

Option B –
Medicine and Drugs
IB Chemistry

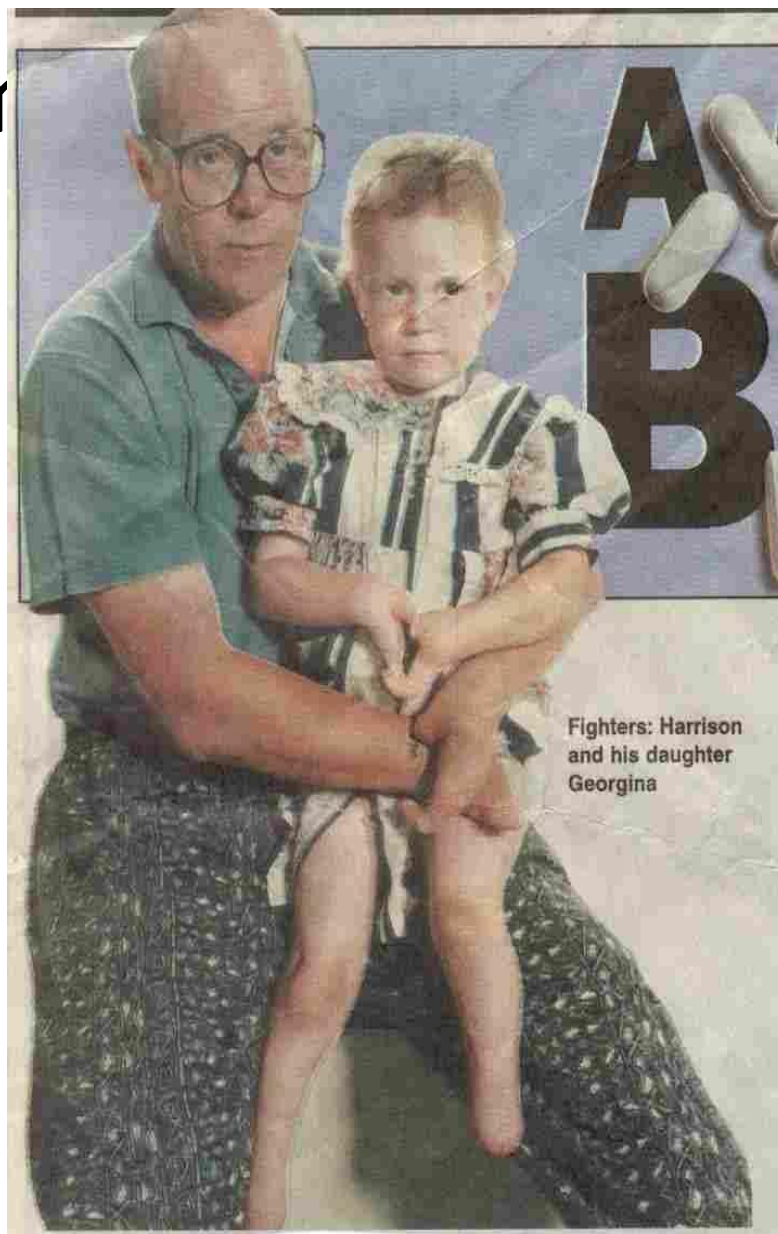
Pharmaceutical Products

- **A drug or medicine is any chemical which:**
 - Alters sensory sensations
 - Alters mood or emotions
 - Alters physiological state (consciousness, activity level, or coordination)

- **Placebo effect:**
 - A pharmacologically inert substance (often a sugar pill) produces a significant reaction because the patient expects, desires, or was told it would happen
 - Used as a control in clinical trials
 - Highlights the body's natural healing powers

- Research and Development:
 - Development of a new drug is a very costly, lengthy process controlled by the government:
 - In 1970, 3620 drugs were tested. 16 came on the market at an average cost of \$20 million
 - Only 1 in 2000 drugs eventually make it to the market
 - Phase I: Initial clinical trials on volunteers after the drug has proven safe when given to animals
 - Phase II: Thorough clinical investigation to eliminate investigator bias
 - Phase III: Extended clinical evaluation

Thalidomide



- **Methods of Administering Drugs:**

- **Orally**

- Effect varies because absorption is affected by stomach content and drug concentration
 - Primary site of absorption is the small intestine

- **Rectally**

- Effective if a drug cannot be taken orally or if a drug is pH sensitive

- **Inhalation**

- Rapid, systemic administration due to extensive network of blood vessels in lungs

