HIGH-YIELD PRINCIPLES IN

Pharmacology

"Cure sometimes, treat often, and comfort always."

—Hippocrates

"One pill makes you larger, and one pill makes you small."

—Jefferson Airplane, *White Rabbit*

"For the chemistry that works on one patient may not work for the next, because even medicine has its own conditions."

—Suzy Kassem

"I wondher why ye can always read a doctor's bill an' ye niver can read his purscription."

—Finley Peter Dunne

"Love is the drug I'm thinking of."

—The Bryan Ferry Orchestra

Preparation for pharmacology questions is not as straightforward as in years past. One major recent change is that the USMLE Step 1 has moved away from testing pharmacotherapeutics. That means you will generally not be required to identify medications indicated for a specific condition. You still need to know mechanisms and important adverse effects of key drugs and their major variants. Obscure derivatives are low-yield. Learn their classic and distinguishing toxicities as well as major drug-drug interactions.

Reviewing associated biochemistry, physiology, and microbiology concepts can be useful while studying pharmacology. The exam has a strong emphasis on ANS, CNS, antimicrobial, and cardiovascular agents as well as on NSAIDs, which are covered throughout the text. Specific drug dosages or trade names are generally not testable. The exam may use graphs to test various pharmacology content, so make sure you are comfortable interpreting them.

▸ PHARMACOLOGY—PHARMACOKINETICS AND PHARMACODYNAMICS

Enzyme kinetics

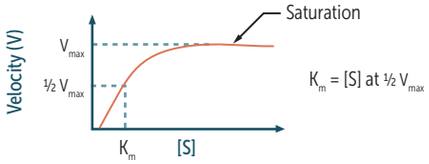
Michaelis-Menten kinetics

K_m is the substrate concentration needed for an enzyme to reach a rate of 1/2 V_{max} and is inversely related to the affinity of the enzyme for its substrate.

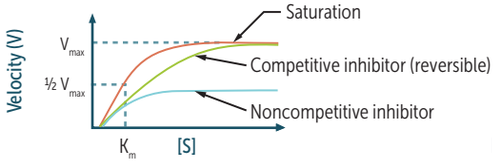
V_{max} is directly proportional to the enzyme concentration.

Most enzymatic reactions follow a hyperbolic curve (ie, Michaelis-Menten kinetics); however, enzymatic reactions that exhibit a sigmoidal curve usually indicate positive cooperativity in substrate binding (eg, aspartate transcarbamoylase).

[S] = concentration of substrate; V = velocity.



Effects of enzyme inhibition



Rx

Lineweaver-Burk plot

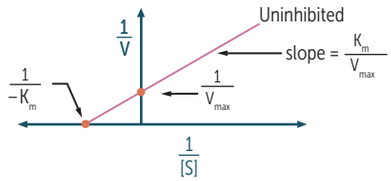
The closer to 0 on the Y-axis, the higher the V_{max}.

The closer to 0 on the X-axis, the higher the K_m.

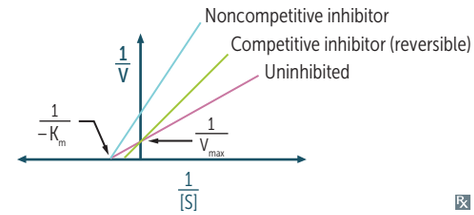
The higher the K_m, the lower the affinity.

Reversible competitive inhibitors cross each other, whereas noncompetitive inhibitors do not.

Kompetitive inhibitors increase K_m.



Effects of enzyme inhibition



Rx

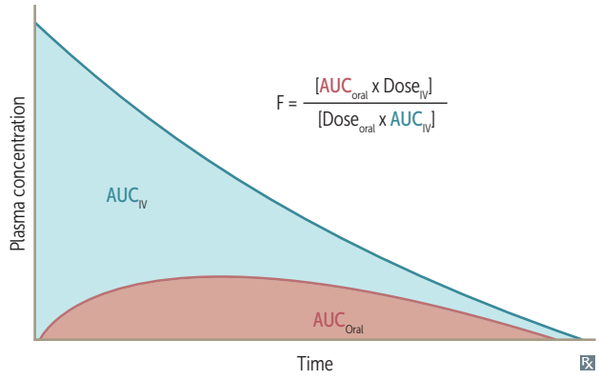
	Competitive inhibitors, reversible	Competitive inhibitors, irreversible	Noncompetitive inhibitors
Resemble substrate	Yes	Yes	No
Overcome by ↑ [S]	Yes	No	No
Bind active site	Yes	Yes	No
Effect on V_{max}	Unchanged	↓	↓
Effect on K_m	↑	Unchanged	Unchanged
Pharmacodynamics	↓ potency	↓ efficacy	↓ efficacy

Pharmacokinetics

Bioavailability (F)

Fraction of administered drug reaching systemic circulation. For an IV dose, F = 100%.

Orally: F typically < 100% due to incomplete absorption and first-pass metabolism. Can be calculated from the area under the curve in a plot of plasma concentration over time.



Volume of distribution (V_d)

Theoretical value that relates drug amount to plasma concentration. Liver and kidney disease increase V_d (↓ protein binding, ↑ V_d). Drugs may be distributed in more than one compartment. Hemodialysis is most effective for drugs with a low V_d.

$$V_d = \frac{\text{amount of drug in the body}}{\text{plasma drug concentration}}$$

V_d	COMPARTMENT	DRUG TYPES
Low	Intravascular	Large/charged molecules; plasma protein bound
Medium	ECF	Small hydrophilic molecules
High	All tissues including fat	Small lipophilic molecules, especially if bound to tissue protein

Clearance (CL)

The volume of plasma cleared of drug per unit time. Clearance may be impaired with defects in cardiac, hepatic, or renal function.

$$CL = \frac{\text{rate of elimination of drug}}{\text{plasma drug concentration}} = V_d \times K_e \text{ (elimination constant)}$$

Half-life ($t_{1/2}$)

The time required to eliminate 1/2 of the drug from the body.

Steady state is a dynamic equilibrium in which drug concentration stays constant (ie, rate of drug elimination = rate of drug administration).

In first-order kinetics, a drug infused at a constant rate takes 4–5 half-lives to reach steady state. It takes 3.3 half-lives to reach 90% of the steady-state level.

$$t_{1/2} = \frac{0.7 \times V_d}{CL} \text{ in first-order elimination}$$

# of half-lives	1	2	3	4
% remaining	50%	25%	12.5%	6.25%

Dosage calculations

$$\text{Loading dose} = \frac{C_p \times V_d}{F}$$

$$\text{Maintenance dose} = \frac{C_p \times CL \times \tau}{F}$$

C_p = target plasma concentration

τ = dosage interval (time between doses); does not apply for continuous infusions

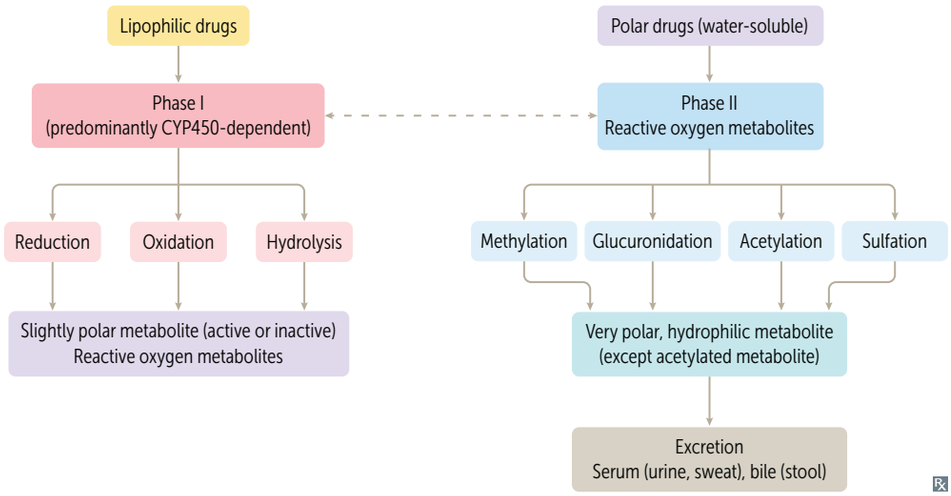
In renal or liver disease, maintenance dose ↓ and loading dose is usually unchanged.

Time to steady state depends primarily on $t_{1/2}$ and is independent of dose and dosing frequency.

Drug metabolism

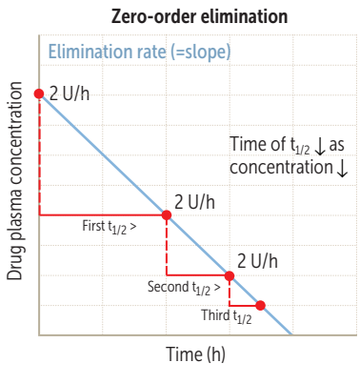
Drugs can be metabolized by either or both phase I and phase II reactions. These reactions serve to bioactivate or deactivate substances, and do not have to take place sequentially (eg, phase I can follow phase II, or take place as a single reaction).

