MCAT DOCTOR

The 20 Amino Acids for the MCAT

Every amino acid you need to know for the MCAT — structures, properties, pKa values, classifications, and high-yield facts. Organised by side chain type for rapid review.

9 Nonpolar
Hydrophobic side chains. Found in protein interiors and membranes.

6 Polar Uncharged
Hydrophilic, H-bond donors/acceptors. Found on protein surfaces.

3 Positively Charged
Basic side chains. Protonated at physiological pH (7.4).

2 Negatively Charged
Acidic side chains. Deprotonated at physiological pH (7.4).

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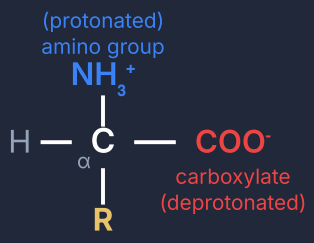
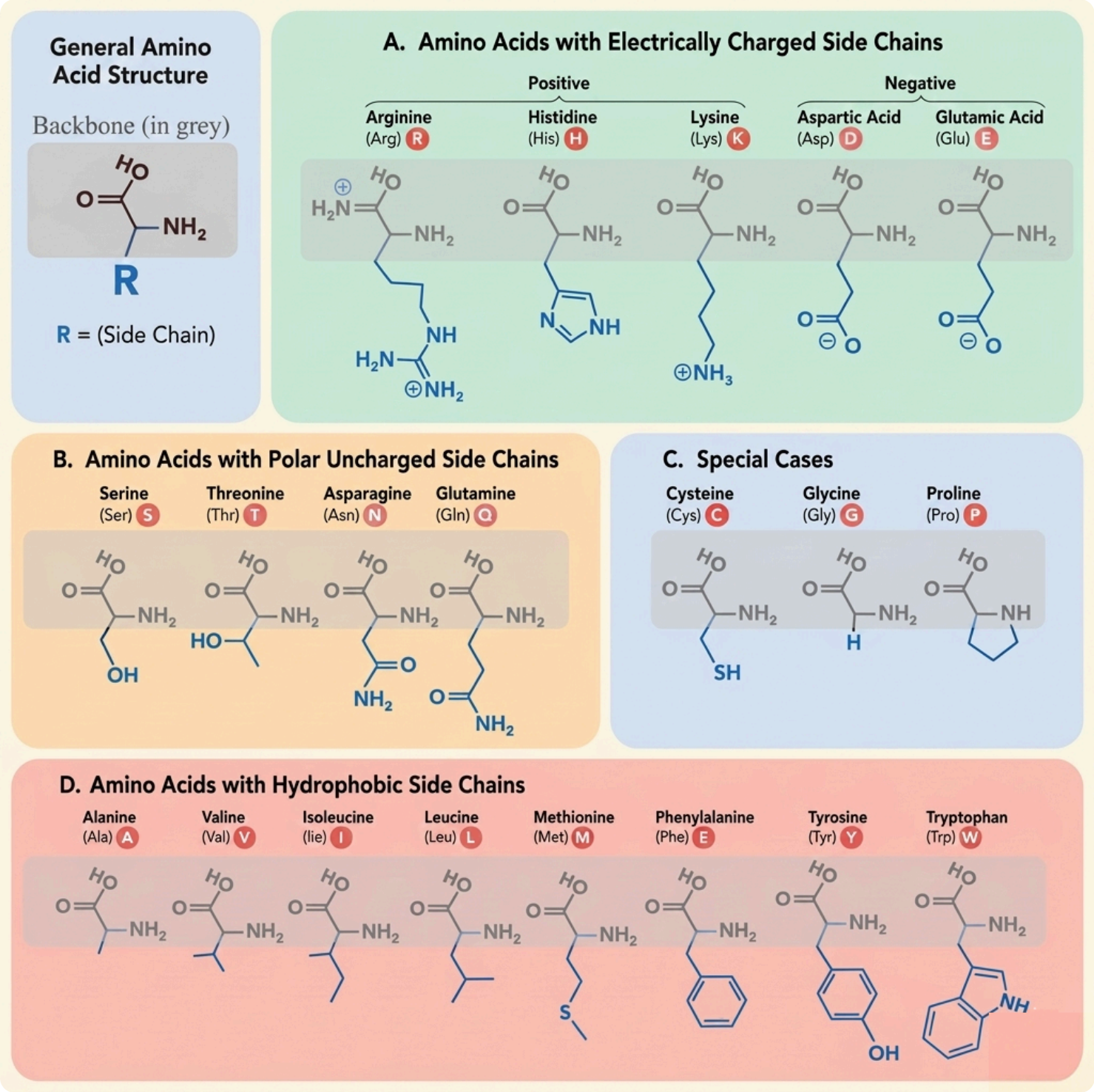
General Amino Acid Structure (at pH 7.4)