– **Parenteral (injection)**

- **Subcutaneous**

- **Beneath the skin**

- **Slow absorption**

- **Intra-muscular**

- **Used when**

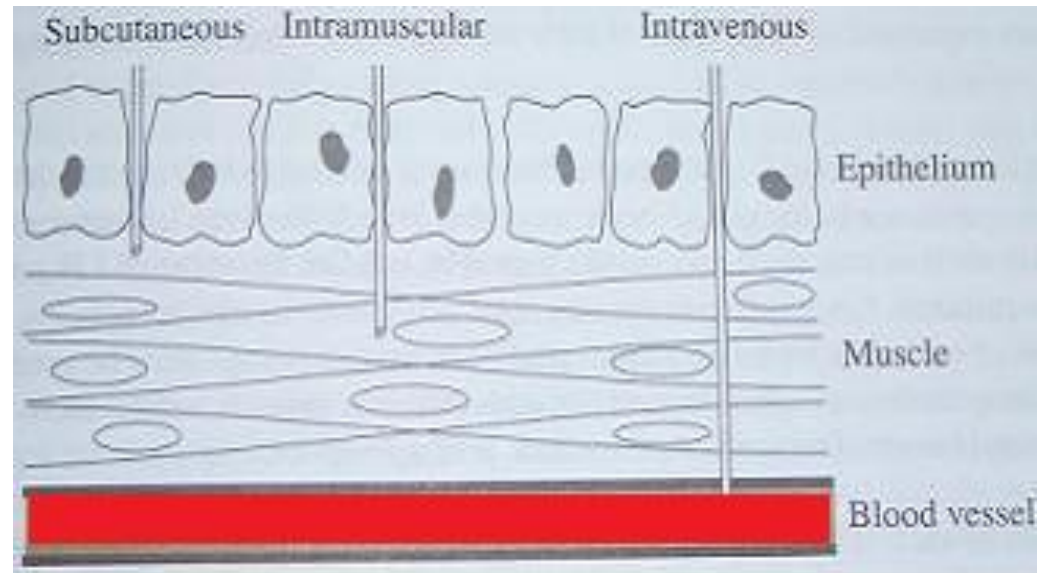
- immediate response is not required

- **Used for large volumes of drug injection**

- **Intravenous**

- **Near instantaneous effect**

- **Concentration not affected by stomach content**



- **More about drugs**

- **Half-life is the time required for half of the drug to be eliminated**

• Toxicity

– LD_{50} is the dose (in mg of substance per kg of body mass) that is lethal to 50% of laboratory animals

– The lower the LD_{50} , the more toxic the substance

- Lowest LD_{50} rating known as of yet: botulism toxin (BoTox) – most toxic substance known [LD50](#) of roughly 0.005-0.05 $\mu\text{g}/\text{kg}$

Tolerance and Dependence

Antacids

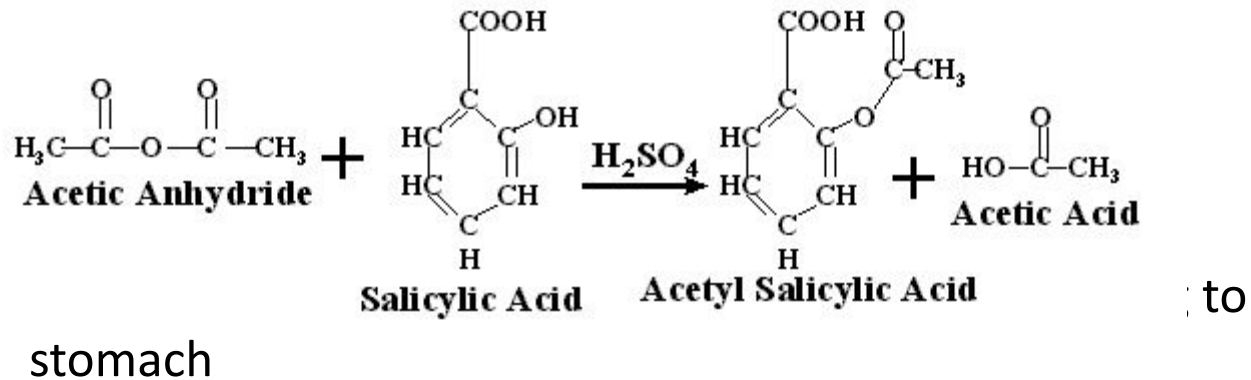
Analgesics

– Prostaglandins:

- Constrict blood vessels
 - Affect hypothalamus (region of brain controlling heat regulation)
 - Increase permeability of capillaries to allow for swelling
-
- Prevents transmission of pain impulses without depressing the central nervous system

- **Mild analgesics**

- Aspirin (acetyl salicylic acid or ASA) produced from salicylic acid (relatively strong acid, difficult to take)



- ASA is called a prodrug: a less active form that is converted to the active form after administration
- ASA can also be used to produce alka-seltzer and other drugs by further modification

– **Uses of salicylic acid and its derivatives:**

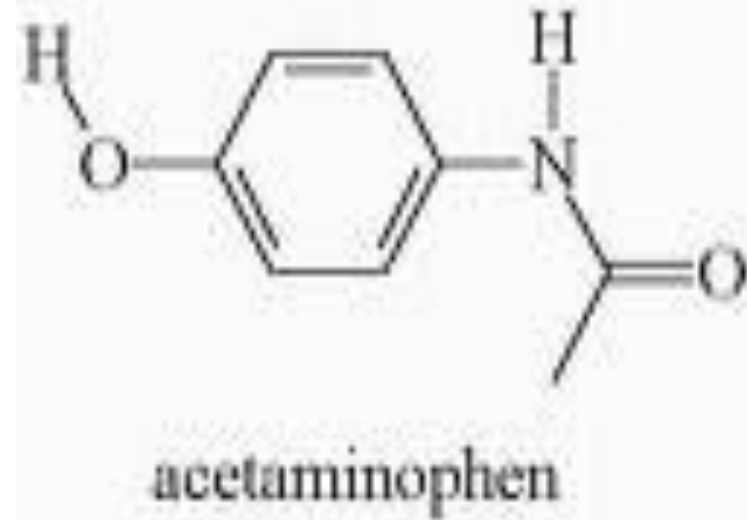
- Relief from minor aches and pains
- Fever reduction (antipyretic)
- Anti-inflammatory agent
- Anti-clotting agent

– **Disadvantages of aspirin:**

- Can cause upset stomach and ulceration
- Risk of severe gastrointestinal bleeding following alcohol consumption
- Small risk of allergy (.5% of population)
- Accidental infant poisoning; small correlation to Reye's syndrome in children