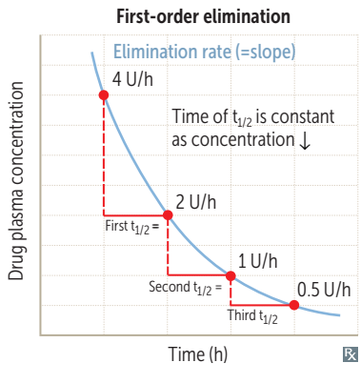
Geriatric patients lose phase I first. Patients who are slow acetylators have ↑ adverse effects from certain drugs because of ↓ rate of metabolism (eg, isoniazid).



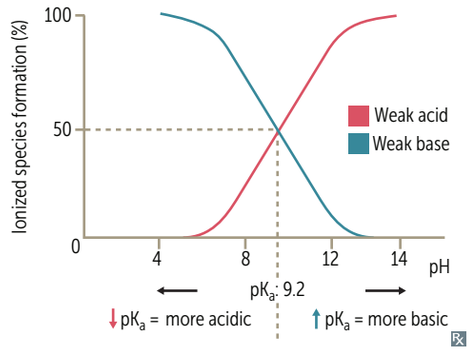
Elimination of drugs

Zero-order elimination	Rate of elimination is constant regardless of C_p (ie, constant **amount** of drug eliminated per unit time). C_p ↓ linearly with time. Examples of drugs—**P**henytoin, **E**thanol, and **A**spirin (at high or toxic concentrations).	Capacity-limited elimination. A **PEA** is round, shaped like the "**0**" in **zero**-order.
First-order elimination	Rate of **f**irst-order elimination is directly proportional to the drug concentration (ie, constant **fraction** of drug eliminated per unit time). C_p ↓ exponentially with time. Applies to most drugs.	**F**low-dependent elimination.





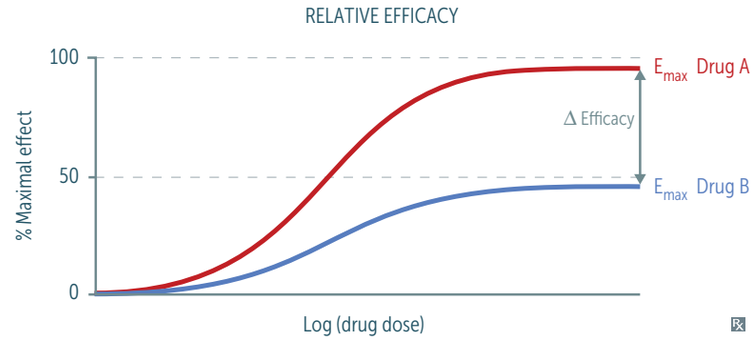
Urine pH and drug elimination	Ionized species are trapped in urine and cleared quickly. Neutral forms can be reabsorbed.
Weak acids	Examples: phenobarbital, methotrexate, aspirin (salicylates). Treat overdose with sodium bicarbonate to alkalinize urine. $\underset{\text{(lipid soluble)}}{RCOOH} \rightleftharpoons \underset{\text{(trapped)}}{RCOO^- + H^+}$
Weak bases	Examples: tricyclic antidepressants (TCAs), amphetamines. Trapped in acidic environments. For severe alkalosis, treat with ammonium chloride to acidify urine. $\underset{\text{(trapped)}}{RNH_3^+} \rightleftharpoons \underset{\text{(lipid soluble)}}{RNH_2 + H^+}$ TCA toxicity is initially treated with sodium bicarbonate to overcome the sodium channel-blocking activity of TCAs. This treats cardiac toxicity, but does not accelerate drug elimination.
pKa	pH at which drugs (weak acid or base) are 50% ionized and 50% nonionized. The pKa represents the strength of the weak acid or base.



Efficacy vs potency

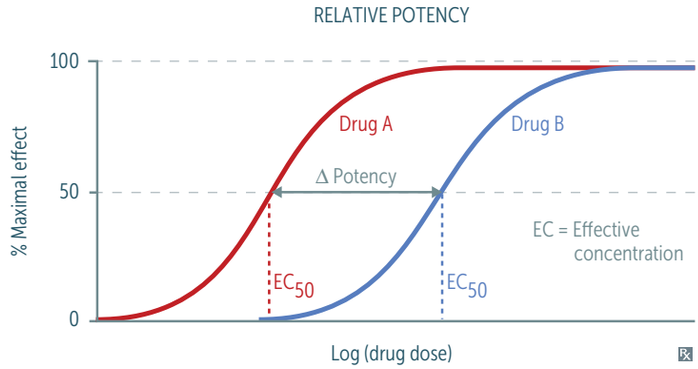
Efficacy

Maximal effect a drug can produce (intrinsic activity). Represented by the y-value (E_{max}). ↑ y-value = ↑ E_{max} = ↑ efficacy. Unrelated to potency (ie, efficacious drugs can have high or low potency). Partial agonists have less efficacy than full agonists.

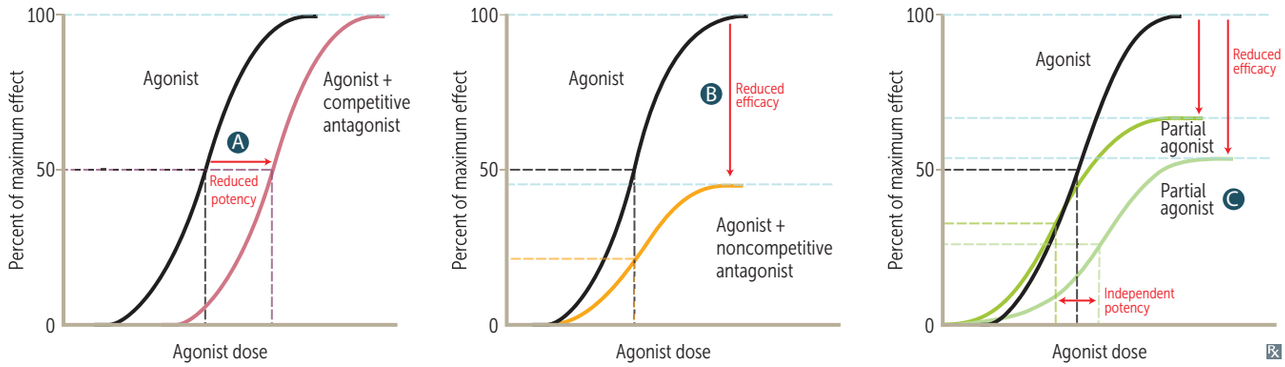


Potency

Amount of drug needed for a given effect. Represented by the x-value (EC_{50}). Left shifting = ↓ EC_{50} = ↑ potency = ↓ drug needed. Unrelated to efficacy (ie, potent drugs can have high or low efficacy).



Receptor binding



AGONIST WITH	POTENCY	EFFICACY	REMARKS	EXAMPLE
A Competitive antagonist	↓	No change	**Can** be overcome by ↑ agonist concentration	Diazepam (agonist) + flumazenil (competitive antagonist) on $GABA_A$ receptor.
B Noncompetitive antagonist	No change	↓	**Cannot** be overcome by ↑ agonist concentration	Norepinephrine (agonist) + phenoxybenzamine (noncompetitive antagonist) on α-receptors.
C Partial agonist (alone)	Independent	↓	Acts at same site as full agonist	Morphine (full agonist) vs buprenorphine (partial agonist) at opioid μ-receptors.
Inverse agonist (alone)	Independent	Independent	Binds to a constitutively active receptor, thereby reducing its activity; has the opposite effect of an agonist	H_1 antihistamines (eg, diphenhydramine)

Therapeutic index

Measurement of drug safety.

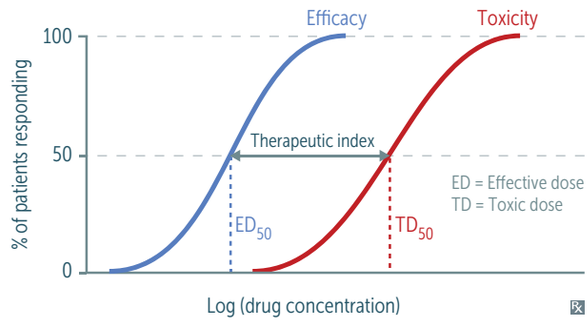
$$\frac{TD_{50}}{ED_{50}} = \frac{\text{median toxic dose}}{\text{median effective dose}}$$

Therapeutic window—range of drug concentrations that can safely and effectively treat disease.

TITE: **T**herapeutic **I**ndex = TD_{50} / ED_{50}.

Safer drugs have higher TI values. Drugs with lower TI values frequently require monitoring (eg, **w**arfarin, **t**heophylline, **d**igoxin, **a**ntiepileptic drugs, **l**ithium; **W**arning! **T**hese **d**rugs **a**re **l**ethal!).

LD_{50} (lethal median dose) often replaces TD_{50} in animal studies.