pKa_1 (COOH) ≈ 2.0
pKa_2 (NH_3^+) ≈ 9.5
pK_{aR} (side chain) — varies

pI = average of the two pKa values flanking the neutral form



Backbone (grey): The NH_2–Cα–COOH core is the same for all 20 amino acids. Only the **R group** (side chain) differs.

At pH 7.4: The backbone amino group is protonated (NH_3^+) and carboxyl is deprotonated (COO^-). Charged side chains (Asp, Glu, Lys, Arg, His) carry additional charges.

All are L-amino acids: Proteins use only the L-enantiomer. All chiral except glycine (R = H). Most L-AAs are *S*-configuration, except **L-cysteine** which is *R* (sulfur's higher priority flips the CIP ranking).

TIPS

How to Learn the 20 Amino Acids

Memorizing the 20 amino acids is a rite of passage for biochemistry and premed students. The most effective approach is to combine classification, mnemonics, and active recall like drawing.

1. Group by Chemical Properties

Instead of memorizing a list of 20, learn them in smaller, related groups:

GROUP	AMINO ACIDS	MNEMONIC
Nonpolar (9)	G, A, V, L, I, M, F, W, P	**G**randma **A**lways **V**isits **L**ondon **I**n **M**ay **F**or **W**inston's **P**arty
Polar Uncharged (6)	S, T, C, N, Q, Y	**S**anta's **T**eam **C**rafts **N**ew **Q**uilts **Y**early
Acidic (–)	D, E	**D**ragons **E**at
Basic (+)	K, R, H	**K**nights **R**iding **H**orses

2. The "Pirate & Dragon" One-Letter Codes

Most codes use the first letter (e.g., Valine = V), but these exceptions need tricks:

R = Arginine — "a**RRRR**ginine" like a pirate

W = Tryptophan — "t**W**yptophan" (Elmer Fudd). Or: the double-ring looks like a **W**

F = Phenylalanine — starts with a "**F**-enyl" sound

N = Asparagine — "Asparag**N**e" — focus on the loud **N**

Q = Glutamine — "**Q**-tamine" — it's **Q**uite like Glutamate but with an amide

K = Lysine — K is the letter right before **L**

D & E = Aspartate & Glutamate — **D**ragons **E**at. D comes before E in the alphabet, just as Aspartate (smaller) comes before Glutamate (larger).

3. Master Structures Through "Logic Building"

Instead of memorizing every atom, learn how one structure builds into another:

4. Puns & Wordplay for Structures

Sometimes a goofy pun is stickier than a formal definition:

Cysteine Chapel — Picture two fingers (sulfur atoms) touching to form a **disulfide bond**, like the Sistine Chapel ceiling.

Leucine vs. Isoleucine — Leucine is the "**L**" shape. Isoleucine is the isomer where the methyl group moved.

Tyrosine (Y) — "**Y** did the tire get a flat?" Because it has a tire-shaped ring with an –OH hole.

Valine (V) — The branched $–CH(CH_3)_2$ side chain literally fans out in a **V** shape.