– Aspirin substitutes

- Acetaminophen (paracetamol)
 - Does not upset stomach or cause bleeding
 - NOT an anti-inflammatory
 - Safe in correct dose, but overdose (>20 tablets) can cause serious liver damage, brain damage, and death)
- Ibuprofen
 - Many of the same effects as aspirin but fewer stomach problems



- **Strong analgesics**

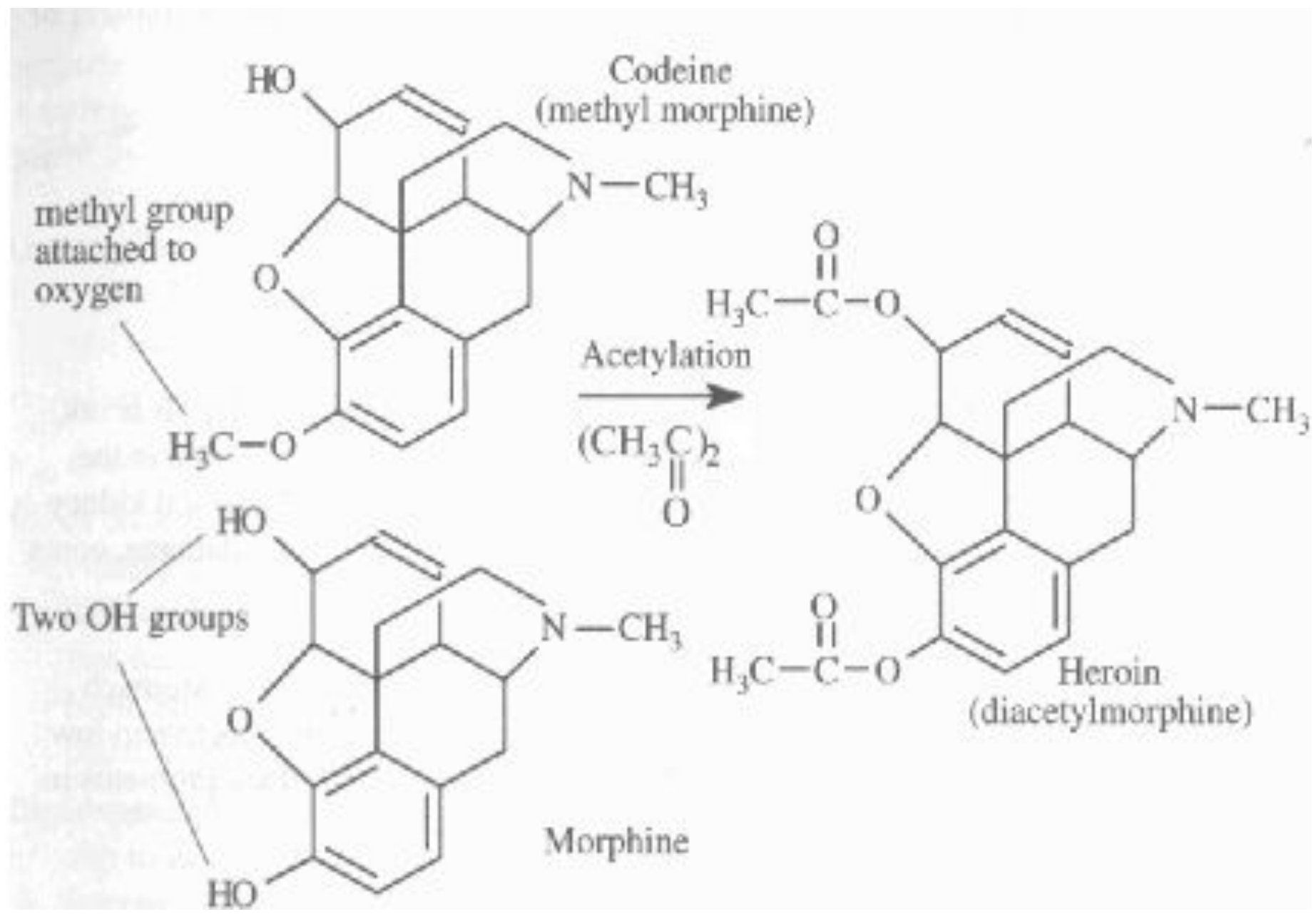
- **Opium alkaloids (morphine, heroin, codeine)**

- Belong to “opiate” class (drug that exerts actions on the body similar to morphine) or “narcotics” (drug that produces a narcotic (sleep-inducing) effect as well as an analgesic (pain relieving) effect)

- **Morphine is principal alkaloid, making up about 10% by mass of raw opium**

- **Codeine is about .5% of raw opium**

- **Heroin is synthesized from morphine (semi-synthetic drug) via a simple acetylation**



- **Advantages of Opiates:**

- **Pharmacological effects**

- Major effects on:

- **Nervous system**

- **The eye**

- **GI tract**

- Uses:

- **Strong analgesic for relieving severe pain**

- **Treatment of diarrhea (produces constipation)**

- **Cough suppressant**

- **Disadvantages:**

- **Psychological effects**

- Drowsiness, mood change, mental fogginess, nausea and vomiting
 - Anxiety, fear, lethargy, sedation, lack of concern, inability to concentrate

- **Tolerance and Dependence**

- Cross-tolerance can occur (users tolerant to one opiate will be tolerant to other opiates)
 - Users may not function properly without the drug, experience withdrawal symptoms (addiction)

Depressants

- Drugs that calm and relax the central nervous system
 - Tranquilizers
 - Alcohol, valium, librium (Reduce distress but do not produce sleep)
 - Sedatives
 - Barbiturates (Reduce distress but do not produce sleep, stronger than tranquilizers)
 - Hypnotics
 - Chloral hydrate (produces sleep in larger doses)

