different outcomes — why?	Different protein expression			
Loss of an organelle most directly disrupts what?	Specific pathways it controls			
Chronic signaling most strongly alters which control layer?	Gene expression			
Acute signaling most strongly alters which control layer?	Protein activity			
Why is blocking protein degradation often more disruptive than blocking synthesis?	Regulatory proteins persist			
Proteasome inhibition most directly affects what type of proteins?	Short-lived regulators			
Lysosomal failure most directly causes accumulation of what?	Organelles and bulk material			

Open chromatin predicts what change?	Increased transcription
Increased transcription does not guarantee what outcome?	Increased protein
Persistent signal over time predicts what cellular change?	Stable expression reprogramming
DNA damage without repair most directly threatens what?	Identity stability
Loss of checkpoints leads to what global outcome?	Uncontrolled proliferation
Immune pathology most often reflects failure of what process?	Recognition or regulation
Core MCAT rule: when predicting outcomes, what matters most?	Control layer affected
Antigen-presenting cells (APCs) — definition	Cells that present antigen on MHC molecules to T cells
Professional antigen-presenting cells	Dendritic cells, macrophages, B cells
MHC I — where it is expressed	All nucleated cells
MHC I — what it presents	Endogenous (intracellular) antigens
MHC I — which T cell recognizes it	$CD8^+$ cytotoxic T cells
MHC II — where it is expressed	Antigen-presenting cells only
MHC II — what it presents	Exogenous (extracellular) antigens
MHC II — which T cell recognizes it	$CD4^+$ helper T cells
$CD8^+$ T cells — primary function	Kill infected or abnormal cells
$CD4^+$ T cells — primary function	Coordinate immune response via cytokines
B cells — primary role	Antibody production
Plasma cells	Activated B cells that secrete antibodies
Memory B cells	Long-lived B cells enabling rapid secondary response
Primary immune response — key features	Slow onset, lower antibody levels
Secondary immune response — key features	Faster, stronger, higher antibody levels
IgG — defining feature	Crosses the placenta
IgA — defining feature	Found in secretions (saliva, tears, breast milk)
IgM — defining feature	First antibody produced in initial infection
IgE — defining feature	Allergic reactions and parasitic infections
IgD — defining role	B-cell receptor function
Humoral immunity — definition	Antibody-mediated immunity (B cells)
Cell-mediated immunity — definition	T-cell–mediated killing and coordination
Innate immunity — characteristics	Rapid, nonspecific, no memory
Adaptive immunity — characteristics	Slower, specific, has memory
Vaccination — immunological principle	Induces memory cells without causing disease
- -	- Netwonian Mechanics and Physics Continued
What does Newtonian mechanics fundamentally explain?	How forces produce changes

What three quantities reduce all of mechanics?	Force, mass, motion
What does Newton’s First Law actually describe?	Persistence of velocity
What does zero net force imply?	No acceleration
Does zero acceleration mean zero velocity?	No
What quantity diagnoses force imbalance?	Acceleration
What is the core meaning of F = ma?	Net force causes acceleration
Does acceleration track individual forces?	No, net force
Why must forces be treated as vectors?	Direction matters
What is the purpose of a free-body diagram?	Identify all forces
What is the first step of any FBD?	Isolate the object
Do third-law force pairs appear on the same FBD?	No
Why don’t third-law forces cancel motion?	Act on different objects
What defines static equilibrium?	Net force = 0
Can an object be moving in equilibrium?	Yes
What is the most common MCAT trap about force?	Motion requires force
Correct framing: what requires force?	Change in motion
If velocity changes, what must exist?	A net force
How does mass affect acceleration (same force)?	Larger mass → smaller acceleration
Core MCAT rule: what do forces cause?	Changes in motion
- -	-
What question signals that energy methods are appropriate?	“How much” change without timing
What is work, conceptually?	Energy transfer by force
When does a force do work?	When it causes displacement
Does perpendicular force do work?	No
What does positive work indicate?	Energy added to system
What does negative work indicate?	Energy removed from system
What is kinetic energy dependent on?	Mass and speed
Does direction matter for kinetic energy?	No
What does potential energy represent?	Stored energy
What does gravitational potential energy depend on?	Height
Why is potential energy relative?	Zero point is arbitrary
What does conservation of energy assume?	No non-conservative work
What are non-conservative forces?	Friction, air resistance
How does friction affect mechanical energy?	Converts it to thermal
What quantity does work–energy theorem relate?	Net work to ΔKE
When is work–energy preferable to F = ma?	Variable forces or paths

What is power, conceptually?	Rate of energy transfer				
What variable distinguishes power from energy?	Time				
Can two processes use same energy but different power?	Yes				
Core MCAT rule: what method ignores time?	Energy methods				
- -	-				
What defines simple harmonic motion (SHM)?	Restoring force proportional to displacement				
What is the direction of the restoring force in SHM?	Toward equilibrium				
What physical system most commonly models SHM on the MCAT?	Mass–spring system				
What does Hooke’s law describe conceptually?	Linear restoring force				
When is Hooke’s law valid?	Small displacements				
What does the equilibrium position represent?	Net force = 0				
Is velocity zero at equilibrium in SHM?	No				
Where is velocity maximal in SHM?	At equilibrium				
Where is acceleration maximal in SHM?	At maximum displacement				
What happens to acceleration at equilibrium?	Zero				
What form of energy is maximum at max displacement?	Potential energy				
What form of energy is maximum at equilibrium?	Kinetic energy				
Is total mechanical energy conserved in ideal SHM?	Yes				
Does changing amplitude change SHM frequency?	No				
What determines SHM frequency for a spring–mass system?	Mass and spring constant				
Does SHM require constant speed?	No				
What happens to SHM if damping is present?	Energy decreases				
What does damping physically represent?	Energy loss				
What MCAT trap confuses SHM acceleration?	Thinking it points with velocity				
Core MCAT rule: what drives oscillation?	Restoring force				
- -	-				
What is a wave, fundamentally?	Transfer of energy without net mass transport				
What two main types of mechanical waves exist?	Transverse and longitudinal				
What moves perpendicular to propagation in transverse waves?	Medium displacement				
What moves parallel to propagation in longitudinal waves?	Medium compression				
What does wave speed depend on?	Properties of the medium				
Does changing frequency change wave speed in a fixed medium?	No				
What variables are related by $v = f\lambda$?	Speed, frequency, wavelength				
If frequency increases and speed is constant, what happens to wavelength?	Decreases				
What does amplitude represent physically?	Energy of the wave				
Does amplitude affect wave speed?	No				

What is a standing wave?	Interference of waves			
What are nodes?	Points of zero displacement			
What are antinodes?	Points of maximum displacement			
Where are nodes located on a string fixed at both ends?	At the ends			
What determines allowed standing wave patterns?	Boundary conditions			
What is the fundamental frequency?	Lowest frequency mode			
What distinguishes harmonics?	Integer multiples of fundamental			
Does changing tension affect frequency?	Yes			
Does changing length affect frequency?	Yes			
Core MCAT rule: what stays fixed for waves in a medium?	Wave speed			
- -	-			
What type of wave is sound?	Longitudinal mechanical wave			
What must be present for sound to propagate?	A medium			
Can sound travel in a vacuum?	No			
What physical quantity oscillates in a sound wave?	Pressure/density			
What determines the speed of sound?	Properties of the medium			
Is sound faster in solids or gases?	Solids			
What wave property corresponds to pitch?	Frequency			
What wave property corresponds to loudness?	Intensity (amplitude)			
Does higher amplitude mean higher pitch?	No			
What does sound intensity measure physically?	Power per area			
Why is the decibel scale logarithmic?	Human hearing response			
Does doubling intensity double decibels?	No			
What happens to intensity as distance increases from a source?	Decreases			
What is the inverse-square law applied to sound?	Intensity $\propto 1/r^2$			
What is resonance in sound?	Large amplitude at natural frequency			
What happens when driving frequency matches natural frequency?	Maximum response			
What is the Doppler effect?	Frequency shift due to relative motion			
When does observed frequency increase in Doppler effect?	Source and observer approach			
Does Doppler effect change wave speed?	No			
Core MCAT rule: what changes in Doppler effect?	Observed frequency			
- -	-			
What type of wave is light on the MCAT?	Electromagnetic wave			
Does light require a medium to propagate?	No			
What determines the speed of light in a medium?	Index of refraction			
What happens to light speed entering a denser medium?	Decreases			