5. Essential Amino Acids (Must Come from Diet)

Use the classic mnemonic **PVT TIM HALL**:
Phe, **V**al, **T**hr, **T**rp, **I**le, **M**et, **H**is, **A**rg*, **L**eu, **L**ys *Arginine is conditionally essential

6. Mastering the Basic (Positively Charged) Amino Acids

Mnemonics: "**His Lies Are Basic**" (His, Lys, Arg). "**HAL is Basic**" (His, Arg, Lys). "**Knights Riding Horses**" — K, R, H codes.

Structures — look for N: **Lys (K)** — long "Line" ending in NH_3^+. **Arg (R)** — 3 Nitrogens ("Nitrogen-Rich"). **His (H)** — House-shaped ring with 2 N.

Charge secret: Arg (pKaR 12.5) & Lys (pKaR 10.5) are **always positive**. His (pKaR ≈ 6.0) flip-flops — the **MVP of enzyme active sites**.

Pro-tip: Spend 15 min each morning drawing all 20 from memory. Within 5 days, muscle memory takes over. Combine with flash cards and the mnemonic groups above.

NONPOLAR

Hydrophobic Side Chains (9)

Found in protein interiors, membrane-spanning regions. Stabilise protein folding via hydrophobic interactions.

G Glycine

Gly • MW 75 • pI 5.97

R = H. Only achiral amino acid — no stereocentre. Extremely flexible (no side chain steric hindrance). Common in collagen (every 3rd residue). Fits in tight turns.

A Alanine

Ala • MW 89 • pI 6.01

R = $-CH_3$. Small, hydrophobic methyl group. Often used as the "generic" amino acid in examples. Very common in α-helices.

V Valine

Val • MW 117 • pI 5.97 • Essential

R = $-CH(CH_3)_2$. Branched-chain amino acid (BCAA). β-branched — bulky at Cβ, destabilises α-helices.

L Leucine

Leu • MW 131 • pI 5.98 • Essential

R = $-CH_2CH(CH_3)_2$. BCAA. Most abundant amino acid in proteins. Strong helix-former.

I Isoleucine

Ile • MW 131 • pI 6.02 • Essential

R = $-CH(CH_3)CH_2CH_3$. BCAA, β-branched. Has **two stereocentres** (α-C and β-C).

P Proline

Pro • MW 115 • pI 6.48

R = cyclic (side chain bonds back to N → imino acid). Rigid — introduces kinks/turns, breaks α-helices. Abundant in collagen. *Cis*-trans isomerisation at Pro peptide bonds.

F Phenylalanine

Phe • MW 165 • pI 5.48 • Essential

R = $-CH_2-C_6H_5$ (benzyl). Aromatic, hydrophobic. UV absorption at 257 nm (weakest of the 3 aromatic AAs). Accumulates in PKU (phenylketonuria).

W Tryptophan

Trp • MW 204 • pI 5.89 • Essential

R = indole ring. Largest amino acid. Aromatic — strongest UV absorption at 280 nm (used to measure protein concentration). Precursor to serotonin and melatonin.

M Methionine

Met • MW 149 • pI 5.74 • Essential

R = $-CH_2CH_2SCH_3$. Contains sulfur (thioether, not reactive like Cys). **Start codon** (AUG) — first amino acid in every protein.

MCAT tip — Essential amino acids: PVT TIM HALL — Phe, Val, Thr, Trp, Ile, Met, His, Arg (conditionally), Leu, Lys. These cannot be synthesised by the body and must come from diet.

POLAR UNCHARGED

Hydrophilic, H-Bond Donors/Acceptors (6)

Found on protein surfaces. Participate in hydrogen bonding, enzyme active sites, post-translational modifications.