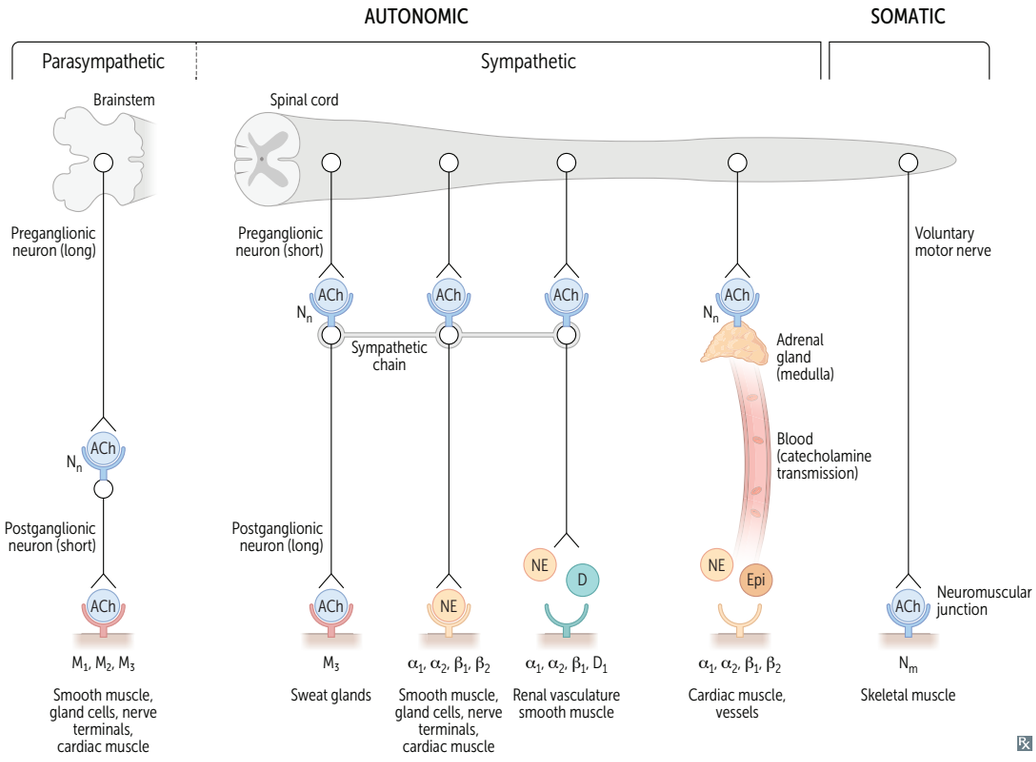


Drug effect modifications

TERM	DEFINITION	EXAMPLE
Additive	Effect of substances A and B together is equal to the sum of their individual effects	Aspirin and acetaminophen "2 + 2 = 4"
Permissive	Presence of substance A is required for the full effects of substance B	Cortisol on catecholamine responsiveness
Synergistic	Effect of substances A and B together is greater than the sum of their individual effects	Clopidogrel with aspirin "2 + 2 > 4"
Potentiation	Similar to synergism, but drug B (with no therapeutic action alone) enhances the therapeutic action of drug A	Carbidopa only blocks enzyme to prevent peripheral conversion of levodopa "2 + 0 > 2"
Antagonistic	Effect of substances A and B together is less than the sum of their individual effects	Morphine with naloxone "2 + 2 < 4"
Tachyphylactic	Acute decrease in response to a drug after initial/repeated administration	Repeat use of intranasal decongestant (eg, oxymetazoline) → ↓ therapeutic response (with rebound congestion)

▶ PHARMACOLOGY—AUTONOMIC DRUGS

Autonomic receptors



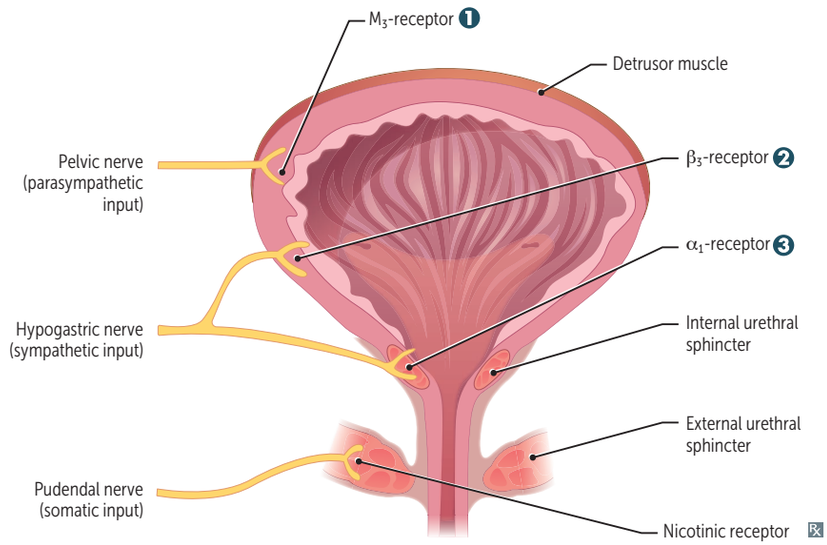
Pelvic splanchnic nerves and CNs III, VII, IX and X are part of the parasympathetic nervous system.
Adrenal medulla is directly innervated by preganglionic sympathetic fibers.
Sweat glands are part of the sympathetic pathway but are innervated by cholinergic fibers (sympathetic nervous system results in a "chold" sweat).

Acetylcholine receptors	Nicotinic ACh receptors are ligand-gated channels allowing efflux of K^+ and influx of Na^+ and in some cases Ca^{2+}. Two subtypes: N_N (found in autonomic ganglia, adrenal medulla) and N_M (found in neuromuscular junction of skeletal muscle). Muscarinic ACh receptors are G-protein–coupled receptors that usually act through 2nd messengers. 5 subtypes: $M_{1–5}$ found in heart, smooth muscle, brain, exocrine glands, and on sweat glands (cholinergic sympathetic).

Pain transmission

Nociceptive pain	Pain signals transmitted to the CNS in response to mechanical, thermal, or chemical stimuli. Transient receptor potential vanilloid ligand receptors cause Ca^{2+} influx–induced Na^+ channel activation. Signals transmitted by Aδ fibers (sharp, acute pain) or C fibers (dull, throbbing, chronic pain). Processes involved in pain transmission: ▪ Transduction—blocked by local anesthetics, α_2-agonists, gabapentinoids, NSAIDs, acetaminophen, glucocorticoids ▪ Transmission—blocked by local anesthetics, α_2-agonists, opioids ▪ Modulation—blocked by TCAs, SSRIs, SNRIs, gabapentinoids ▪ Perception—blocked by α_2-agonists, opioids, TCAs, SSRIs, SNRIs
Neuropathic pain	Caused by neuronal dysfunction of the CNS or PNS. Transmitted via upregulation and persistent activation of voltage-gated Na^+ channels. Example: diabetic peripheral neuropathy.

Micturition control



Micturition center in pons regulates involuntary bladder function via coordination of sympathetic and parasympathetic nervous systems.
⊕ sympathetic → ↑ urinary retention.
⊕ parasympathetic → ↑ urine voiding.
Some autonomic drugs act on smooth muscle receptors to treat bladder dysfunction.
Baby one more time.

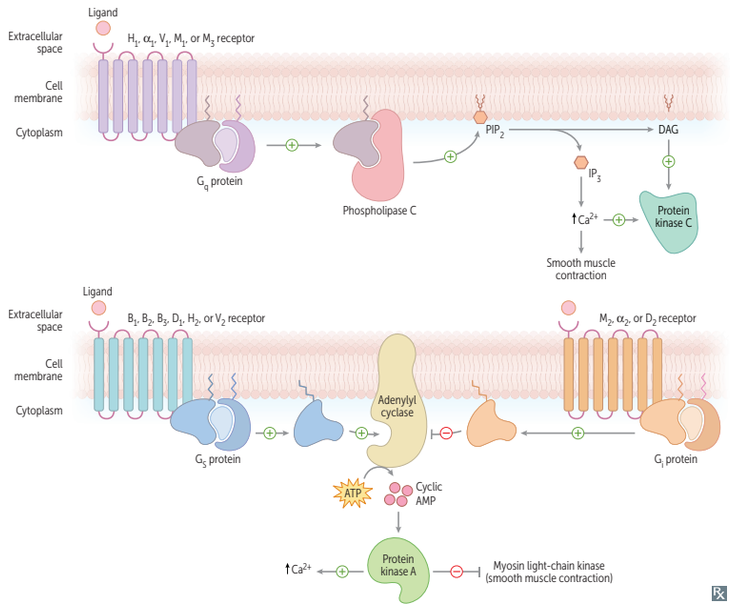
DRUGS	MECHANISM	APPLICATIONS
❶ **Muscarinic agonists** (eg, bethanechol)	⊕ M_3 receptor → contraction of detrusor smooth muscle → ↑ bladder emptying	Urinary retention
❶ **Muscarinic antagonists** (eg, oxybutynin)	⊖ M_3 receptor → relaxation of detrusor smooth muscle → ↓ detrusor overactivity	Urgency incontinence
❷ **Sympathomimetics** (eg, mirabegron)	⊕ β_3 receptor → relaxation of detrusor smooth muscle → ↑ bladder capacity	Urgency incontinence
❸ **α_1-antagonists** (eg, tamsulosin)	⊖ α_1-receptor → relaxation of smooth muscle (bladder neck, prostate) → ↓ urinary obstruction	BPH