Which property of light changes at a boundary?	Speed and wavelength			
Which property of light remains constant at a boundary?	Frequency			
What is refraction?	Bending due to speed change			
When does light bend toward the normal?	Entering higher n			
When does light bend away from the normal?	Entering lower n			
What is reflection?	Light bouncing off a surface			
What law governs reflection?	Angle in = angle out			
What is total internal reflection?	No refraction, full reflection			
What conditions are required for TIR?	Higher to lower n + critical angle			
What optical device relies on TIR?	Fiber optics			
What defines a real image?	Light rays actually converge			
What defines a virtual image?	Rays appear to diverge			
Which mirrors form virtual images?	Convex mirrors			
Which lenses can form real images?	Converging lenses			
What determines image orientation?	Ray geometry			
Core MCAT rule: what never changes for light at boundaries?	Frequency			
- -	-			
What is pressure, conceptually?	Force distributed over area			
Does increasing area increase pressure (same force)?	No			
What does fluid pressure depend on at rest?	Depth and density			
Does container shape affect pressure at a given depth?	No			
What does Pascal’s principle describe?	Pressure transmission			
What is buoyant force equal to?	Weight of displaced fluid			
What determines whether an object floats?	Density comparison			
What does continuity describe in fluid flow?	Conservation of flow rate			
How does speed change when cross-sectional area decreases?	Increases			
What does Bernoulli’s principle relate?	Speed, pressure, height			
In Bernoulli flow, what happens to pressure as speed increases?	Decreases			
When is Bernoulli’s equation applicable?	Incompressible, non-viscous flow			
What physical effect explains lift (simplified)?	Pressure differences			
What role does viscosity play in flow?	Resistance			
How does increased viscosity affect flow rate?	Decreases			
What kind of flow is laminar?	Smooth, layered			
What kind of flow is turbulent?	Chaotic			
Does higher speed always mean higher flow rate?	No			
What MCAT trap confuses fluids?	Pressure vs force			

Core MCAT rule: what is conserved in steady flow?	Flow rate				
- -	-				
What problem does electrostatics describe?	Interactions between charges				
What is electric charge, conceptually?	Property that causes electric forces				
What does electric force act between?	Charges				
What determines the direction of electric force?	Charge signs				
What is an electric field?	Force per unit charge				
Does a charge need to move to experience a field?	No				
What does electric potential measure?	Electric potential energy per charge				
Is electric potential a vector?	No				
What causes current to flow?	Potential difference				
What is current, conceptually?	Flow of charge				
What does resistance represent physically?	Opposition to charge flow				
What happens to current if resistance increases (same V)?	Decreases				
What defines a series circuit?	Single path for current				
What is the same everywhere in a series circuit?	Current				
What changes across elements in series?	Voltage				
What defines a parallel circuit?	Multiple paths for current				
What is the same across all branches in parallel?	Voltage				
What changes across branches in parallel?	Current				
What happens to total resistance when adding parallel resistors?	Decreases				
Core MCAT rule: what drives current?	Potential difference				
- -	-				
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What does electric potential measure?	Electric potential energy per charge				
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What changes across elements in series?	Voltage				
What defines a parallel circuit?	Multiple paths for current				
What is the same across all branches in parallel?	Voltage				
What changes across branches in parallel?	Current				
What happens to total resistance when adding parallel resistors?	Decreases				
Core MCAT rule: what drives current?	Potential difference				
- -	-				
What does thermodynamics study?	Energy transfer and transformation				
What is temperature, conceptually?	Average kinetic energy				
What is heat?	Energy in transit due to temperature difference				
Can an object “contain” heat?	No				
What determines the direction of heat flow?	Temperature difference				
What is a thermodynamic system?	Portion of universe under study				
What is the surroundings?	Everything outside the system				
What is internal energy?	Total microscopic energy				
Is internal energy a state function?	Yes				
Is heat a state function?	No				
Is work a state function?	No				
What does the First Law of Thermodynamics state?	Energy is conserved				
What does ΔU = Q − W represent?	Energy bookkeeping				
What does positive work (by system) mean?	Energy leaves system				
What does the Second Law of Thermodynamics state?	Entropy increases				
What is entropy, conceptually?	Energy dispersal				
Why is entropy increase favored?	More microstates				
Can entropy decrease locally?	Yes				
What is required for local entropy decrease?	Energy input				
Core MCAT rule: what distinguishes states from processes?	Path dependence				
- -	-	Psychology Sociology			
What question does sensation answer?	What physical signal reaches receptors				
What question does perception answer?	What the brain interprets the signal as				
Where does sensation occur?	Sensory receptors				
Where does perception occur?	Brain				
Is sensation psychological or biophysical?	Biophysical				

Is perception purely bottom-up?	No
What does “bottom-up processing” mean?	Data-driven from stimulus
What does “top-down processing” mean?	Influenced by expectations and memory
Can the same stimulus lead to different perceptions?	Yes
What explains different perceptions of the same stimulus?	Top-down effects
What is sensory transduction?	Conversion of physical energy to neural signals
Is transduction a psychological process?	No
What types of energy are transduced by sensory systems?	Light, sound, pressure
Do neurons respond directly to physical energy?	No
What must occur before Psych/Soc begins?	Transduction
What is the absolute threshold?	Minimum intensity for detection
Is detection all-or-none?	No
Why is detection probabilistic?	Noise and variability
What is the difference threshold (JND)?	Smallest detectable change
Core MCAT rule: perception is best described as what?	Inference constrained by sensation
- -	-
What does Weber’s Law describe?	Sensitivity to relative change
What is the Weber fraction?	ΔI / I
According to Weber’s Law, what determines detectability?	Proportional change
Why is a louder sound needed to notice a change at high volume?	Larger baseline intensity
Does Weber’s Law apply equally at all intensities?	No
What type of perception does Weber’s Law model well?	Magnitude discrimination
What problem does Signal Detection Theory address?	Detection under uncertainty
Why is perception probabilistic in SDT?	Noise in sensory systems
What are the four possible SDT outcomes?	Hit, miss, false alarm, correct rejection
What is a “hit” in SDT?	Signal present, detected
What is a “miss” in SDT?	Signal present, not detected
What is a “false alarm” in SDT?	Signal absent, detected
What is a “correct rejection” in SDT?	Signal absent, not detected
What does sensitivity (d′) represent?	Ability to distinguish signal from noise
What affects sensitivity (d′)?	Signal-to-noise ratio
What does response criterion represent?	Decision bias
What happens if criterion is very liberal?	More hits and false alarms
What happens if criterion is very conservative?	Fewer false alarms, more misses
Can two people have same sensitivity but different criteria?	Yes
Core MCAT rule: what separates sensation from decision?	Criterion placement

- -	-
What is sensory adaptation?	Decreased responsiveness to constant stimulus
Does sensory adaptation occur at the receptor or perception level?	Both (primarily receptor-level)
Why does sensory adaptation exist?	Emphasize change over constancy
Does adaptation improve detection of new stimuli?	Yes
What MCAT trap misrepresents adaptation?	“Stimulus disappears entirely”
What is perceptual organization?	Grouping sensory input into meaningful wholes
What are Gestalt principles?	Rules of perceptual grouping
What does the principle of proximity state?	Nearby objects are grouped
What does the principle of similarity state?	Similar objects are grouped
What does the principle of continuity state?	Smooth paths are favored
What does the principle of closure state?	Gaps are perceptually filled
Are Gestalt principles conscious rules?	No
What is figure–ground perception?	Object vs background distinction
What happens when figure–ground reverses?	Ambiguous perception
What is perceptual constancy?	Stable perception despite change
What does size constancy preserve?	Perceived object size
What does shape constancy preserve?	Perceived shape
What does color constancy preserve?	Perceived color
Why is constancy important?	Environmental stability
Core MCAT rule: perception is best described as what?	Constructive and adaptive
- -	-
What type of stimulus does vision transduce?	Light (electromagnetic energy)
Where does visual transduction occur?	Retina
What are rods specialized for?	Low-light vision
What are cones specialized for?	Color and detail
Which photoreceptors are more numerous?	Rods
Where are cones most densely packed?	Fovea
Where are rods absent?	Fovea
What visual ability is highest in the fovea?	Visual acuity
What happens to photoreceptors when light hits them?	Hyperpolarization
Why is photoreceptor response counterintuitive?	Light decreases firing
What pathway carries visual information to cortex?	Optic nerve → optic tract
Where do optic nerves partially cross?	Optic chiasm
What information crosses at the optic chiasm?	Nasal retinal fibers
What visual field is processed by the left visual cortex?	Right visual field