S Serine

Ser • MW 105

R = –CH_2OH. Hydroxyl group — H-bond donor/acceptor. Site of **phosphorylation** (Ser/Thr/Tyr kinases). Found in enzyme active sites (serine proteases). Can be O-glycosylated.

pKa_1 **2.21** • pKa_2 **9.15** • pI **5.68**

T Threonine

Thr • MW 119

R = –$CH(OH)CH_3$. Hydroxyl group like Ser. β-branched. Has **two stereocentres**. Site of phosphorylation and O-glycosylation. **Essential.**

pKa_1 **2.11** • pKa_2 **9.62** • pI **5.87**

N Asparagine

Asn • MW 132

R = –CH_2CONH_2. Amide of aspartate. H-bond donor and acceptor. Site of **N-linked glycosylation** (Asn-X-Ser/Thr sequon). Cannot be charged.

pKa_1 **2.02** • pKa_2 **8.80** • pI **5.41**

Q Glutamine

Gln • MW 146

R = –$CH_2CH_2CONH_2$. Amide of glutamate. Major nitrogen carrier in blood (glutamine shuttle). Fuel for rapidly dividing cells (enterocytes, immune cells).

pKa_1 **2.17** • pKa_2 **9.13** • pI **5.65**

Y Tyrosine

Tyr • MW 181

R = –CH_2–C_6H_4–OH (phenol). Aromatic — UV absorption at 274 nm. The –OH can be **phosphorylated** (receptor tyrosine kinases). Precursor to thyroid hormones, dopamine, melanin. pKaR ≈ 10.1 (phenol OH, mostly protonated at pH 7.4).

pKa_1 **2.20** • pKa_2 **9.11** • pKaR **10.07** • pI **5.66**

C Cysteine

Cys • MW 121

R = –CH_2SH (thiol). Forms **disulfide bonds** (Cys–S–S–Cys) — covalent cross-links that stabilise protein tertiary/quaternary structure. The –SH is a nucleophile (active site of cysteine proteases). pKaR ≈ 8.3.

pKa_1 **1.96** • pKa_2 **10.28** • pKaR **8.18** • pI **5.07**

MCAT tip — Phosphorylation targets: Only **Ser, Thr, and Tyr** can be phosphorylated (they have –OH groups). This is the most common post-translational modification tested on the MCAT.

POSITIVE — Basic / Positively Charged at pH 7.4 (3)

Side chains are protonated (cationic) at physiological pH. Form salt bridges with negatively charged residues.

K — Lysine

Lys • MW 146

R = $-(CH_2)_4NH_3^+$. Long flexible chain ending in ε-amino group (pKaR ≈ 10.5 → fully protonated at pH 7.4). **Essential.** Ubiquitination occurs on Lys. Acetylation of Lys on histones regulates gene expression.

pKa_1 **2.18** • pKa_2 **8.95** • pKaR **10.53** • pI **9.74**

R — Arginine

Arg • MW 174

R = guanidinium group (pKaR ≈ 12.5 → always protonated at any biological pH). Most basic amino acid. Charge delocalised across 3 N atoms. Found in DNA-binding proteins (binds phosphate backbone). **Conditionally essential.**

pKa_1 **2.17** • pKa_2 **9.04** • pKaR **12.48** • pI **10.76**

H — Histidine

His • MW 155

R = imidazole ring (pKaR ≈ 6.0). **The only amino acid with pKa near physiological pH** → can act as both proton donor and acceptor. Found in enzyme active sites (acid-base catalysis). Buffering capacity at pH ~6. **Essential.**

pKa_1 **1.82** • pKa_2 **9.17** • pKaR **6.00** • pI **7.59**

NEGATIVE — Acidic / Negatively Charged at pH 7.4 (2)

Side chains are deprotonated (anionic) at physiological pH. Form salt bridges with positively charged residues.

D — Aspartate (Aspartic Acid)

Asp • MW 133

R = $-CH_2COO^-$ (pKaR ≈ 3.65 → deprotonated at pH 7.4). Short side chain. Participates in salt bridges and enzyme catalysis. Transamination product: oxaloacetate.

pKa_1 **1.88** • pKa_2 **9.60** • pKaR **3.65** • pI **2.77**

E — Glutamate (Glutamic Acid)

Glu • MW 147

R = $-CH_2CH_2COO^-$ (pKaR ≈ 4.25 → deprotonated at pH 7.4). One CH_2 longer than Asp. Major excitatory neurotransmitter in the CNS. Transamination product: α-ketoglutarate. Key in nitrogen metabolism (glutamate dehydrogenase).

pKa_1 **2.19** • pKa_2 **9.67** • pKaR **4.25** • pI **3.22**

MCAT tip — Calculating pI: For neutral AAs: pI = (pKa_1 + pKa_2) / 2. For acidic AAs (Asp, Glu): pI = (pKa_1 + pKaR) / 2. For basic AAs (Lys, Arg, His): pI = (pKa_2 + pKaR) / 2. Always average the two pKa values that *flank* the neutral (zwitterionic) form.