Tissue distribution of adrenergic receptors

RECEPTOR	TISSUE	EFFECT(S)
α_1	Vascular smooth muscle	Vasoconstriction
	Visceral smooth muscle	Smooth muscle contraction
α_2	Pancreas	Inhibition of insulin secretion
	Presynaptic terminals	Inhibition of neurotransmitter release
	Salivary glands	Inhibition of salivary secretion
β_1	Heart	↑ heart rate, contractility
	Kidney	↑ renin secretion
β_2	Bronchioles	Bronchodilation
	Cardiac muscle	↑ heart rate, contractility
	Liver	Glycogenolysis, glucose release
	Arterial smooth muscle	Vasodilation
	Pancreas	Stimulation of insulin secretion
β_3	Adipose	↑ lipolysis

G-protein–linked second messengers

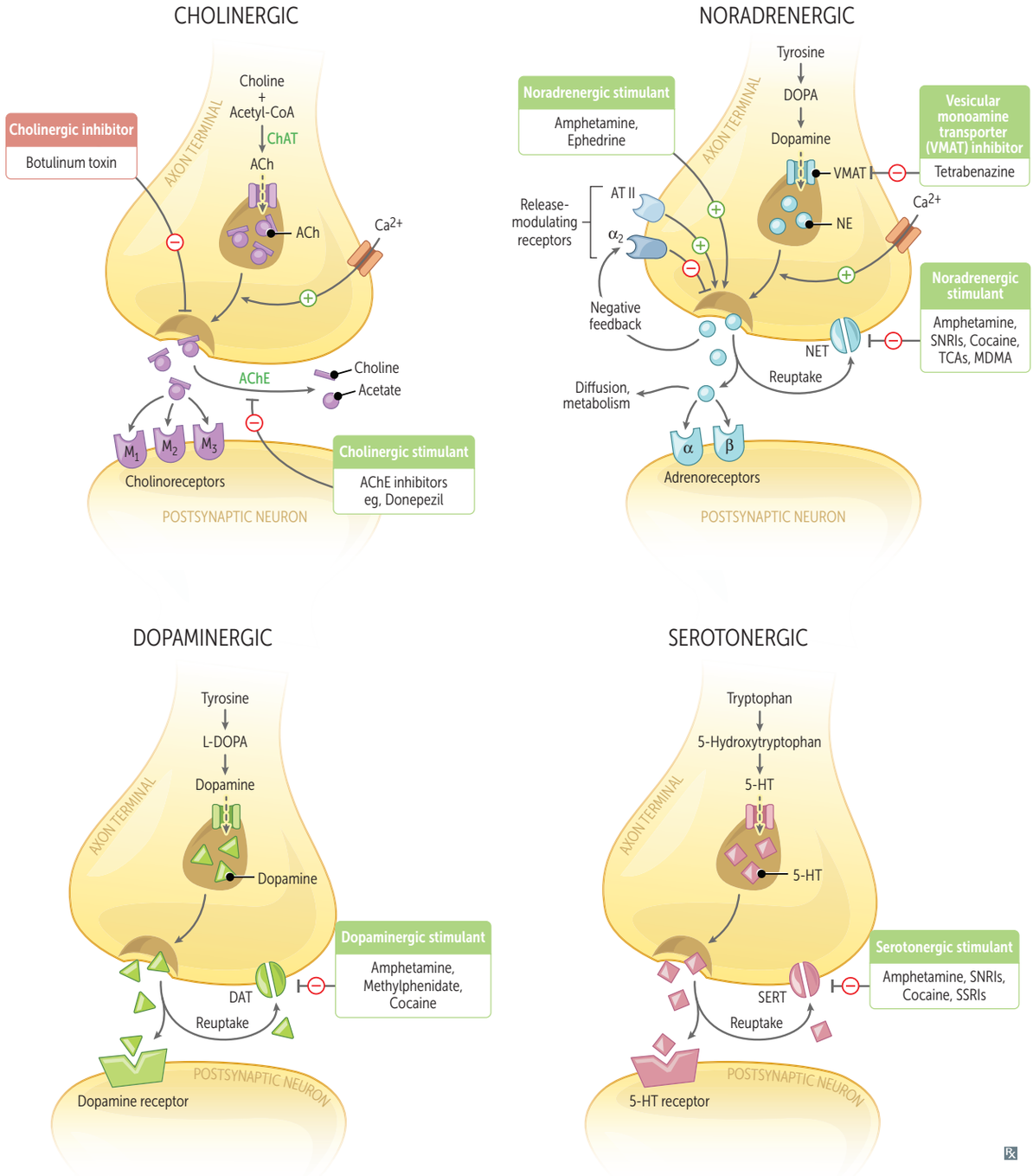
RECEPTOR	G-PROTEIN CLASS	MAJOR FUNCTIONS
Adrenergic		
α_1	q	↑ vascular smooth muscle contraction, ↑ pupillary dilator muscle contraction (mydriasis), ↑ intestinal and bladder sphincter muscle contraction
α_2	i	↓ sympathetic (adrenergic) outflow, ↓ insulin release, ↓ lipolysis, ↑ platelet aggregation, ↓ aqueous humor production
β_1	s	↑ heart rate, ↑ contractility (one heart), ↑ renin release, ↑ lipolysis
β_2	s	Vasodilation, bronchodilation (two lungs), ↑ lipolysis, ↑ insulin release, ↑ glycogenolysis, ↓ uterine tone (tocolysis), ↑ aqueous humor production, ↑ cellular K^+ uptake
β_3	s	↑ lipolysis, ↑ thermogenesis in skeletal muscle, ↑ bladder relaxation
Cholinergic		
M_1	q	Mediates higher cognitive functions, stimulates enteric nervous system, ↑ exocrine gland secretions
M_2	i	↓ heart rate, AV node conduction velocity, and atrial contractility
M_3	q	↑ exocrine gland secretions, gut peristalsis, bladder contraction, bronchoconstriction, vasodilation, ↑ pupillary sphincter muscle contraction (miosis), ciliary muscle contraction (accommodation)
Dopamine		
D_1	s	Relaxes renal vascular smooth muscle, activates direct pathway of striatum
D_2	i	Modulates transmitter release, especially in brain, inhibits indirect pathway of striatum
Histamine		
H_1	q	↑ bronchoconstriction, airway mucus production, ↑ vascular permeability/vasodilation, pruritus
H_2	s	↑ gastric acid secretion
Vasopressin		
V_1	q	↑ vascular smooth muscle contraction
V_2	s	↑ H_2O permeability and reabsorption via upregulating aquaporin-2 in collecting twobules (tubules) of kidney, ↑ release of vWF



Autonomic drugs

Release of norepinephrine from a sympathetic nerve ending is modulated by NE itself, acting on presynaptic α_2-autoreceptors → negative feedback.

Amphetamines use the NE transporter (NET) to enter the presynaptic terminal, where they utilize the vesicular monoamine transporter (VMAT) to enter neurosecretory vesicles. This displaces NE from the vesicles. Once NE reaches a concentration threshold within the presynaptic terminal, the action of NET is reversed, and NE is expelled into the synaptic cleft, contributing to the characteristics and effects of ↑ NE observed in patients taking amphetamines.



Cholinomimetic agents — Watch for exacerbation of COPD, asthma, and peptic ulcers in susceptible patients.

DRUG	ACTION	APPLICATIONS
Direct agonists		
Bethanechol	Activates **bladder** smooth muscle; resistant to AChE. Acts on muscarinic receptors; no nicotinic activity. "**Bethan**y, call me to activate your **bladder**."	Urinary retention.
Carbachol	**Carb**on copy of **a**cetyl**chol**ine (but resistant to AChE).	Constricts pupil. Used for intraoperative miosis induction.
Methacholine	Stimulates **m**uscarinic receptors in airway when inhaled.	Challenge test for diagnosis of asthma.
Pilocarpine	Contracts ciliary muscle of eye (open-angle glaucoma), pupillary sphincter (closed-angle glaucoma); resistant to AChE, can cross blood-brain barrier. "You cry, drool, and sweat on your '**pilo**w.'"	Potent stimulator of sweat, tears, and saliva Open-angle and closed-angle glaucoma, xerostomia (Sjögren syndrome).
Indirect agonists (anticholinesterases)		
Donepezil, rivastigmine, galantamine	↑ ACh.	1st line for Alzheimer disease (**Don**a **Riva** forgot the **gala**).
Neostigmine	↑ ACh. **Neo** = **no** blood-brain barrier penetration due to positive charge.	Postoperative and neurogenic ileus and urinary retention, myasthenia gravis, reversal of neuromuscular junction blockade (postoperative).
Pyridostigmine	↑ ACh; ↑ muscle strength. Does not penetrate CNS. Py**rid**osti**gm**ine gets **rid** of **m**yasthenia **g**ravis.	Myasthenia gravis (long acting). Used with glycopyrrolate or hyoscyamine to control pyridostigmine adverse effects.
Physostigmine	↑ ACh. **Ph**reely (freely) crosses blood-brain barrier as not charged → CNS.	Antidote for anticholinergic toxicity; **phy**sostigmine "**phy**xes" atropine overdose.

Anticholinesterase poisoning — Often due to organophosphates (eg, fenthion, parathion, malathion) that irreversibly inhibit AChE. Organophosphates commonly used as insecticides; poisoning usually seen in farmers.