What visual field is processed by the right visual cortex?	Left visual field
Damage to the optic nerve causes what deficit?	Vision loss in one eye
Damage at the optic chiasm causes what deficit?	Loss of peripheral vision
Damage to optic tract causes what deficit?	Contralateral visual field loss
Why does the MCAT love visual pathway lesions?	Predictable logic
Core MCAT rule: visual field maps to cortex how?	Contralaterally
- -	-
What type of stimulus does hearing transduce?	Sound waves (mechanical energy)
What structure first collects sound waves?	Outer ear (pinna)
What structure converts air vibrations to mechanical motion?	Tympanic membrane
What is the function of the ossicles?	Amplify vibrations
Where does auditory transduction occur?	Cochlea
What structure contains auditory hair cells?	Organ of Corti
What physical property of sound determines pitch?	Frequency
What physical property of sound determines loudness?	Amplitude
How is pitch encoded in the cochlea?	Place and frequency coding
Which part of the cochlea responds to high frequencies?	Base
Which part of the cochlea responds to low frequencies?	Apex
What happens when hair cells bend?	Ion channels open
Does auditory transduction involve hyperpolarization or depolarization?	Depolarization
What causes sensorineural hearing loss?	Hair cell or nerve damage
What causes conductive hearing loss?	Impaired sound transmission
What system detects head movement and balance?	Vestibular system
Which structures detect rotational acceleration?	Semicircular canals
Which structures detect linear acceleration?	Otolith organs
What role do otoliths play?	Sense gravity/linear motion
Core MCAT rule: what distinguishes auditory coding?	Frequency maps to place
- -	-
What does somatosensation include?	Touch, pressure, temperature, pain
What type of receptors detect touch and pressure?	Mechanoreceptors
What type of receptors detect temperature?	Thermoreceptors
What type of receptors detect pain?	Nociceptors
Is pain detection purely sensory?	No — affective component exists
What is referred pain?	Pain perceived at a different location
Why does referred pain occur?	Shared neural pathways
What does the gate control theory of pain propose?	Pain is modulated

Can non-painful stimuli reduce pain perception?	Yes				
What distinguishes fast vs slow pain fibers?	Myelination				
What sensory modality adapts the least?	Pain				
What type of receptors detect chemical stimuli?	Chemoreceptors				
What sensory modality detects volatile chemicals?	Olfaction				
What sensory modality detects dissolved chemicals?	Gustation				
Why is smell strongly linked to memory?	Limbic system connections				
Which sensory modality bypasses the thalamus initially?	Olfaction				
What taste qualities are classically recognized?	Sweet, sour, salty, bitter, umami				
Does taste adapt quickly or slowly?	Moderately				
What sensory modality adapts most rapidly?	Olfaction				
Core MCAT rule: what distinguishes sensory systems?	Transduction mechanisms				
- -	-				
What is attention, conceptually?	Allocation of cognitive resources				
Is attention unlimited?	No				
What does selective attention allow?	Focus on one stimulus				
What does divided attention involve?	Processing multiple stimuli				
Why is divided attention limited?	Cognitive resource constraints				
What is inattentional blindness?	Missing stimuli outside focus				
What classic phenomenon shows inattentional blindness?	“Invisible gorilla” effect				
What is change blindness?	Failure to notice changes				
What does cognitive load refer to?	Mental processing demand				
How does increased cognitive load affect performance?	Decreases accuracy/speed				
What is consciousness?	Awareness of self and environment				
Is consciousness all-or-none?	No				
What is controlled processing?	Effortful, conscious processing				
What is automatic processing?	Fast, unconscious processing				
Which type of processing requires attention?	Controlled processing				
How does practice affect processing type?	Shifts controlled → automatic				
What is the global workspace idea of consciousness?	Shared information access				
Why does the MCAT emphasize attention limits?	Explains performance errors				
What MCAT trap confuses attention and perception?	Assuming perception equals awareness				
Core MCAT rule: what limits cognition most?	Attention capacity				
- -	-				
What is learning, conceptually?	Relatively permanent change in behavior				
What defines classical conditioning?	Learning associations between stimuli				

In classical conditioning, what is paired?	Neutral stimulus with unconditioned stimulus			
What is the unconditioned stimulus (US)?	Stimulus that naturally elicits a response			
What is the unconditioned response (UR)?	Natural response to US			
What is the conditioned stimulus (CS)?	Previously neutral stimulus			
What is the conditioned response (CR)?	Learned response to CS			
What defines operant conditioning?	Learning through consequences			
What is reinforcement?	Increases behavior			
What is punishment?	Decreases behavior			
What does positive mean in conditioning?	Adding a stimulus			
What does negative mean in conditioning?	Removing a stimulus			
Does negative reinforcement decrease behavior?	No			
Which reinforcement schedule is most resistant to extinction?	Variable ratio			
What is extinction?	Decrease in learned response			
Does extinction erase learning?	No			
What is spontaneous recovery?	Reappearance after extinction			
What is shaping?	Reinforcing successive approximations			
What MCAT trap confuses conditioning terms?	Positive vs negative			
Core MCAT rule: what drives operant learning?	Consequences			
- -	-			
What are the three core stages of memory?	Encoding, storage, retrieval			
What is encoding?	Processing information into memory			
What improves encoding most effectively?	Meaningful processing			
What is storage?	Retention of information over time			
What is retrieval?	Accessing stored information			
What type of memory holds sensory input briefly?	Sensory memory			
What type of memory holds information temporarily for use?	Working memory			
How is working memory different from short-term memory?	Active manipulation			
What limits working memory capacity?	Cognitive load			
What type of memory stores information long-term?	Long-term memory			
What is explicit (declarative) memory?	Conscious recall			
What are the two types of explicit memory?	Semantic and episodic			
What is semantic memory?	Facts and knowledge			
What is episodic memory?	Personal experiences			
What is implicit (nondeclarative) memory?	Unconscious memory			
What is a classic example of implicit memory?	Procedural skills			

Does amnesia affect implicit and explicit memory equally?	No
What does the encoding specificity principle state?	Context aids retrieval
Why can retrieval fail even if storage is intact?	Cue mismatch
Core MCAT rule: what most often limits memory performance?	Encoding quality
- -	-
What is language, psychologically?	System of symbols for communication
What is a phoneme?	Smallest unit of sound
What is a morpheme?	Smallest unit of meaning
What is syntax?	Rules for sentence structure
What is semantics?	Meaning of words and sentences
What brain function is language most tied to on the MCAT?	Symbolic processing
What is cognition?	Mental processing of information
What is problem-solving?	Identifying solutions to goals
What is an algorithm?	Step-by-step problem-solving method
What is a heuristic?	Mental shortcut
Why are heuristics used?	Reduce cognitive load
What is the availability heuristic?	Judging likelihood by ease of recall
What is the representativeness heuristic?	Judging by similarity to prototype
What is anchoring bias?	Overreliance on initial information
What is confirmation bias?	Favoring information that supports beliefs
What is belief perseverance?	Clinging to beliefs despite evidence
What is fixation in problem-solving?	Inability to see alternatives
Why does the MCAT test heuristics heavily?	Explains reasoning errors
What MCAT trap confuses heuristics?	Thinking they are always bad
Core MCAT rule: what tradeoff do heuristics represent?	Speed vs accuracy
- -	-
What are emotions, psychologically?	Coordinated physiological and cognitive responses
What does the James–Lange theory propose?	Arousal precedes emotion
What does the Cannon–Bard theory propose?	Arousal and emotion occur simultaneously
What does the Schachter–Singer (two-factor) theory propose?	Arousal + cognitive label
Which emotion theory emphasizes interpretation of arousal?	Schachter–Singer
What is stress, conceptually?	Response to perceived challenge
Is stress always negative?	No
What is eustress?	Beneficial stress