MCAT tip — Histidine is special: pKaR ≈ 6.0 means it's ~50% protonated at pH 6.0. At pH 7.4, it's mostly deprotonated (neutral). This makes His the best amino acid for acid-base catalysis in enzyme active sites — it can both donate and accept protons near physiological pH.

All 20 Amino Acids — Quick Reference Table

1-LETTER	3-LETTER	NAME	SIDE CHAIN (R)	TYPE	PKAR	PI	KEY FACT
G	Gly	Glycine	–H	NP	—	5.97	Achiral, flexible, collagen
A	Ala	Alanine	$-CH_3$	NP	—	6.01	Simplest chiral AA
V	Val	Valine	$-CH(CH_3)_2$	NP	—	5.97	BCAA, β-branched, essential
L	Leu	Leucine	$-CH_2CH(CH_3)_2$	NP	—	5.98	Most abundant AA, essential
I	Ile	Isoleucine	$-CH(CH_3)CH_2CH_3$	NP	—	6.02	BCAA, 2 stereocentres, essential
P	Pro	Proline	cyclic	NP	—	6.48	Imino acid, rigid, helix breaker
F	Phe	Phenylalanine	$-CH_2C_6H_5$	NP	—	5.48	Aromatic, PKU, essential
W	Trp	Tryptophan	indole	NP	—	5.89	Largest AA, UV 280nm, essential
M	Met	Methionine	$-CH_2CH_2SCH_3$	NP	—	5.74	Start codon (AUG), essential
S	Ser	Serine	$-CH_2OH$	Polar	—	5.68	Phosphorylation, active sites
T	Thr	Threonine	$-CH(OH)CH_3$	Polar	—	5.87	Phosphorylation, essential
N	Asn	Asparagine	$-CH_2CONH_2$	Polar	—	5.41	N-linked glycosylation
Q	Gln	Glutamine	$-CH_2CH_2CONH_2$	Polar	—	5.65	Nitrogen carrier, fuel
Y	Tyr	Tyrosine	$-CH_2C_6H_4OH$	Polar	10.07	5.66	Phosphorylation, UV 274nm
C	Cys	Cysteine	$-CH_2SH$	Polar	8.18	5.07	Disulfide bonds (S–S)
K	Lys	Lysine	$-(CH_2)_4NH_3^+$	(+)	10.53	9.74	Ubiquitination, acetylation
R	Arg	Arginine	guanidinium	(+)	12.48	10.76	Most basic, always charged
H	His	Histidine	imidazole	(+)	6.00	7.59	pKa ≈ pH, acid-base catalysis
D	Asp	Aspartate	$-CH_2COO^-$	(–)	3.65	2.77	Short chain, OAA link
E	Glu	Glutamate	$-CH_2CH_2COO^-$	(–)	4.25	3.22	Neurotransmitter, α-KG link

UV absorption (280 nm): Trp (strongest) > Tyr > Phe (weakest). Used to estimate protein concentration by A_{280}.

Disulfide bonds: Only Cys forms –S–S– bridges. Oxidising conditions form them; reducing agents (DTT, β-ME) break them.

Amino acids with 2 stereocentres: Isoleucine (Cα + Cβ) and Threonine (Cα + Cβ). All others have only one (except Gly which has zero).

Amino acid → neurotransmitter: Trp → serotonin/melatonin. Tyr → dopamine/NE/epi. Glu → GABA (via decarboxylation). His → histamine.