Muscarinic effects	**D**iarrhea, **U**rination, **M**iosis, **B**ronchospasm, **B**radycardia, **E**mesis, **L**acrimation, **S**weating, **S**alivation.	**DUMBBELSS**. Reversed by atropine, a competitive inhibitor. Atropine can cross BBB to relieve CNS symptoms.
Nicotinic effects	Neuromuscular blockade (mechanism similar to succinylcholine).	Reversed by pralidoxime, regenerates AChE via dephosphorylation if given early. Must be coadministered with atropine to prevent transient worsening of symptoms. Pralidoxime does not readily cross BBB.
CNS effects	Respiratory depression, lethargy, seizures, coma.	

Muscarinic antagonists

DRUGS	ORGAN SYSTEMS	APPLICATIONS
Atropine, homatropine, tropicamide	Eye	Produce mydriasis and cycloplegia
Benztropine, trihexyphenidyl	CNS	**Park**inson disease ("**park** my **Benz**") Acute dystonia
Glycopyrrolate	GI, respiratory	Parenteral: preoperative use to reduce airway secretions Oral: reduces drooling, peptic ulcer
Hyoscyamine, dicyclomine	GI	Antispasmodics for irritable bowel syndrome
Ipratropium, tiotropium	Respiratory	COPD, asthma Duration: tiotropium > ipratropium
Solifenacin, Oxybutynin, Flavoxate, Tolterodine	Genitourinary	Reduce bladder spasms and urge urinary incontinence (overactive bladder) Make bladder **SOFT**
Scopolamine	CNS	Motion sickness

Atropine

Muscarinic antagonist. Used to treat bradycardia and for ophthalmic applications.

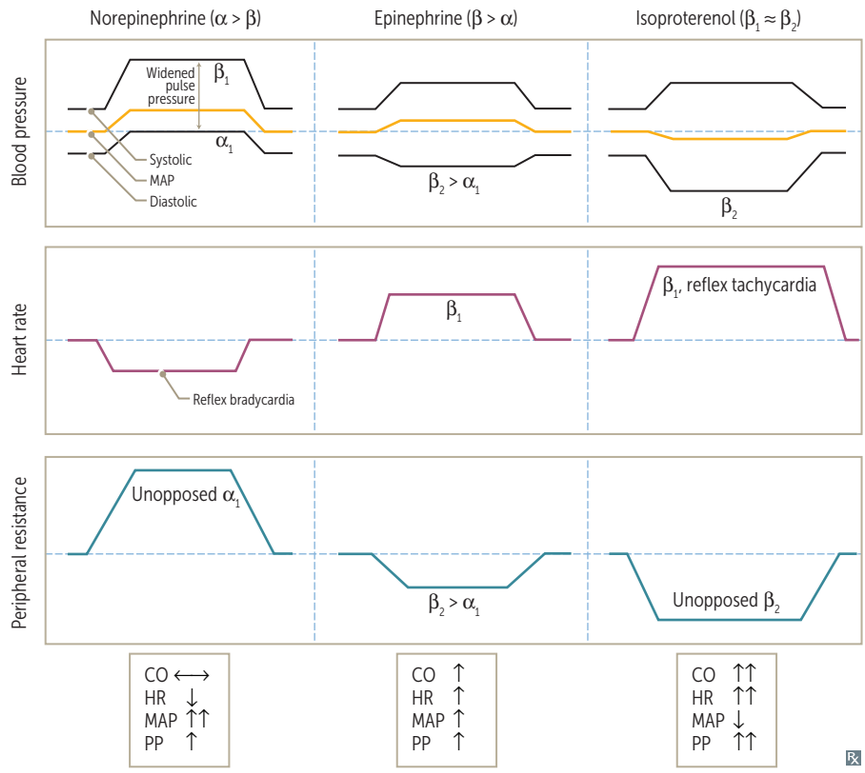
ORGAN SYSTEM	ACTION	NOTES
Eye	↑ pupil dilation, cycloplegia	Blocks muscarinic effects (**DUMBBELSS**) of anticholinesterases, but not the nicotinic effects
Airway	Bronchodilation, ↓ secretions	
Heart	↑ heart rate	
Stomach	↓ acid secretion	
Gut	↓ motility	
Bladder	↓ urgency in cystitis	
ADVERSE EFFECTS	↑ body **temperature** (due to ↓ sweating); ↑ **HR**; dry mouth; **dry, flushed skin**; **cycloplegia**; constipation; **disorientation** Can cause acute angle-closure glaucoma in older adults (due to mydriasis), **urinary retention** in men with prostatic hyperplasia, and hyperthermia in infants	Adverse effects: **Hot** as a hare **Fast** as a fiddle **Dry** as a bone **Red** as a beet **Blind** as a bat **Mad** as a hatter **Full** as a flask Jimson weed *(Datura)* → gardener's pupil (mydriasis)

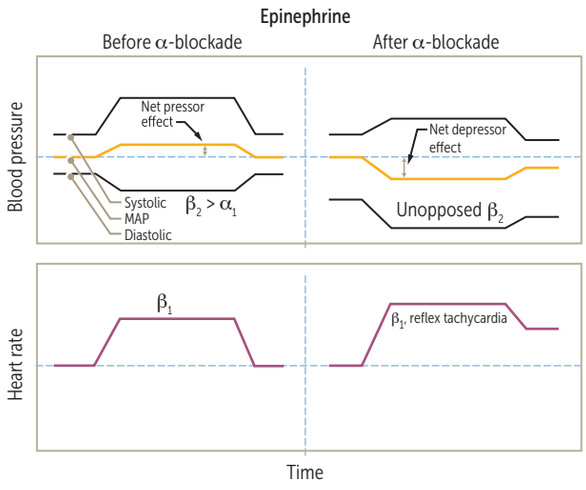
Sympathomimetics

DRUG	SITE	HEMODYNAMIC CHANGES	APPLICATIONS
Direct sympathomimetics			
Albuterol, salmeterol, terbutaline	$\beta_2 > \beta_1$	↑ HR (little effect)	Albuterol for acute asthma/COPD. Salmeterol for serial (long-term) asthma/COPD. Terbutaline for acute bronchospasm in asthma and tocolysis.
Dobutamine	$\beta_1 > \beta_2, \alpha$	–/↓ BP, ↑ HR, ↑ CO	Cardiac stress testing, acute decompensated heart failure (HF) with cardiogenic shock (inotrope)
Dopamine	$D_1 = D_2 > \beta > \alpha$	↑ BP (high dose), ↑ HR, ↑ CO	Unstable bradycardia, shock; inotropic and chronotropic effects at lower doses via β effects; vasoconstriction at high doses via α effects.
Epinephrine	$\beta > \alpha$	↑ BP (high dose), ↑ HR, ↑ CO	Anaphylaxis, asthma, shock, open-angle glaucoma; α effects predominate at high doses. Stronger effect at β_2-receptor than norepinephrine.
Fenoldopam	D_1	↓ BP (vasodilation), ↑ HR, ↑ CO	Postoperative hypertension, hypertensive crisis. Vasodilator (coronary, peripheral, renal, and splanchnic). Promotes natriuresis. Can cause hypotension, tachycardia, flushing, headache.
Isoproterenol	$\beta_1 = \beta_2$	↓ BP (vasodilation), ↑ HR, ↑ CO	Electrophysiologic evaluation of tachyarrhythmias. Can worsen ischemia. Has negligible α effect.
Midodrine	α_1	↑ BP (vasoconstriction), ↓ HR, –/↓ CO	Autonomic insufficiency and postural hypotension. May exacerbate supine hypertension.
Mirabegron	β_3		Urinary urgency or incontinence or overactive bladder. Think "mirab3gron."
Norepinephrine	$\alpha_1 > \alpha_2 > \beta_1$	↑ BP, –/↓ HR (may have minor reflexive change in response to ↑ BP due to α_1 agonism outweighing direct β_1 chronotropic effect), –/↑ CO	Hypotension, septic shock.
Phenylephrine	$\alpha_1 > \alpha_2$	↑ BP (vasoconstriction), ↓ HR, –/↓ CO	Hypotension (vasoconstrictor), ocular procedures (mydriatic), rhinitis (decongestant), ischemic priapism.
Indirect sympathomimetics			
Amphetamine	Indirect general agonist, reuptake inhibitor, also releases stored catecholamines.		Narcolepsy, obesity, ADHD.
Cocaine	Indirect general agonist, reuptake inhibitor. Causes vasoconstriction and local anesthesia. Caution when giving β-blockers if cocaine intoxication is suspected (unopposed α_1 activation → ↑↑↑ BP, coronary vasospasm).		Causes mydriasis in eyes with intact sympathetic innervation → used to confirm Horner syndrome.
Ephedrine	Indirect general agonist, releases stored catecholamines.		Nasal decongestion (pseudoephedrine), urinary incontinence, hypotension.