What is distress?	Harmful stress
What physiological system mediates acute stress?	Sympathetic nervous system
What physiological system mediates chronic stress?	HPA axis
What hormone is central to the HPA axis?	Cortisol
What is the general adaptation syndrome (GAS)?	Stages of stress response
What are the stages of GAS?	Alarm, resistance, exhaustion
What is motivation?	Drive to pursue goals
What does drive-reduction theory emphasize?	Homeostasis
What does incentive theory emphasize?	External rewards
What does self-determination theory emphasize?	Autonomy, competence, relatedness
What MCAT trap confuses emotion theories?	Mixing sequence of arousal/emotion
Core MCAT rule: emotion depends on what interaction?	Physiology + cognitio
- -	-
What is personality, psychologically?	Enduring patterns of thoughts and behavior
What distinguishes trait theories of personality?	Quantifiable characteristics
What is the “Big Five” model?	Five core personality traits
What traits make up the Big Five?	OCEAN
What is openness?	Curiosity and creativity
What is conscientiousness?	Organization and responsibility
What is extraversion?	Sociability and energy
What is agreeableness?	Cooperation and trust
What is neuroticism?	Emotional instability
What distinguishes type theories of personality?	Categorical classification
What is a limitation of type theories?	Oversimplification
What is the psychoanalytic view of personality?	Unconscious conflict
What structures compose Freud’s model?	Id, ego, superego
What is the humanistic view of personality?	Growth and self-actualization
What does Maslow’s hierarchy emphasize?	Progressive fulfillment of needs
What is the social-cognitive view of personality?	Interaction of person and environment
What is locus of control?	Perceived control over outcomes
What distinguishes internal locus of control?	Outcomes attributed to self
What distinguishes external locus of control?	Outcomes attributed to outside forces
Core MCAT rule: personality theories differ mainly in what?	Explanatory focus
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How does the MCAT define a psychological disorder?	Persistent dysfunction causing distress or impairment
What distinguishes normal variation from disorder?	Degree and functional impact
Are psychological disorders purely biological?	No
What model integrates biological, psychological, and social factors?	Biopsychosocial model
What is comorbidity?	Co-occurrence of multiple disorders
Why is comorbidity common?	Shared risk factors
What characterizes anxiety disorders broadly?	Excessive fear or worry
What distinguishes phobias from generalized anxiety?	Specific vs diffuse fear
What defines major depressive disorder conceptually?	Persistent low mood and anhedonia
What cognitive pattern is common in depression?	Negative attribution bias
What distinguishes bipolar disorders from depression?	Presence of mania
What defines mania behaviorally?	Elevated mood, energy, impulsivity
What characterizes schizophrenia spectrum disorders?	Psychosis and disorganized thinking
What is psychosis?	Loss of contact with reality
What symptom type includes hallucinations and delusions?	Positive symptoms
What symptom type includes flat affect and withdrawal?	Negative symptoms
What distinguishes PTSD from acute stress disorder?	Duration
What role does stress play in many disorders?	Trigger and amplifier
Why does the MCAT avoid DSM criteria?	Focuses on reasoning, not diagnosis
Core MCAT rule: mental disorders are best understood as what?	Multifactorial
- -	-
What does sociology primarily study?	Social structures and interactions
What is social influence?	How others affect behavior
What is conformity?	Adjusting behavior to group norms
What classic factor increases conformity?	Group unanimity
What is obedience?	Compliance with authority
How does obedience differ from conformity?	Authority vs peers
What is social facilitation?	Improved performance with others present
When does social facilitation impair performance?	Complex or unfamiliar tasks
What is social loafing?	Reduced effort in groups
What reduces social loafing?	Individual accountability
What is deindividuation?	Loss of self-awareness in groups
What increases deindividuation?	Anonymity
What is group polarization?	Strengthening of group attitudes

What is groupthink?	Desire for harmony overrides judgment			
What is a social norm?	Shared behavioral expectations			
What is socialization?	Learning norms and roles			
What is social stratification?	Structured inequality			
What commonly defines socioeconomic status (SES)?	Income, education, occupation			
How does SES affect health outcomes?	Access and exposure differences			
Core MCAT rule: social behavior reflects what interaction?	Individual + structure			
Sigmund Freud — core contribution	Psychoanalytic theory of personality			
Freud — id	Primitive, unconscious drives; pleasure principle			
Freud — ego	Rational mediator; reality principle			
Freud — superego	Internalized moral standards			
Freud — level of mind most behavior originates from	Unconscious			
Erik Erikson — core contribution	Psychosocial development across the lifespan			
Erikson — major focus of development	Social relationships and identity			
Erikson stage: Trust vs Mistrust	Infancy			
Erikson stage: Autonomy vs Shame and Doubt	Toddlerhood			
Erikson stage: Initiative vs Guilt	Early childhood			
Erikson stage: Industry vs Inferiority	Middle childhood			
Erikson stage: Identity vs Role Confusion	Adolescence			
Erikson stage: Intimacy vs Isolation	Young adulthood			
Erikson stage: Generativity vs Stagnation	Middle adulthood			
Erikson stage: Integrity vs Despair	Late adulthood			
Jean Piaget — core contribution	Cognitive development theory			
Piaget — focus of development	How thinking changes with age			
Piaget stage: Sensorimotor	Birth–2 years			
Piaget stage: Preoperational	2–7 years			
Piaget stage: Concrete operational	7–11 years			
Piaget stage: Formal operational	12+ years			
Sensorimotor stage — key feature	Object permanence			
Preoperational stage — limitation	Egocentrism			
Concrete operational stage — key ability	Logical reasoning about concrete events			
Formal operational stage — key ability	Abstract and hypothetical reasoning			
Lawrence Kohlberg — core contribution	Moral development theory			
Kohlberg — level 1	Preconventional morality			
Kohlberg — level 2	Conventional morality			
Kohlberg — level 3	Postconventional morality			

Preconventional morality — guiding principle	Avoid punishment / seek reward
Conventional morality — guiding principle	Follow rules and social norms
Postconventional morality — guiding principle	Universal ethical principles
Ivan Pavlov — core contribution	Classical conditioning
B. F. Skinner — core contribution	Operant conditioning
Classical vs operant conditioning — key distinction	Association between stimuli vs consequences of behavior
-	**Back**
Mental disorder — MCAT framing	Diagnosed by symptom patterns and functional impairment
Major depressive disorder — hallmark symptom	Persistent depressed mood and/or anhedonia
Major depressive disorder — minimum duration	≥ 2 weeks
Major depressive disorder — common treatment class	Antidepressants and psychotherapy
Bipolar I disorder — defining feature	At least one manic episode
Mania — key characteristics	Elevated mood, decreased need for sleep, impulsivity
Bipolar II disorder — defining feature	Hypomania + major depressive episodes
Bipolar I vs Bipolar II — key distinction	Mania (I) vs hypomania (II)
Schizophrenia — hallmark symptom category	Psychosis (delusions, hallucinations)
Schizophrenia — minimum duration	≥ 6 months
Schizophrenia — symptom type associated with dopamine excess	Positive symptoms
Schizophrenia — common treatment class	Antipsychotic medications
Obsessive-compulsive disorder — hallmark feature	Intrusive thoughts and compulsive behaviors
OCD — insight status	Usually recognizes thoughts are irrational
OCD — common treatment class	SSRIs and cognitive behavioral therapy
Post-traumatic stress disorder — defining trigger	Exposure to traumatic event
PTSD — symptom cluster	Re-experiencing, avoidance, hyperarousal
PTSD — key time criterion	Symptoms > 1 month
Generalized anxiety disorder — hallmark feature	Excessive, uncontrollable worry
Generalized anxiety disorder — minimum duration	≥ 6 months
Panic disorder — defining feature	Recurrent, unexpected panic attacks
Panic disorder — hallmark symptom	Intense physical fear response
Attention-deficit/hyperactivity disorder — core features	Inattention and/or hyperactivity-impulsivity
ADHD — typical age of onset	Childhood
Autism spectrum disorder — core deficit	Social communication impairment
Autism spectrum disorder — associated feature	Restricted or repetitive behaviors
Autism spectrum disorder — developmental timing	Early childhood onset
Phobia — defining feature	Irrational fear of specific object or situation
Somatic symptom disorder — hallmark feature	Excessive focus on physical symptoms