- Alcohol

- Small, fat-soluble organic molecule – readily penetrates cell membrane and is easily absorbed from the GI tract

- Social effects:

- Costs

- Sickness and death associated with abuse
 - Crime and traffic costs

- Physiological effects

- Short term:

- Reduces anxiety and inhibitions
 - Impairs attention, judgment, and control
 - Violent or aggressive behavior
 - Loss of motor function
 - Effect depends on body mass and concentration of alcohol in the blood

- Long-term

- Alcoholism is caused by an inability to reduce alcohol intake
 - » Withdrawal symptoms (nausea, sweating, anxiety, hypertension)
 - » Tolerance
- Cirrhosis (scarring) and cancer of the liver (the major detoxification organ)
- Heart disease
- Hypertension
- Strokes
- Gastritis
- Ulcers
- Depression
- Birth defects

- Alcohol interacts with other drugs
 - Can produce coma or death when combined with sleeping pills or barbiturates
 - Can cause stomach bleeding with aspirin
 - Can inhibit breakdown of other drugs

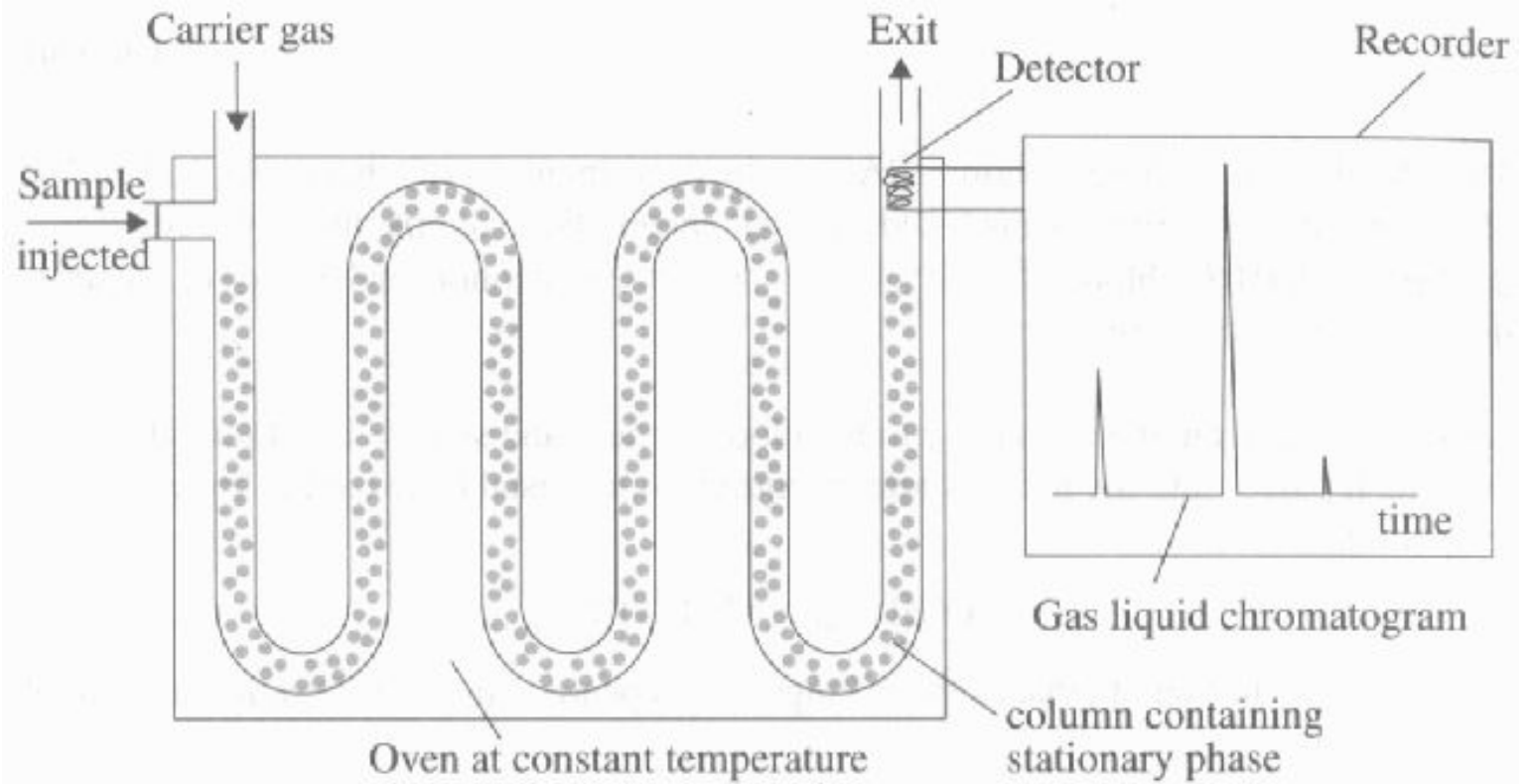
- Measuring blood alcohol concentration (BAC)
 - Mass (g) of ethanol per 100 cm³ of blood
 - .08% is legal limit in US (.080 g per 100 cm³ of blood)
 - Ethanol is easily absorbed from the stomach to the blood, where it is exhaled by the lungs (ethanol is fairly volatile)

$$\text{C}_2\text{H}_5\text{OH}_{(l)} \rightleftharpoons \text{C}_2\text{H}_5\text{OH}_{(g)}$$
 - The alcohol vapor can be detected by a number of methods