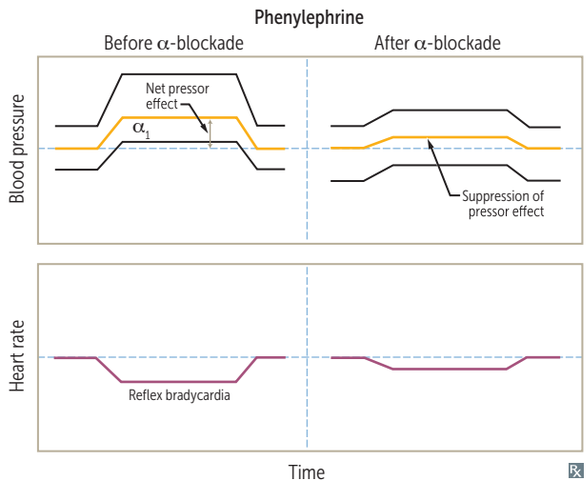
Physiologic effects of sympathomimetics

NE ↑ systolic and diastolic pressures as a result of α_1-mediated vasoconstriction → ↑ mean arterial pressure → reflex bradycardia. However, isoproterenol (rarely used) has little α effect but causes β_2-mediated vasodilation, resulting in ↓ mean arterial pressure and ↑ heart rate through β_1 and reflex activity.





Epinephrine response exhibits reversal of mean arterial pressure from a net increase (the α response) to a net decrease (the β_2 response).



Phenylephrine response is suppressed but not reversed because it is a "pure" α-agonist (lacks β-agonist properties).

Sympatholytics (α_2-agonists)

DRUG	APPLICATIONS	ADVERSE EFFECTS
Clonidine, guanfacine	Hypertensive urgency (limited situations), ADHD, Tourette syndrome, symptom control in opioid withdrawal	CNS depression, bradycardia, hypotension, respiratory depression, miosis, rebound hypertension with abrupt cessation
α-methyldopa	Hypertension in pregnancy	Direct Coombs ⊕ hemolysis, drug-induced lupus, hyperprolactinemia
Tizanidine	Relief of spasticity	Hypotension, weakness, xerostomia

α-blockers

DRUG	APPLICATIONS	ADVERSE EFFECTS
Nonselective		
Phenoxybenzamine	Irreversible. Pheochromocytoma (used preoperatively) to prevent catecholamine (hypertensive) crisis.	Orthostatic hypotension, reflex tachycardia.
Phentolamine	Reversible. Given to patients on MAO inhibitors who eat tyramine-containing foods and for severe cocaine-induced hypertension (2nd line). Also used to treat norepinephrine extravasation.	
α_1 selective (-osin ending)		
Prazosin, terazosin, doxazosin, tamsulosin	Urinary symptoms of BPH; PTSD (prazosin); hypertension (except tamsulosin).	1st-dose orthostatic hypotension, dizziness, headache.
α_2 selective		
Mirtazapine	Depression.	Sedation, ↑ serum cholesterol, ↑ appetite.

β-blockers Atenolol, betaxolol, bisoprolol, carvedilol, esmolol, labetalol, metoprolol, nadolol, nebivolol, propranolol, timolol.

APPLICATION	ACTIONS	NOTES/EXAMPLES
Angina pectoris	↓ heart rate and contractility → ↓ O_2 consumption	
Glaucoma	↓ production of aqueous humor	Timolol
Heart failure	Blockade of neurohormonal stress → prevention of deleterious cardiac remodeling → ↓ mortality	**B**isoprolol, **c**arvedilol, **m**etoprolol (β-blockers **c**urb **m**ortality)
Hypertension	↓ cardiac output, ↓ renin secretion (due to β_1-receptor blockade on JG cells)	
Hyperthyroidism/ thyroid storm	Symptom control (↓ heart rate, ↓ tremor)	Propranolol
Hypertrophic cardiomyopathy	↓ heart rate → ↑ filling time, relieving obstruction	
Migraine	↓ nitric oxide production	Effective for prevention
Myocardial infarction	↓ O_2 demand (short-term), ↓ mortality (long-term)	
Supraventricular tachycardia (eg, atrial fibrillation)	↓ AV conduction velocity (class II antiarrhythmic)	Metoprolol, esmolol
Variceal bleeding	↓ hepatic venous pressure gradient and portal hypertension (prophylactic use)	**N**adolol, **p**ropranolol, **c**arvedilol for **n**o **p**ortal **c**irculation
ADVERSE EFFECTS	Erectile dysfunction, cardiovascular (bradycardia, AV block, HF), CNS (seizures, sleep alterations), dyslipidemia (metoprolol), masked hypoglycemia, asthma/COPD exacerbations	Use of β-blockers for acute cocaine-associated chest pain remains controversial due to unsubstantiated concern for unopposed α-adrenergic stimulation
SELECTIVITY	β_1-selective antagonists ($\beta_1 > \beta_2$)—**a**tenolol, **b**etaxolol, **b**isoprolol, **e**smolol, **m**etoprolol	Selective antagonists mostly go from **A** to **M** (β_1 with **1**st half of alphabet)
	Nonselective antagonists ($\beta_1 = \beta_2$)—**n**adolol, **p**ropranolol, **t**imolol	**N**on**Z**elective antagonists mostly go from **N** to **Z** (β_2 with **2**nd half of alphabet)
	Nonselective α- and β-antagonists—carved**ilol**, labet**alol**	Nonselective α- and β-antagonists have **modified suffixes** (instead of "-olol")
	Nebivolol combines cardiac-selective β_1-adrenergic blockade with stimulation of β_3-receptors (activate NO synthase in the vasculature and ↓ SVR)	Nebiv**O**lol increases **NO**

Phosphodiesterase inhibitors

Phosphodiesterase (PDE) inhibitors inhibit PDE, which catalyzes the hydrolysis of cAMP and/or cGMP, and thereby increase cAMP and/or cGMP. These inhibitors have varying specificity for PDE isoforms and thus have different clinical uses.

TYPE OF INHIBITOR	MECHANISM OF ACTION	CLINICAL USES	ADVERSE EFFECTS
Nonspecific PDE inhibitor Theophylline	↓ cAMP hydrolysis → ↑ cAMP → bronchial smooth muscle relaxation → bronchodilation	COPD/asthma (rarely used)	Cardiotoxicity (eg, tachycardia, arrhythmia), neurotoxicity (eg, seizures, headache), abdominal pain
PDE-5 inhibitors Sildena**fil**, varden**afil**, tadal**afil**, avan**afil**	↓ hydrolysis of cGMP → ↑ cGMP → ↑ smooth muscle relaxation by enhancing NO activity → pulmonary vasodilation and ↑ blood flow in corpus cavernosum **fil**ls the penis	Erectile dysfunction Pulmonary hypertension Benign pros**ta**tic hyperplasia (**ta**dalafil only)	Facial flushing, headache, dyspepsia, hypotension in patients taking nitrates; "**h**ot and sweaty," then **h**eadache, **h**eartburn, **h**ypotension **S**ildenafil only: cyanopia (blue-tinted vision) via inhibition of PDE-6 (**s**ix) in retina
PDE-4 inhibitor Roflumilast	↑ cAMP in neutrophils, granulocytes, and bronchial epithelium	Severe COPD	Abdominal pain, weight loss, depression, anxiety, insomnia
PDE-3 inhibitor Milrinone	In cardiomyocytes: ↑ cAMP → ↑ Ca^{2+} influx → ↑ ionotropy and chronotropy In vascular smooth muscle: ↑ cAMP → MLCK inhibition → vasodilation → ↓ preload and afterload	Acute decompensated HF with cardiogenic shock (inotrope)	Tachycardia, ventricular arrhythmias, hypotension
"Platelet inhibitors" Cilostazol[a] Dipyridamole[b]	In platelets: ↑ cAMP → inhibition of platelet aggregation	Intermittent claudication Stroke or TIA prevention (with aspirin) Cardiac stress testing (dipyridamole only, due to coronary vasodilation) Prevention of coronary stent restenosis	Nausea, headache, facial flushing, hypotension, abdominal pain

[a]Cilostazol is a PDE-3 inhibitor, but due to its indications is categorized as a platelet inhibitor together with dipyridamole.
[b]Dipyridamole is a nonspecific PDE inhibitor, leading to inhibition of platelet aggregation. It also prevents adenosine reuptake by platelets → ↑ extracellular adenosine → ↑ vasodilation.

▸ PHARMACOLOGY—TOXICITIES AND ADVERSE EFFECTS

Ingested seafood toxins

Toxin actions include histamine release, total block of Na^+ channels, or opening of Na^+ channels to cause depolarization.

TOXIN	SOURCE	ACTION	SYMPTOMS	TREATMENT
Histamine (scombroid poisoning)	Spoiled dark-meat fish such as tuna, mahi-mahi, mackerel, and bonito	Bacterial histidine decarboxylase converts histidine to histamine Frequently misdiagnosed as fish allergy	Mimics anaphylaxis: oral burning sensation, facial flushing, erythema, urticaria, itching; may progress to bronchospasm, angioedema, hypotension	Antihistamines Albuterol +/– epinephrine
Tetrodotoxin	Pufferfish	Binds fast voltage-gated Na^+ channels in nerve tissue, preventing depolarization	Nausea, diarrhea, paresthesias, weakness, dizziness, loss of reflexes	Supportive
Ciguatoxin	Reef fish such as barracuda, snapper, and moray eel	Opens Na^+ channels, causing depolarization	Nausea, vomiting, diarrhea; perioral numbness; reversal of hot and cold sensations; bradycardia, heart block, hypotension	Supportive

Age-related changes in pharmacokinetics

Aging alters the passage of drugs through the body and standard doses can result in ↑ plasma concentrations. Older patients often require reduced doses to prevent toxicity.