Mental disorder vs normal variation — MCAT distinction	Disorder causes functional impairment or distress
-	**Back**
Sociology — MCAT focus	How social structures influence behavior and outcomes
Social structure — definition	Organized pattern of social relationships and institutions
Social institution — examples	Family, education, religion, government, economy
Agent of socialization — definition	Entity that transmits norms and values
Primary agents of socialization	Family and peers
Secondary agents of socialization	School, media, workplace, religion
Social norms — definition	Shared expectations for behavior
Social values — definition	Collective ideas about what is desirable or important
Culture — definition	Shared beliefs, norms, values, and practices
Cultural capital — definition	Nonfinancial social assets (education, skills, tastes)
Social capital — definition	Resources gained through social networks
Economic capital — definition	Financial resources and material wealth
Social stratification — definition	Structured inequality among social groups
Socioeconomic status (SES) — components	Income, education, occupation
Absolute poverty — definition	Inability to meet basic living needs
Relative poverty — definition	Economic disadvantage compared to societal standards
Demographic transition model — purpose	Describes population change with economic development
Demographic transition — early stage	High birth rate, high death rate
Demographic transition — late stage	Low birth rate, low death rate
Urbanization — definition	Population shift from rural to urban areas
Epidemiology — definition	Study of disease distribution in populations
Incidence — definition	Number of new cases over time
Prevalence — definition	Total number of existing cases
Cohort study — definition	Follows exposed vs unexposed groups forward in time
Case-control study — definition	Compares diseased vs non-diseased groups retrospectively
Cross-sectional study — definition	Snapshot of a population at one time
Confounding variable — definition	External factor affecting both variables
Social mobility — definition	Movement between social classes
Meritocracy — definition	Advancement based on ability and effort
Health disparity — definition	Differences in health outcomes between populations
	Physiololgy Patch
Core Variables (Foundation Cards)	
Front	Back

What is cardiac output (CO)?	CO = HR × SV; total blood flow generated by the heart per minute
What does stroke volume (SV) represent?	Volume ejected by one ventricle per beat
What three factors determine stroke volume?	Preload, afterload, contractility
What is mean arterial pressure (MAP) conceptually?	Average driving pressure for systemic blood flow
What two variables primarily determine MAP?	MAP ≈ CO × TPR
Preload, Afterload, Contractility (High-Yield Logic)	
Front	Back
What is preload?	Ventricular filling (end-diastolic volume); stretch before contraction
What increases preload?	↑ Venous return, ↑ blood volume, ↓ venous compliance
How does preload affect stroke volume?	↑ preload → ↑ SV via Frank–Starling mechanism
What is afterload?	Resistance the ventricle must overcome to eject blood
What increases afterload?	↑ Arterial pressure, ↑ vascular resistance
How does increased afterload affect SV?	↑ afterload → ↓ SV
What is contractility?	Intrinsic strength of cardiac muscle contraction
What increases contractility?	Sympathetic stimulation, Ca^{2+} availability
Frank–Starling Law (MCAT Favorite)	
Front	Back
What does the Frank–Starling law state?	↑ Ventricular filling → ↑ force of contraction
Why does stretch increase contraction strength?	Optimizes actin–myosin overlap
What does Frank–Starling help the heart do?	Match output to venous return without neural input
Does Frank–Starling change contractility?	No — it changes force via stretch, not intrinsic strength
Pressure–Flow Relationships	
Front	Back
What equation governs blood flow?	Flow = ΔP / Resistance
What primarily determines vascular resistance?	Vessel radius
How does radius affect resistance?	Resistance ∝ $1/r^4$ (small changes matter a lot)
Why do arterioles control blood distribution?	They offer the greatest adjustable resistance
Venous System & Venous Return	
Front	Back
Why are veins called capacitance vessels?	They store large volumes at low pressure
What increases venous return?	Muscle pump, venoconstriction, ↑ blood volume
How does venous return affect CO?	↑ venous return → ↑ preload → ↑ CO
Why does standing suddenly cause dizziness?	Venous pooling → ↓ preload → ↓ CO
Integration & Compensation Cards	
Front	Back
If TPR increases suddenly, what happens immediately to CO?	CO decreases

How does the body compensate for increased TPR?	↑ HR, ↑ contractility			
What happens to cardiac workload when afterload increases?	Workload and energy demand increase			
Why does hypertension strain the heart?	Chronic high afterload → ↑ work → hypertrophy			
Common MCAT Traps (Explicit)				
Front	Back			
Does the heart “pull” blood in?	No — filling is pressure-driven			
Do valves actively pump blood?	No — they open/close passively via pressure			
Does higher pressure always mean higher flow?	No — flow depends on resistance			
Passage Reasoning Templates (High ROI)				
Front	Back			
Increased venous return → ?	↑ Preload → ↑ SV → ↑ CO			
Increased arterial resistance → ?	↑ Afterload → ↓ SV → ↓ CO			
Increased sympathetic tone → ?	↑ HR + ↑ contractility → ↑ CO			
Vasodilation in one tissue → ?	↓ local resistance → ↑ local flow			
Core Identity of Pulmonary Circulation				
Front	Back			
What is the primary purpose of pulmonary circulation?	Gas exchange (oxygenation of blood)			
How does pulmonary circulation differ from systemic circulation?	Low pressure, low resistance			
Why must pulmonary pressure be low?	To prevent fluid leakage into alveoli			
Does the right heart generate high pressure?	No — it is a volume pump, not a pressure pump			
Pressure & Resistance Logic (High-Yield)				
Front	Back			
Why is pulmonary vascular resistance low?	Short vessels, large total cross-sectional area			
What happens if pulmonary resistance increases?	↑ Right ventricular workload			
Why is pulmonary hypertension dangerous?	Right heart is not built for high pressure			
Which ventricle is affected first by lung disease?	Right ventricle			
Gravity & Blood Flow Distribution				
Front	Back			
How does gravity affect pulmonary blood flow?	More flow to lung bases than apices			
Why do lung bases receive more blood?	Higher hydrostatic pressure			
Is ventilation evenly distributed in lungs?	No — also greater at bases			
Which is affected more by gravity: perfusion or ventilation?	Perfusion			
Ventilation–Perfusion (V/Q) Logic				
Front	Back			
What does the V/Q ratio describe?	Matching of airflow (V) to blood flow (Q)			
What is the ideal V/Q ratio?	~1 (matched ventilation and perfusion)			

What happens when V ≠ Q?	Inefficient gas exchange				
Does high ventilation guarantee good oxygenation?	No — perfusion must also be present				
V/Q Extremes (Classic MCAT Scenarios)					
Front	Back				
What is a shunt?	Perfusion without ventilation (Q without V)				
Example of a shunt?	Airway obstruction, pneumonia				
What is dead space?	Ventilation without perfusion (V without Q)				
Example of dead space?	Pulmonary embolism				
Which is worse for oxygenation: shunt or dead space?	Shunt				
Oxygenation & Hemoglobin Coupling					
Front	Back				
What is the main variable determining oxygen uptake?	Alveolar oxygen partial pressure				
Does oxygen content depend only on PaO_2?	No — hemoglobin matters				
Why can PaO_2 be normal but O_2 delivery low?	Anemia or low hemoglobin				
Why does pulmonary circulation optimize diffusion distance?	Thin alveolar–capillary membrane				
Hypoxic Pulmonary Vasoconstriction (VERY High-Yield)					
Front	Back				
How do pulmonary vessels respond to hypoxia?	Vasoconstrict				
Why is hypoxic vasoconstriction useful in lungs?	Redirects blood to better-ventilated areas				
Is hypoxic vasoconstriction good or bad systemically?	Bad systemically, adaptive in lungs				
What happens in global hypoxia (e.g., high altitude)?	Widespread vasoconstriction → ↑ pulmonary pressure				
Integration with Cardiac Physiology					
Front	Back				
What happens to RV preload if pulmonary resistance increases?	RV preload increases				
Chronic lung disease leads to what cardiac condition?	Cor pulmonale (right heart failure)				
Why does left heart failure cause pulmonary edema?	Blood backs up into pulmonary circulation				
Pulmonary edema impairs which process first?	Gas diffusion				
Common MCAT Traps (Explicit)					
Front	Back				
Is pulmonary circulation high pressure?	No				
Does oxygen drive pulmonary vasodilation or constriction?	Vasodilation				
Are lungs optimized for pressure generation?	No — optimized for exchange				
Does increasing ventilation always improve oxygenation?	Not if perfusion is limited				
1 Passage Reasoning Templates ( )					
Front	Back				
Blocked airway → ?	↓ V → shunt → ↓ oxygenation				