- Breathalyzer test

- Subject breathes into an analyzer containing an oxidizing agent and a detector
- Potassium dichromate (K_2CrO_4) is the oxidizing agent
 - » Oxidizes ethanol to ethanoic acid
 - » This is an oxidation-reduction reaction that involves an electron transfer
 - » This electron transfer generates an electric current which can be detected by the machine
- Unreliable in legal cases

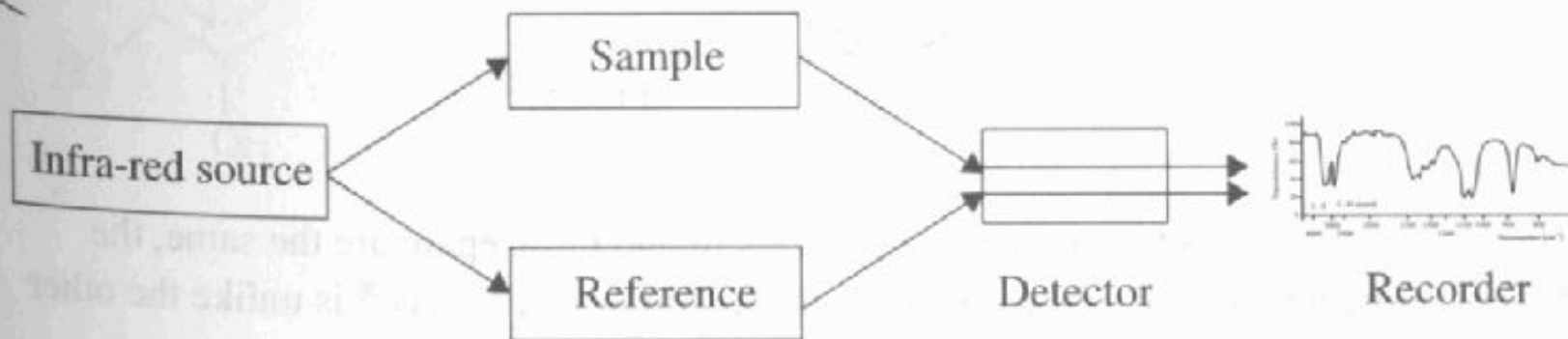
- Gas Liquid Chromatography
 - More precise than breathalyzer
 - Uses a stationary phase (non-volatile liquid or solid support) and a mobile phase (inert gas, like N₂)
 - Breath components (CO₂, H₂O, and alcohol vapor) are injected into the machine and partitioned (divided) between the stationary and mobile phases
 - Components exit at different intervals (each substance has a different affinity and bond strength for the two phases, and thus move through at different rates)
 - Components are detected
 - » Retention time for each component is measured (time taken for each component to pass through the column)
 - » Blood alcohol's retention time is compared to the retention time for a standard ethanol sample



- Infra-Red Spectroscopy

- IR light does not promote electrons to higher levels, but does provide enough energy to make molecules “vibrate”
 - » Vibrational motion depends on the mass of the molecule and the types of bonds present
- IR spectrum therefore depends on types of molecules present (“molecular fingerprint”)
- Scale is based on wavenumber (1/wavelength)
- Police use intoximeter (IR spectrometer) to confirm breathalyzer test
 - » IR radiation is passed through breath sample
 - » C-H group in alcohol absorbs a certain frequency of IR light
 - » % transmittance of the C-H frequency is determined, indicating amount of alcohol present

A simplified schematic diagram of a double-beam IR spectrophotometer



- Other Depressants

- Diazepam (Valium) is a tranquilizer used to relieve anxiety and tension
- Nitrazepam (Mogadon) is a hypnotic drug used to induce sleep
- Fluoxetine hydrochloride (Prozac) is used to treat mental depression by increasing activity of serotonin (a neurotransmitter)

Stimulants

- Stimulate brain and central nervous system
 - Cause increased alertness and awareness
 - Include amphetamines, nicotine, and caffeine

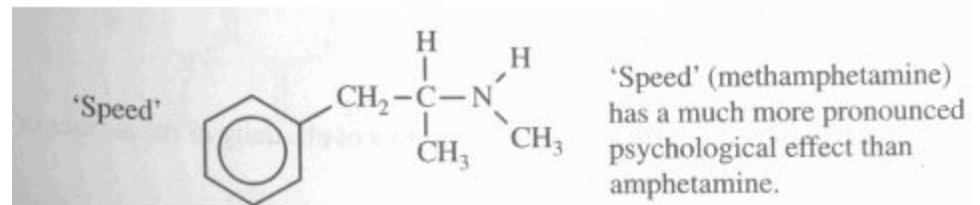
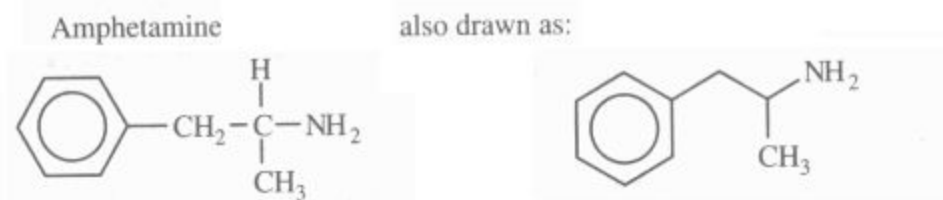
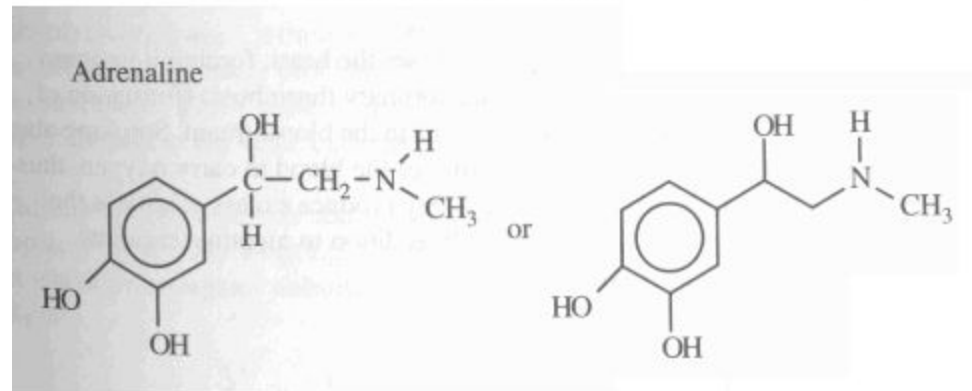
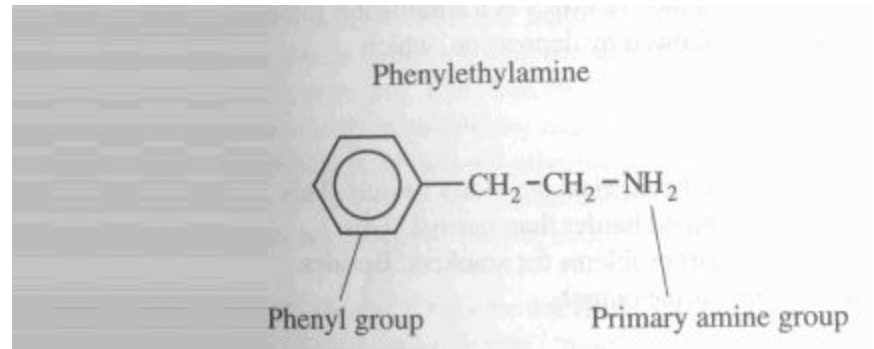
- Amphetamines