- Absorption—mostly unaffected.
- Distribution—↓ total body water (↓ V_d of hydrophilic drugs → ↑ concentration), ↑ total body fat (↑ V_d of lipophilic drugs → ↑ half-life).
- Metabolism—↓ hepatic mass and blood flow → ↓ first-pass metabolism, ↓ hepatic clearance. Phase I of drug metabolism is decreased; phase II is relatively preserved.
- Excretion—↓ renal mass and blood flow (↓ GFR) → ↓ renal clearance.

Specific toxicity treatments

TOXIN	TREATMENT
Acetaminophen	*N*-acetylcysteine (replenishes glutathione)
AChE inhibitors, organophosphates	Atropine > pralidoxime
Antimuscarinic, anticholinergic agents	Physostigmine (crosses BBB), control hyperthermia
Arsenic	Dimercaprol, succimer
Benzodiazepines	Flumazenil
β-blockers	Atropine, glucagon, saline
Carbon monoxide	100% O_2, hyperbaric O_2
Copper	"Penny"cillamine (penicillamine), trientine (3 copper pennies)
Cyanide	Hydroxocobalamin, nitrites + sodium thiosulfate
Dabigatran	Idarucizumab
Digoxin	Digoxin-specific antibody fragments
Direct factor Xa inhibitors (eg, apixaban)	Andexanet alfa
Heparin	Protamine sulfate
Iron (Fe)	Deferoxamine, deferasirox, deferiprone
Lead	Penicillamine, calcium disodium EDTA, Dimercaprol, Succimer, (correct lead poisoning in PEDS patients)
Mercury	Dimercaprol, succimer
Methanol, ethylene glycol (antifreeze)	Fomepizole > ethanol, dialysis
Methemoglobin	Methylene blue, vitamin C (reducing agent)
Methotrexate	Leucovorin
Opioids	Naloxone
Salicylates	$NaHCO_3$ (alkalinizes urine), dialysis
TCAs	$NaHCO_3$ (stabilizes cardiac cell membrane)
Warfarin	Vitamin K (delayed effect), PCC (prothrombin complex concentrate)/FFP (immediate effect)

Drug reactions—cardiovascular

DRUG REACTION	CAUSAL AGENTS
Coronary vasospasm	Cocaine, Amphetamines, Sumatriptan, Ergot alkaloids (CASE)
Cutaneous flushing	Vancomycin, Adenosine, Niacin, Ca^{2+} channel blockers, Echinocandins, Nitrates (flushed from VANCEN [dancing]) Vancomycin infusion reaction (formerly called red man syndrome)—histamine release → widespread pruritic erythema. Infusion rate–dependent. Manage with slower infusion rate, diphenhydramine.
Dilated cardiomyopathy	Alcohol, anthracycline (eg, doxorubicin, daunorubicin; prevent with dexrazoxane), trastuzumab
Peripheral edema	Dihydropyridine Ca^{2+} channel blockers (eg, amlodipine)
Torsades de pointes	Associated with agents that prolong QT interval: Methadone, antiArrhythmics (class IA, III), antiBiotics (eg, macrolides, fluoroquinolones), anti"C"ychotics (eg, ziprasidone), antiDepressants (eg, TCAs), antiEmetics (eg, ondansetron), antiFungals (eg, fluconazole) (Memorize your ABCDEF)

Drug reactions—endocrine/reproductive

DRUG REACTION	CAUSAL AGENTS	NOTES
Adrenocortical insufficiency	HPA suppression secondary to chronic exogenous glucocorticoid use	Abrupt withdrawal of exogenous glucocorticoids leads to adrenal crisis
Diabetes insipidus	Lithium, demeclocycline	
Gynecomastia	Ketoconazole, cimetidine, spironolactone, GnRH analogs/antagonists, androgen receptor inhibitors, 5α-reductase inhibitors	
Hot flashes	SERMs (eg, tamoxifen, clomiphene, raloxifene)	
Hyperglycemia	Tacrolimus, protease inhibitors, niacin, HCTZ, glucocorticoids	The people need High glucose
Hyperprolactinemia	Typical antipsychotics (eg, haloperidol), atypical antipsychotics (eg, risperidone), metoclopramide, methyldopa, verapamil	Presents with hypogonadism (eg, infertility, amenorrhea, erectile dysfunction) and galactorrhea
Hyperthyroidism	Amiodarone, iodine, lithium	
Hypothyroidism	Amiodarone, lithium	I am lethargic
SIADH	Carbamazepine, Cyclophosphamide, SSRIs	Can't Concentrate Serum Sodium

Drug reactions—gastrointestinal

DRUG REACTION	CAUSAL AGENTS	NOTES
Acute cholestatic hepatitis, jaundice	Macrolides (eg, erythromycin)	
Constipation	Antimuscarinics (eg, atropine), antipsychotics, opioids, non-dihydropyridine CCBs, ranolazine, amiodarone, aluminum hydroxide, loperamide, 5HT3 receptor antagonist (ondansetron), vincristine	
Diarrhea	Acamprosate, antidiabetic agents (acarbose, metformin, pramlintide), colchicine, cholinesterase inhibitors, lipid-lowering agents (eg, ezetimibe, orlistat), macrolides (eg, erythromycin), SSRIs, chemotherapy (eg, irinotecan)	
Focal to massive hepatic necrosis	*Amanita phalloides* (death cap mushroom), valproate, acetaminophen	
Hepatitis	Rifampin, isoniazid, pyrazinamide, statins, fibrates	
Pancreatitis	Diuretics (eg, furosemide, HCTZ), glucocorticoids, alcohol, valproate, azathioprine	Drugs generate a violent abdominal distress
Medication-induced esophagitis	Potassium chloride, NSAIDs, bisphosphonates, ferrous sulfate, tetracyclines Pills Not beneficial for food tube	Usually occurs at anatomic sites of esophageal narrowing (eg, near level of aortic arch); caustic effect minimized with upright posture and adequate water ingestion
Pseudomembranous colitis	Ampicillin, cephalosporins, clindamycin, fluoroquinolones, PPIs	Antibiotics predispose to superinfection by resistant *C difficile*

Drug reactions—hematologic

DRUG REACTION	CAUSAL AGENTS	NOTES
Agranulocytosis	Dapsone, clozapine, carbamazepine, propylthiouracil, methimazole, ganciclovir, colchicine	Drugs can cause pretty major granulocytes collapse
Aplastic anemia	Carbamazepine, methimazole, NSAIDs, benzene, chloramphenicol, propylthiouracil	Can't make New blood cells properly
Direct Coombs ⊕ hemolytic anemia	Penicillin, cephalosporins, methyldopa	Pooh classically munches on honey Coombs
Drug Reaction with Eosinophilia and Systemic Symptoms	Phenytoin, carbamazepine, minocycline, sulfa drugs, allopurinol, vancomycin	T cell-mediated hypersensitivity reaction. Also known as drug-induced hypersensitivity syndrome (DIHS) DRESSes partially cover my skin and viscera
Hemolysis in G6PD deficiency	Sulfonamides, dapsone, primaquine, aspirin, nitrofurantoin	
Megaloblastic anemia	Hydroxyurea, Phenytoin, Methotrexate, Sulfa drugs	You're having a mega blast with PMS
Thrombocytopenia	Heparin, quinidine, ganciclovir, vancomycin, linezolid	
Thrombotic complications	Combined oral contraceptives, hormone replacement therapy, SERMs Testosterone supplements, epoetin alfa	Estrogen-mediated ↑ blood viscosity and platelet accumulation

Drug reactions—musculoskeletal/skin/connective tissue

DRUG REACTION	CAUSAL AGENTS	NOTES
Drug-induced lupus	Hydralazine, procainamide, quinidine	
Fat redistribution	Protease inhibitors, glucocorticoids	Fat protects glutes
Gingival hyperplasia	Cyclosporine, Ca^{2+} channel blockers, phenytoin	Can Cause puffy gums
Hyperuricemia (gout)	Pyrazinamide, thiazides, furosemide, niacin, cyclosporine	Painful tophi and feet need care
Malignant hyperthermia	Inhaled anesthetics (eg, isoflurane)	Individuals with ryanodine receptor mutation; antidote is dantrolene
Myopathy	Statins, fibrates, niacin, colchicine, daptomycin, hydroxychloroquine, interferon-α, penicillamine, glucocorticoids	
Osteoporosis	Glucocorticoids, depot medroxyprogesterone acetate, GnRH agonists, aromatase inhibitors, anticonvulsants, heparin, PPIs	
Photosensitivity	Sulfonamides, amiodarone, tetracyclines, fluoroquinolones	Sat for photo
Rash (Stevens-Johnson syndrome)	Anti-epileptic drugs (especially lamotrigine), allopurinol, sulfa drugs, penicillin	Steven Johnson has epileptic allergy to sulfa drugs and penicillin
Teeth discoloration	Tetracyclines	Teethracyclines
Tendon/cartilage damage	Fluoroquinolones	