Pulmonary embolism → ?	↓ Q → dead space				
High altitude → ?	Hypoxia → pulmonary vasoconstriction				
Lung bases vs apices → ?	Higher perfusion at bases				
Big Picture Role of the Kidneys					
Front	Back				
What is the kidney’s primary cardiovascular role?	Long-term regulation of blood pressure				
How do kidneys regulate blood pressure?	By controlling blood volume				
Does the heart control long-term BP?	No — it adjusts output, not volume				
Does vascular tone control long-term BP?	No — kidneys reset baseline				
Pressure vs Volume Control					
Front	Back				
What variable do kidneys directly control?	Blood volume				
How does blood volume affect BP?	↑ volume → ↑ venous return → ↑ CO → ↑ BP				
What is the kidney’s response to high BP?	Excrete Na^+ and water				
What is the kidney’s response to low BP?	Retain Na^+ and water				
Renin–Angiotensin–Aldosterone System (RAAS)					
Front	Back				
What triggers renin release?	Low renal perfusion, low NaCl, sympathetic input				
What is renin’s purpose?	Restore blood pressure				
What does angiotensin II do overall?	Increases BP				
How does angiotensin II raise BP?	Vasoconstriction + aldosterone + ADH				
What does aldosterone increase?	Na^+ (and water) reabsorption				
Where does aldosterone act?	Distal nephron				
ADH (Vasopressin) Logic					
Front	Back				
What does ADH directly regulate?	Water reabsorption				
What triggers ADH release?	High osmolality or low BP				
Where does ADH act?	Collecting duct				
What is ADH’s cardiovascular effect?	↑ blood volume → ↑ BP				
Does ADH affect solute?	No — water only				
ANP — The Counter-Regulator					
Front	Back				
What triggers ANP release?	Atrial stretch (high volume)				
What is ANP’s purpose?	Lower blood pressure				
How does ANP lower BP?	↑ Na^+ excretion, ↓ RAAS				
When is ANP active?	Volume overload states				

Time-Scale Reasoning (VERY High-Yield)					
Front	Back				
Fast BP control (seconds–minutes)	Heart rate, vascular tone				
Intermediate BP control (minutes–hours)	Hormones (RAAS, ADH)				
Long-term BP control (days)	Kidneys (volume)				
Why is kidney control slow?	Requires changing total body water				
Integration with Cardiac Function					
Front	Back				
How does kidney retention affect preload?	Increases preload				
How does increased preload affect CO?	↑ CO via Frank–Starling				
Chronic RAAS activation leads to what?	Hypertension				
Why is RAAS maladaptive in heart failure?	Volume overload worsens workload				
Disease & Perturbation Logic					
Front	Back				
Renal artery stenosis → BP?	↑ BP (perceived low perfusion)				
Heart failure → RAAS activation?	Yes				
Why does HF cause edema?	Kidneys retain volume despite overload				
Diuretics lower BP by doing what?	Reducing blood volume				
Common MCAT Traps					
Front	Back				
Do kidneys directly control heart rate?	No				
Is RAAS always beneficial?	No — context dependent				
Does vasoconstriction increase volume?	No				
Does aldosterone increase K^+?	No — increases Na^+, decreases K^+				
Core Acid–Base Framework (Non-Negotiable)					
Front	Back				
What determines blood pH?	Ratio of H^+ to buffering capacity				
What is the major blood buffer?	Bicarbonate (HCO_3^-)				
What equation governs acid–base balance?	$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$				
Increasing CO_2 shifts pH which way?	↓ pH (more acidic)				
Division of Labor: Lungs vs Kidneys					
Front	Back				
What do the lungs control?	CO_2				
What do the kidneys control?	H^+ and HCO_3^-				
Which system responds faster?	Lungs				
Which provides long-term correction?	Kidneys				

Respiratory Disorders (Primary CO_2 Problem)					
Front	Back				
What causes respiratory acidosis?	CO_2 retention (hypoventilation)				
What causes respiratory alkalosis?	CO_2 loss (hyperventilation)				
Kidney response to respiratory acidosis?	↑ HCO_3^- reabsorption				
Kidney response to respiratory alkalosis?	↑ HCO_3^- excretion				
Metabolic Disorders (Primary HCO_3^- / H^+ Problem)					
Front	Back				
What causes metabolic acidosis?	↑ H^+ or ↓ HCO_3^-				
What causes metabolic alkalosis?	↓ H^+ or ↑ HCO_3^-				
Lung response to metabolic acidosis?	↑ ventilation (blow off CO_2)				
Lung response to metabolic alkalosis?	↓ ventilation (retain CO_2)				
Directional Logic (MCAT Gold)					
Front	Back				
Compensation fixes pH or cause?	pH only (never the cause)				
Does compensation overshoot?	No				
Can lungs fix metabolic cause?	No				
Can kidneys fix respiratory cause?	No				
Classic MCAT Scenarios					
Front	Back				
Panic attack → ?	Respiratory alkalosis				
COPD exacerbation → ?	Respiratory acidosis				
Diarrhea → ?	Metabolic acidosis				
Vomiting → ?	Metabolic alkalosis				
High altitude → ?	Respiratory alkalosis (early)				
Cardio–Pulm–Renal Integration					
Front	Back				
Why does hypoventilation affect BP?	↑ CO_2 → vasodilation				
Why does acidosis stress the heart?	↓ contractility				
Why do kidneys matter in chronic lung disease?	Long-term pH correction				
Why does edema worsen gas exchange?	↑ diffusion distance				
Compensation Time-Scale Synthesis					
Front	Back				
Seconds–minutes	Ventilation changes				
Hours–days	Renal H^+ / HCO_3^- handling				
Chronic disease compensation	Renal dominates				

Common MCAT Traps					
Front	Back				
Is pH determined by oxygen?	No				
Is hyperventilation always bad?	No — compensatory				
Does compensation normalize $PaCO_2$?	No				
Does normal pH mean no disorder?	No — compensated state				
Big Picture: What Kidneys Actually Do					
Front	Back				
What are the kidneys optimizing?	Composition of blood				
What must kidneys balance constantly?	Waste removal vs useful retention				
What is filtration?	Bulk movement of plasma into nephron				
What is reabsorption?	Returning useful substances to blood				
What is secretion?	Adding substances into tubule				
Glomerular Filtration Logic (VERY High-Yield)					
Front	Back				
What drives glomerular filtration?	Blood pressure				
What opposes filtration?	Capsular pressure + oncotic pressure				
What does GFR measure?	Rate of plasma filtration				
If renal BP drops, what happens to GFR?	GFR decreases				
Why must filtration be pressure-driven?	No active transport at glomerulus				
What Gets Filtered (Rule-Based, Not Lists)					
Front	Back				
What determines if something is filtered?	Size + charge				
Are cells filtered?	No				
Are proteins filtered?	No				
Are small solutes filtered?	Yes				
Is filtration selective by usefulness?	No				
Proximal Tubule — Bulk Recovery Zone					
Front	Back				
What is the role of the proximal tubule?	Reclaim most useful substances				
What is reabsorbed here?	Na^+, glucose, amino acids, water				
Is reabsorption here regulated?	No — it’s bulk				
What happens if glucose transport saturates?	Glucose appears in urine				
Loop of Henle — Gradient Builder					
Front	Back				
What is the loop of Henle’s purpose?	Create osmotic gradient				