- Have structures similar to adrenaline

- Both are derived from Phenylethylamine

- Mimic the actions of adrenaline (sympathomimetic)

- Constrict arteries, increase sweat production, increase heart rate, blood pressure, respiration



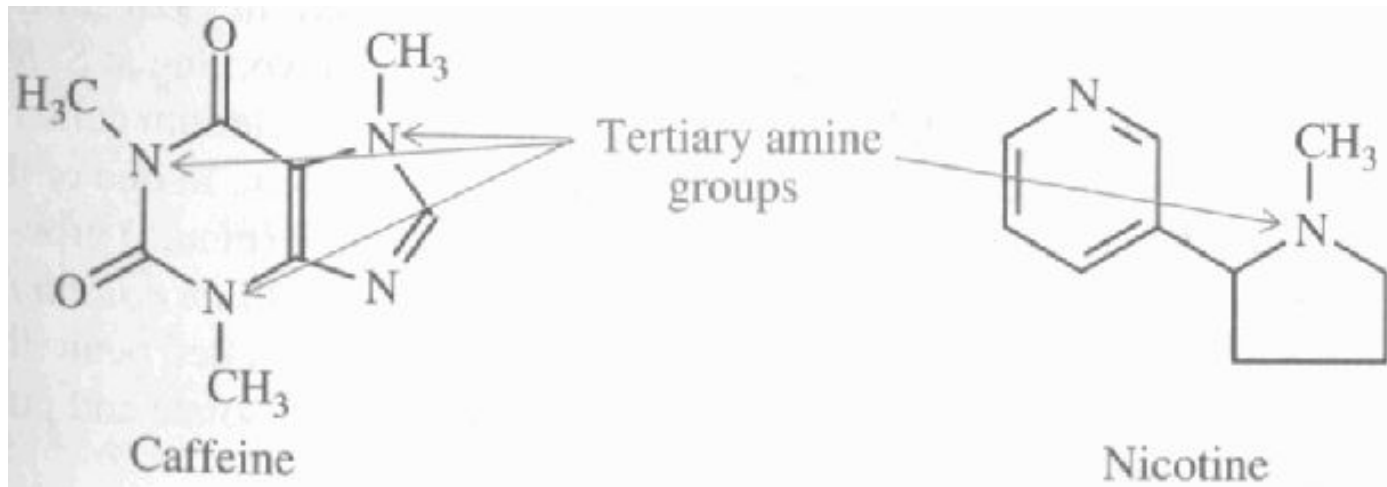
- Nicotine
 - Initial stimulant effect, followed by depression, which encourages frequent use
 - Short term effects:
 - Increased heart rate and blood pressure, putting stress on the heart
 - Reduces urine output
 - Long term effects
 - Increased risk of heart disease and blood clot (thrombosis)
 - Inhibits oxygen-carrying capacity of blood
 - Increased risk of peptic ulcers

- Smoking can also lead to
 - Lung cancer
 - Cancer of the larynx and mouth
 - Heart and blood vessel disease
 - Emphysema
 - Chronic bronchitis
 - Air pollution
 - Fires!!
 - Stained fingers and teeth
 - Bad breath
- Very easy to develop dependence on nicotine compared to alcohol or barbiturates
 - Withdrawal symptoms: weight gain, nausea, insomnia, irritability, fatigue, depression, and inability to concentrate

- Caffeine

- Increases rate of cellular metabolism and therefore respiration
- In low doses, enhances wellbeing, alertness, energy, and motivation
- In large amounts, physical coordination and timing are affected, and sleeplessness may also result.
- Weak diuretic (increases urine flow)
- Tolerance occurs, but no physical dependence
- Vasoconstrictor (blood vessel constriction), so can help in treating migraines
- Can help newborn babies to breathe as it increases respiration