Drug reactions—neurologic

DRUG REACTION	CAUSAL AGENTS	NOTES
Cinchonism	Quinidine, quinine	Can present with tinnitus, hearing/vision loss, psychosis, and cognitive impairment
Parkinson-like syndrome	Antipsychotics, metoclopramide	Cogwheel rigidity of arm
Peripheral neuropathy	Platinum agents (eg, cisplatin), isoniazid, vincristine, paclitaxel, phenytoin	Cis, it's very painful peripherally
Idiopathic intracranial hypertension	Corticosteroids, danazol, vitamin A, growth hormones, tetracyclines	Crime and debt Always grow head tension
Seizures	Isoniazid, bupropion, imipenem/cilastatin, tramadol	With seizures, I bit my tongue
Tardive dyskinesia	Antipsychotics, metoclopramide	
Visual disturbances	Topiramate (blurred vision/diplopia, haloes), hydroxychloroquine (↓ visual acuity, visual field defects), digoxin (yellow-tinged vision), isoniazid (optic neuritis), ivabradine (luminous phenomena), PDE-5 inhibitors (blue-tinged vision), ethambutol (color vision changes)	These horrible drugs iirritate Precious eyes

Drug reactions—renal/genitourinary

DRUG REACTION	CAUSAL AGENTS	NOTES
Fanconi syndrome	Cisplatin, ifosfamide, expired tetracyclines, tenofovir	
Hemorrhagic cystitis	Cyclophosphamide, ifosfamide	Prevent by coadministering with mesna
Interstitial nephritis	Diuretics (Pee), NSAIDs (Pain-free), Penicillins and cephalosporins, PPIs, rifamPin, sulfa drugs	Remember the 5 P's
Nephrotoxicity	Cisplatin, aminoglycosides, amphotericin, vancomycin	

Drug reactions—respiratory

DRUG REACTION	CAUSAL AGENTS	NOTES
Dry cough	ACE inhibitors	
Pulmonary fibrosis	Methotrexate, nitrofurantoin, carmustine, bleomycin, busulfan, amiodarone	My nose cannot breathe bad air

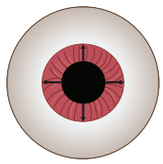
Drug reactions—multiorgan

DRUG REACTION	CAUSAL AGENTS	NOTES
Antimuscarinic	Atropine, TCAs, H_1-blockers, antipsychotics	
Disulfiram-like reaction	1st-generation sulfonylureas, procarbazine, certain cephalosporins, griseofulvin, metronidazole	Sorry pals, can't go mingle

Drugs affecting pupil size

↑ pupil size (mydriasis)

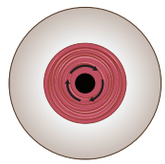
Anticholinergics (eg, atropine, TCAs, tropicamide, scopolamine, antihistamines)
Indirect sympathomimetics (eg, amphetamines, cocaine, LSD), meperidine
Direct sympathomimetics



Radial muscle contraction
(α_1 receptor mediated) ℞

↓ pupil size (miosis)

Sympatholytics (eg, α_2-agonists)
Opioids (except meperidine)
Parasympathomimetics (eg, pilocarpine), organophosphates



Sphincter muscle contraction
(M_3 receptor mediated) ℞

Cytochrome P-450 interactions (selected)

Inducers (+)	Substrates	Inhibitors (–)
St. John's wort	Theophylline	Sodium valproate
Phenytoin	OCPs	Isoniazid
Phenobarbital	Anti-epileptics	Cimetidine
Modafinil	Warfarin	Ketoconazole
Nevirapine		Fluconazole
Rifampin		Acute alcohol overuse
Griseofulvin		Chloramphenicol
Carbamazepine		Erythromycin/clarithromycin
Chronic alcohol overuse		Sulfonamides
		Ciprofloxacin
		Omeprazole
		Amiodarone
		Ritonavir
		Grapefruit juice
St. John's funny funny (phen-phen) mom never refuses greasy carbs and chronic alcohol	The OCPs are anti-war	SICK FACES come when I am really drinking grapefruit juice

Sulfa drugs

Sulfonamide antibiotics, Sulfasalazine, Probenecid, Furosemide, Acetazolamide, Celecoxib, Thiazides, Sulfonylureas.
Patients with sulfa allergies may develop fever, urinary tract infection, Stevens-Johnson syndrome, hemolytic anemia, thrombocytopenia, agranulocytosis, acute interstitial nephritis, and urticaria (hives), and photosensitivity.

Scary Sulfa Pharm FACTS

▸ PHARMACOLOGY—MISCELLANEOUS

Drug names

ENDING	CATEGORY	EXAMPLE
Antimicrobial		
-asvir	NS5A inhibitor	Ledipasvir
-bendazole	Antiparasitic/antihelminthic	Mebendazole
-buvir	NS5B inhibitor	Sofosbuvir
-cillin	Transpeptidase inhibitor	Ampicillin
-conazole	Ergosterol synthesis inhibitor	Ketoconazole
-cycline	Protein synthesis inhibitor	Tetracycline
-floxacin	Fluoroquinolone	Ciprofloxacin
-mivir	Neuraminidase inhibitor	Oseltamivir
-navir	Protease inhibitor	Ritonavir
-ovir	Viral DNA polymerase inhibitor	Acyclovir
-previr	NS3/4A inhibitor	Grazoprevir
-tegravir	Integrase inhibitor	Dolutegravir
-thromycin	Macrolide	Azithromycin
Antineoplastic		
-case	Recombinant uricase	Rasburicase
-mustine	Nitrosourea	Carmustine
-platin	Platinum compound	Cisplatin
-poside	Topoisomerase II inhibitor	Etoposide
-rubicin	Anthracycline	Doxorubicin
-taxel	Taxane	Paclitaxel
-tecan	Topoisomerase I inhibitor	Irinotecan
CNS		
-flurane	Inhaled anesthetic	Sevoflurane
-apine, -idone	Atypical antipsychotic	Quetiapine, risperidone
-azine	Typical antipsychotic	Thioridazine
-barbital	Barbiturate	Phenobarbital
-benazine	VMAT inhibitor	Tetrabenazine
-caine	Local anesthetic	Lidocaine
-capone	COMT inhibitor	Entacapone
-curium, -curonium	Nondepolarizing neuromuscular blocker	Atracurium, pancuronium
-giline	MAO-B inhibitor	Selegiline
-ipramine, -triptyline	TCA	Imipramine, amitriptyline
-triptan	5-$HT_{1B/1D}$ agonist	Sumatriptan
-zepam, -zolam	Benzodiazepine	Diazepam, alprazolam

Drug names *(continued)*

ENDING	CATEGORY	EXAMPLE
Autonomic		
-chol	Cholinergic agonist	Bethanechol
-olol	β-blocker	Propranolol
-stigmine	AChE inhibitor	Neostigmine
-terol	β_2-agonist	Albuterol
-zosin	α_1-blocker	Prazosin
Cardiovascular		
-afil	PDE-5 inhibitor	Sildenafil
-dipine	Dihydropyridine Ca^{2+} channel blocker	Amlodipine
-parin	Low-molecular-weight heparin	Enoxaparin
-plase	Thrombolytic	Alteplase
-pril	ACE inhibitor	Captopril
-sartan	Angiotensin-II receptor blocker	Losartan
-xaban	Direct factor Xa inhibitor	Apixaban
Metabolic		
-gliflozin	SGLT-2 inhibitor	Dapagliflozin
-glinide	Meglitinide	Repaglinide
-gliptin	DPP-4 inhibitor	Sitagliptin
-glitazone	PPAR-γ activator	Pioglitazone
-glutide	GLP-1 analog	Liraglutide
-statin	HMG-CoA reductase inhibitor	Atorvastatin
Other		
-caftor	CFTR modulator	Lumacaftor
-dronate	Bisphosphonate	Alendronate
-lukast	CysLT1 receptor blocker	Montelukast
-lutamide	Androgen receptor inhibitor	Flutamide
-pitant	NK_1 blocker	Aprepitant
-prazole	Proton pump inhibitor	Omeprazole
-prost	Prostaglandin analog	Latanoprost
-sentan	Endothelin receptor antagonist	Bosentan
-setron	5-HT_3 blocker	Ondansetron
-steride	5α-reductase inhibitor	Finasteride
-tadine	H_1-antagonist	Loratadine
-tidine	H_2-antagonist	Cimetidine
-trozole	Aromatase inhibitor	Anastrozole
-vaptan	ADH antagonist	Tolvaptan

Biologic agents

ENDING	CATEGORY	EXAMPLE
Monoclonal antibodies (-mab)—target overexpressed cell surface receptors		
-ximab	Chimeric human-mouse monoclonal antibody	Rituximab
-zumab	Humanized monoclonal antibody	Bevacizumab
-umab	Human monoclonal antibody	Denosumab
Small molecule inhibitors (-ib)—target intracellular molecules		
-ciclib	Cyclin-dependent kinase inhibitor	Palbociclib
-coxib	COX-2 inhibitor	Celecoxib
-parib	Poly(ADP-ribose) polymerase inhibitor	Olaparib
-rafenib	BRAF inhibitor	Vemurafenib
-tinib	Tyrosine kinase inhibitor	Imatinib
-zomib	Proteasome inhibitor	Bortezomib
Interleukin receptor modulators (-kin)—agonists and antagonists of interleukin receptors		
-leukin	Interleukin-2 agonist/analog	Aldesleukin
-kinra	Interleukin receptor antagonist	Anakinra