Descending limb permeability?	Water only				
Ascending limb permeability?	Salt only				
Does ascending limb allow water movement?	No				
What is countercurrent multiplication?	Repeated gradient reinforcement				
Countercurrent Logic (MCAT Favorite)					
Front	Back				
Why is the medulla hyperosmotic?	Active salt pumping				
What does this gradient allow?	Concentrated urine				
Does the loop concentrate urine directly?	No				
What structure uses the gradient?	Collecting duct				
ADH Revisited — Now It Makes Sense					
Front	Back				
What does ADH insert into collecting duct?	Aquaporins				
What happens when ADH is high?	Water reabsorbed				
What happens to urine with high ADH?	Concentrated				
What happens to plasma volume?	Increases				
Dilute vs Concentrated Urine					
Front	Back				
When is urine dilute?	Low ADH				
When is urine concentrated?	High ADH				
Does concentrating urine require more solute?	No — requires water removal				
Why can kidneys excrete dilute urine?	Ascending limb blocks water				
Integration with Blood Pressure					
Front	Back				
How does filtration affect BP long-term?	Volume determines BP				
What happens if kidneys retain Na^+?	Water follows → ↑ volume				
Why do diuretics lower BP?	Reduce volume				
Why does kidney failure cause hypertension?	Inability to excrete volume				
Hormone Classes (Foundational Logic)					
Front	Back				
Two major hormone classes?	Peptide/protein vs steroid				
Peptide hormone receptor location	Cell surface				
Steroid hormone receptor location	Intracellular (cytosolic or nuclear)				
Which act faster?	Peptide hormones				
Which act longer?	Steroid hormones				
Second Messenger Logic (MCAT Core)					

Front	Back
Why do peptide hormones need second messengers?	Cannot cross membrane
cAMP generally causes what?	Signal amplification
IP_3/DAG generally causes what?	Ca^{2+} release
Do second messengers change DNA directly?	No
Insulin vs Glucagon (Metabolic Counter-Regulation)	
Front	Back
What does insulin signal?	Energy abundance
What does glucagon signal?	Energy scarcity
Insulin effect on blood glucose	Decreases
Glucagon effect on blood glucose	Increases
Primary insulin target tissues	Muscle, adipose, liver
Does insulin affect gene transcription?	Yes (indirectly)
Cortisol — Stress & Long-Term Adaptation	
Front	Back
What kind of hormone is cortisol?	Steroid
Cortisol time scale	Hours to days
Cortisol effect on glucose	Increases
Cortisol effect on immune system	Suppressive
Why does cortisol raise glucose?	Ensure fuel during stress
Thyroid Hormone — Metabolic Rate Setter	
Front	Back
Thyroid hormone type	Steroid-like
Thyroid hormone main effect	↑ basal metabolic rate
Effect on oxygen consumption	Increases
Effect on heat production	Increases
Why thyroid affects heart rate	Increases metabolic demand
Endocrine Control of Blood Pressure	
Front	Back
Which hormones raise BP?	Ang II, aldosterone, ADH, cortisol
Which hormones lower BP?	ANP
Aldosterone affects what directly?	Na^+ retention
ADH affects what directly?	Water retention
Cortisol permissive for what?	Vasoconstriction
Time-Scale Integration (Very High-Yield)	
Front	Back

Seconds–minutes	Neural signals				
Minutes–hours	Peptide hormones				
Hours–days	Steroid hormones				
Long-term baseline control	Endocrine + renal				
Disease & Perturbation Reasoning					
Front	Back				
Insulin deficiency → ?	Hyperglycemia				
Cortisol excess → ?	Immunosuppression, hyperglycemia				
Thyroid excess → ?	Tachycardia, heat intolerance				
Thyroid deficiency → ?	Bradycardia, cold intolerance				
Common MCAT Traps					
Front	Back				
Do all hormones use second messengers?	No				
Does fast signaling mean weak signaling?	No				
Do steroid hormones act immediately?	No				
Is cortisol “bad”?	No — context dependent				
Core Framing: What Inflammation Actually Is					
Front	Back				
What is inflammation fundamentally?	A vascular response to injury or infection				
Primary goals of inflammation	Deliver immune cells and molecules				
Is inflammation inherently bad?	No — it is protective				
What system executes inflammation first?	Vasculature				
Vascular Changes in Inflammation (VERY High-Yield)					
Front	Back				
First vascular change in inflammation	Vasodilation				
Effect of vasodilation	↑ blood flow				
Second vascular change	↑ permeability				
Effect of ↑ permeability	Plasma proteins & cells exit vessels				
Why does tissue swell?	Fluid leakage into interstitium				
Mediators & Directional Logic (No Lists)					
Front	Back				
What do inflammatory mediators generally do?	Dilate vessels & increase permeability				
Does inflammation increase or decrease resistance locally?	Decreases				
Does inflammation increase or decrease local flow?	Increases				
Why does redness occur?	Increased blood flow				
Immune Cell Recruitment (Flow-Based Logic)					

Front	Back
How do immune cells reach tissues?	Exit bloodstream
What enables immune cell exit?	Increased permeability
Do immune cells randomly diffuse?	No — directed recruitment
Why are capillaries ideal for exchange?	Thin walls + low velocity
Local vs Systemic Inflammation	
Front	Back
Local inflammation affects what?	Tissue-level blood flow
Systemic inflammation affects what?	Total vascular tone & BP
Cytokines released systemically cause?	Fever, hypotension
Why can systemic inflammation be dangerous?	Loss of BP control
Shock States (EXTREMELY High-Yield)	
Front	Back
What is shock?	Inadequate tissue perfusion
Does shock always involve low BP?	Usually
Common final pathway of shock	↓ oxygen delivery
Which organ fails first in shock?	Brain
Types of Shock (Mechanism-Based)	
Front	Back
Septic shock mechanism	Excessive vasodilation + permeability
Cardiogenic shock mechanism	Pump failure
Hypovolemic shock mechanism	Low volume
Anaphylactic shock mechanism	Immune-mediated vasodilation
Immune–Cardio–Renal Integration	
Front	Back
Why does inflammation lower BP?	↓ resistance + ↓ volume
Kidney response to inflammatory hypotension	Activate RAAS
Why can RAAS worsen edema?	Volume retention + leaky vessels
Why is septic shock hard to treat?	Vasodilation overwhelms compensation
Fever Logic (Classic MCAT)	
Front	Back
What causes fever?	Cytokine-mediated hypothalamic reset
Fever effect on immune function	Enhances
Why do patients feel cold during fever onset?	Body raises set point
Why does sweating occur during fever break?	Set point decreases
Big Picture: What the GI System Is Doing	

Front	Back
Primary purpose of the GI system	Absorb nutrients into the body
Is digestion the main goal?	No — absorption is
Why is surface area critical in GI tract?	Maximizes absorption
What structures increase surface area?	Folds, villi, microvilli
Segmentation of Function (VERY High-Yield)	
Front	Back
Main role of the stomach	Mechanical & chemical breakdown
Main role of small intestine	Nutrient absorption
Main role of large intestine	Water & electrolyte absorption
Where does most absorption occur?	Small intestine
Nutrient Absorption Logic (Rule-Based)	
Front	Back
Where are carbohydrates absorbed?	Small intestine
How are carbs absorbed?	As monosaccharides
Where are proteins absorbed?	Small intestine
How are proteins absorbed?	As amino acids / small peptides
Where are fats absorbed?	Small intestine
Special requirement for fat absorption	Bile
Fat Digestion & Absorption (MCAT Favorite)	
Front	Back
Why are fats difficult to digest?	Hydrophobic
Role of bile	Emulsifies fats
Where is bile made?	Liver
Where is bile stored?	Gallbladder
What absorbs fats after digestion?	Enterocytes → lymph
Why do fats enter lymph first?	Too large for capillaries
Portal Circulation (Critical Integration)	
Front	Back
What is portal circulation?	Blood from GI → liver
Why does blood go to liver first?	Processing & detoxification
What nutrients go via portal vein?	Sugars, amino acids
What bypasses portal vein initially?	Fats
Why is portal flow important clinically?	First-pass metabolism
GI Hormones (Logic, Not Lists)	
Front	Back