- Caffeine, like nicotine, contains a tertiary amine group (nitrogen atom attached to three organic [i.e. carbon-containing] substituents):



Antibacterials

- Antibacterials are selective: they attack infectious bacteria rather than human cells
 - Can be
 - Bacteriostatic (inhibit bacterial cell division) or
 - Bacteriocidal (directly kill bacteria)
 - Normally ineffective against viruses because viruses live within host cell, which are unaffected by most antibiotics

- Penicillins:
 - Produced from fungi (*penicillium* genus)
 - Accidentally discovered by Alexander Fleming, who noticed that bacteria did not grow around a spot of *penicillium notatum* mold on a culture plate
 - Fleming could not isolate the “penicillin,” and later gave up the research
 - Florey and Chain, at Oxford, renewed the research and started administering the drug to humans
 - Awarded the Nobel Prize
 - Thousands of lives were saved during WWII

- Structure

- Penicillins all have a certain structural feature in common, the 6-APA group

- (6-aminopenicillic acid)

- Structure has no effect on bacterial growth, but when an extra side chain is added to the amino (NH_2) group, it becomes “active”

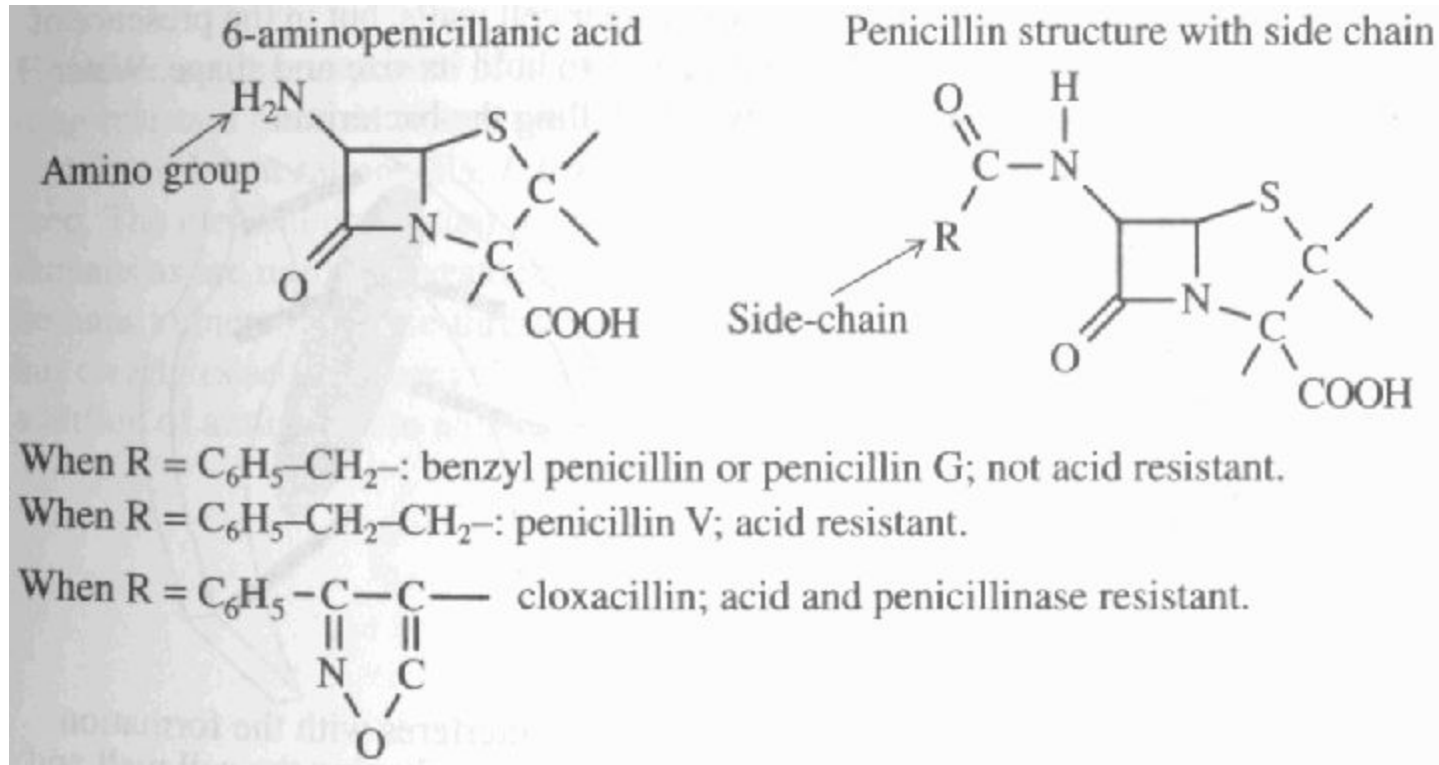
- Side chain varies between different types of penicillin:

- » Penicillin G, the first type created, is not acid-resistant, and must be injected to bypass the stomach