What do GI hormones coordinate?	Digestion with absorption
When are GI hormones released?	In response to food
CCK released in response to?	Fats & proteins
CCK effects	↑ bile release, ↑ pancreatic enzymes
Secretin released in response to?	Acid
Secretin effect	↑ bicarbonate
Gastrin effect	↑ gastric acid
Blood Flow & Feeding State	
Front	Back
What happens to GI blood flow after eating?	Increases
Why does GI blood flow increase?	Support absorption
What happens to GI blood flow during exercise?	Decreases
Why can exercise cause GI discomfort?	Reduced perfusion
Integration with Metabolism & Endocrine	
Front	Back
Why does insulin rise after meals?	Increased glucose absorption
How does liver regulate blood glucose post-meal?	Glycogen synthesis
Why is liver central to metabolism?	Receives portal blood
Why does liver disease affect nutrition?	Processing failure
Disease & Perturbation Reasoning	
Front	Back
Gallstones affect absorption of what?	Fats
Pancreatic enzyme deficiency causes?	Malabsorption
Loss of villi causes?	↓ absorption
Portal hypertension affects?	GI blood flow
Big Picture: Why Neuro + Endocrine Must Work Together	
Front	Back
Why are neuro and endocrine systems integrated?	Combine speed (neural) with persistence (hormonal)
Neural signaling time scale	Milliseconds–seconds
Endocrine signaling time scale	Minutes–days
What coordinates both systems?	Hypothalamus
Hypothalamus — The Master Integrator	
Front	Back
What information does the hypothalamus integrate?	Neural, hormonal, metabolic
How does the hypothalamus control endocrine glands?	Releasing hormones
Does the hypothalamus act as an endocrine organ?	Yes

Hypothalamus role summary	Translates neural signals into hormonal output				
Pituitary Gland Logic (MCAT Favorite)					
Front	Back				
Why is the pituitary called the “master gland”?	Releases hormones controlling other glands				
Anterior pituitary control mechanism	Hypothalamic releasing hormones				
Posterior pituitary control mechanism	Direct neural signals				
Does the pituitary initiate signals itself?	No — it responds				
Posterior Pituitary (Neural Extension)					
Front	Back				
Hormones released by posterior pituitary	ADH, oxytocin				
Where are posterior pituitary hormones synthesized?	Hypothalamus				
Why is posterior pituitary “neural”?	Hormones released via axons				
ADH cardiovascular role	↑ water retention → ↑ BP				
Anterior Pituitary (Hormonal Cascade)					
Front	Back				
Anterior pituitary hormones do what?	Stimulate endocrine glands				
Example: ACTH target	Adrenal cortex				
Example: TSH target	Thyroid gland				
Anterior pituitary signal style	Amplified, multi-step				
HPA Axis — Stress Response Core					
Front	Back				
What triggers the HPA axis?	Stress				
HPA step 1	Hypothalamus releases CRH				
HPA step 2	Pituitary releases ACTH				
HPA step 3	Adrenal cortex releases cortisol				
Purpose of cortisol	Mobilize energy, maintain BP				
Cortisol — System-Wide Effects					
Front	Back				
Cortisol time scale	Hours–days				
Cortisol effect on glucose	Increases				
Cortisol effect on immune system	Suppresses				
Cortisol effect on vasculature	Permissive for vasoconstriction				
Why cortisol helps in stress	Ensures fuel & pressure				
Negative Feedback (VERY High-Yield)					
Front	Back				
What is negative feedback?	Downstream hormone suppresses upstream release				

Cortisol feeds back on what?	Hypothalamus + pituitary				
Why is feedback essential?	Prevents overactivation				
Loss of feedback causes?	Hormone excess				
Acute vs Chronic Stress Logic					
Front	Back				
Acute stress main controller	Sympathetic nervous system				
Acute stress hormones	Epinephrine, norepinephrine				
Chronic stress main controller	HPA axis				
Chronic stress hormone	Cortisol				
Why chronic stress is harmful	Persistent catabolism & immunosuppression				
Neuro–Endocrine–Cardio Integration					
Front	Back				
Stress effect on heart rate	Increases				
Stress effect on BP	Increases				
Why cortisol supports BP	Enhances catecholamine response				
Why stress increases glucose	Fuel for brain & muscles				
Neuro–Endocrine–Immune Integration					
Front	Back				
Acute stress effect on immunity	Temporary enhancement				
Chronic stress effect on immunity	Suppression				
Why immune suppression is adaptive short-term	Prevents overreaction				
Why it’s harmful long-term	Infection risk				
Common MCAT Traps					
Front	Back				
Does cortisol act immediately?	No				
Is pituitary autonomous?	No				
Are all pituitary hormones tropic?	No				
Is stress always pathological?	No				
Big Picture: Reproduction Is Endocrine Control					
Front	Back				
What axis controls reproduction?	Hypothalamic–Pituitary–Gonadal (HPG) axis				
Why is reproduction hormonally controlled?	Requires timing & coordination				
Is reproduction essential for survival?	No — it is suppressible				
What suppresses reproduction?	Stress, energy deficit				
HPG Axis Core Logic (Universal)					
Front	Back				

Hypothalamic hormone in reproduction	GnRH				
Pituitary hormones in reproduction	LH and FSH				
Gonadal outputs	Sex steroids + gametes				
GnRH secretion pattern	Pulsatile				
Why pulsatile GnRH matters	Continuous → suppression				
Male Reproductive Physiology					
Front	Back				
LH target in males	Leydig cells				
LH effect in males	Testosterone production				
FSH target in males	Sertoli cells				
FSH effect in males	Spermatogenesis support				
Testosterone feedback target	Hypothalamus + pituitary				
Inhibin source	Sertoli cells				
Inhibin effect	↓ FSH				
Female Reproductive Physiology — Ovarian Cycle					
Front	Back				
Two ovarian cycle phases	Follicular, luteal				
Dominant hormone in follicular phase	Estrogen				
Dominant hormone in luteal phase	Progesterone				
What event separates phases?	Ovulation				
Ovulation triggered by	LH surge				
Estrogen Feedback Logic (VERY High-Yield)					
Front	Back				
Estrogen feedback at low–moderate levels	Negative feedback				
Estrogen feedback at high levels	Positive feedback				
What causes LH surge?	Sustained high estrogen				
Why is positive feedback rare?	Destabilizing by design				
Progesterone Logic (Post-Ovulation)					
Front	Back				
Progesterone source	Corpus luteum				
Progesterone main role	Maintain uterine lining				
Progesterone feedback	Negative				
What happens if no fertilization occurs?	Progesterone drops				
Progesterone drop causes	Menstruation				
Uterine Cycle Integration					
Front	Back				

Estrogen effect on uterus	Proliferation				
Progesterone effect on uterus	Secretory maintenance				
Menstrual phase cause	Hormone withdrawal				
Why uterine cycle lags ovarian cycle	Hormonal signaling delay				
Pregnancy Logic (High-Yield)					
Front	Back				
Hormone that maintains pregnancy early	hCG				
hCG source	Embryo/placenta				
hCG acts like which hormone?	LH				
Purpose of hCG	Maintain corpus luteum				
Later progesterone source	Placenta				
Contraception Logic (MCAT Favorite)					
Front	Back				
Hormonal contraception principle	Prevent ovulation				
How estrogen/progestin prevent ovulation	Suppress GnRH/LH/FSH				
Why steady hormone levels matter	Prevent LH surge				
Does contraception mimic pregnancy?	Functionally, yes				
Sex Differences in Regulation					
Front	Back				
Male HPG axis pattern	Tonic, continuous				
Female HPG axis pattern	Cyclic				
Why females have cycles	Positive feedback capability				
Which is more sensitive to stress	Female reproductive axis				
Stress & Energy Integration (Cross-System)					
Front	Back				
Effect of stress on reproduction	Suppression				
Cortisol effect on GnRH	Inhibitory				
Why reproduction halts under stress	Energy prioritization				
Which axis dominates under stress	HPA over HPG				
Common MCAT Traps					
Front	Back				
Does progesterone trigger ovulation?	No				
Is estrogen always negative feedback?	No				
Is menstruation hormone-driven or damage-driven?	Hormone withdrawal				
Does fertilization occur in uterus?	No — fallopian tube				