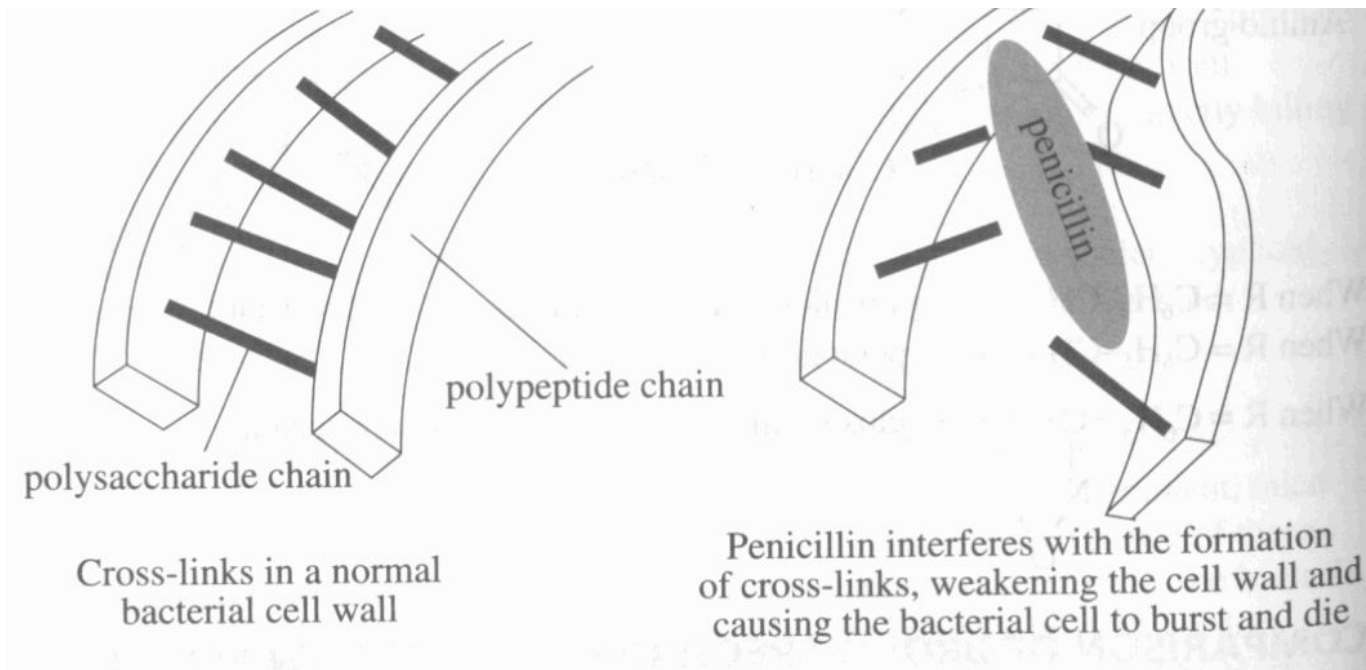
- » Penicillin V is acid-resistant

- » Cloxacillin is acid and penicillinase (bacteria-produced enzyme that breaks down penicillin) resistant

- Penicillins differ only in their type of side chain



- Penicillins function by interfering with the cross-links that connect separate layers of the bacterial cell wall
 - Cell wall is weakened and the bacterial cell bursts, killing the bacteria



penicillins

- Disadvantages of penicillins
 - About 10% of the population is allergic
 - Side effects include fever, body rash, shock, and death
 - Overprescription can result in destruction of harmless bacteria in the digestive tract, allowing harmful bacteria to colonize
 - Overprescription leads to genetics resistance over time, rendering the antibiotic eventually useless
 - Thus, antibiotics should only be prescribed when there is no other option that can reduce suffering or save a life

- Broad vs. Narrow Spectrum Antibiotics:
 - Broad spectrum
 - Effective against a wide variety of bacteria
 - Tetracyclines (Aureomycin, Terramycin)
 - Repeated use may wipe out harmless bacteria in the digestive tract, which may be replaced by harmful strains
 - Narrow spectrum
 - Effective against only certain types of bacteria
 - Penicillins
 - Typically, a broad spectrum is initially prescribed until the bacteria can be identified, at which point a narrow spectrum is prescribed

- Antibiotics in animal feed
 - Antibiotics are added to animal feed to prevent the spread of infection throughout livestock
 - However, this can encourage the development of drug-resistant bacteria that humans will eventually be exposed to

Antivirals

- Viruses are submicroscopic, non-cellular infectious particles that can only reproduce inside a living host cell
- Unlike bacteria, which have a cellular structure, viruses have no nucleus, cytoplasm, or cell membrane
- This limits the effectiveness of antibacterial drugs on viruses

- Controlling viruses
 - Antibacterials may be effective if they block the transfer of genetic information, although few do
 - Vaccination is primary method of prevention
 - Patient is exposed to weakened or inert viral particles to stimulate immune system
 - Immune system produces antibodies, crucial in the immune response, specific to that virus
 - Future exposure to active viral particles is more easily controlled because antibodies have already been produced against it

- Many antiviral drugs work to inhibit the function of replication-specific enzymes

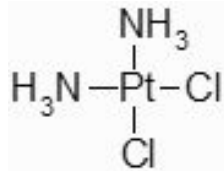
- Latent viruses are viruses that inject their genetic material into a host cell, but the material is not expressed until a later date
 - Herpes simplex virus, certain types of cancer

- AIDS virus
 - Attacks immune system by binding to a receptor glycoprotein (CD4) on T4 immune cells
 - Difficult to fight because of:
 - its ability to mutate (thus rendering a previous treatment ineffective)
 - Its metabolism is similar to human cells

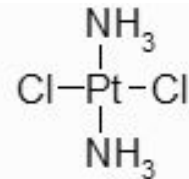
Stereochemistry in Drug Action and Design (HL only)

- Stereoisomers are isomers with the same molecular formula AND the same structural formula, but a different arrangement of atoms in space.
- Geometric isomers:
 - If a pair of stereoisomers contains a double bond, cis and trans arrangements can exist:
 - cis: substituents are on the same side of the double bond
 - trans: substituents are on opposite sides of the double bond

- Geometric isomers have:
 - different physical properties, including polarity, boiling point, melting point, and solubility
 - Different chemical properties, and thus different pharmacological effects
 - Ex. Cisplatin



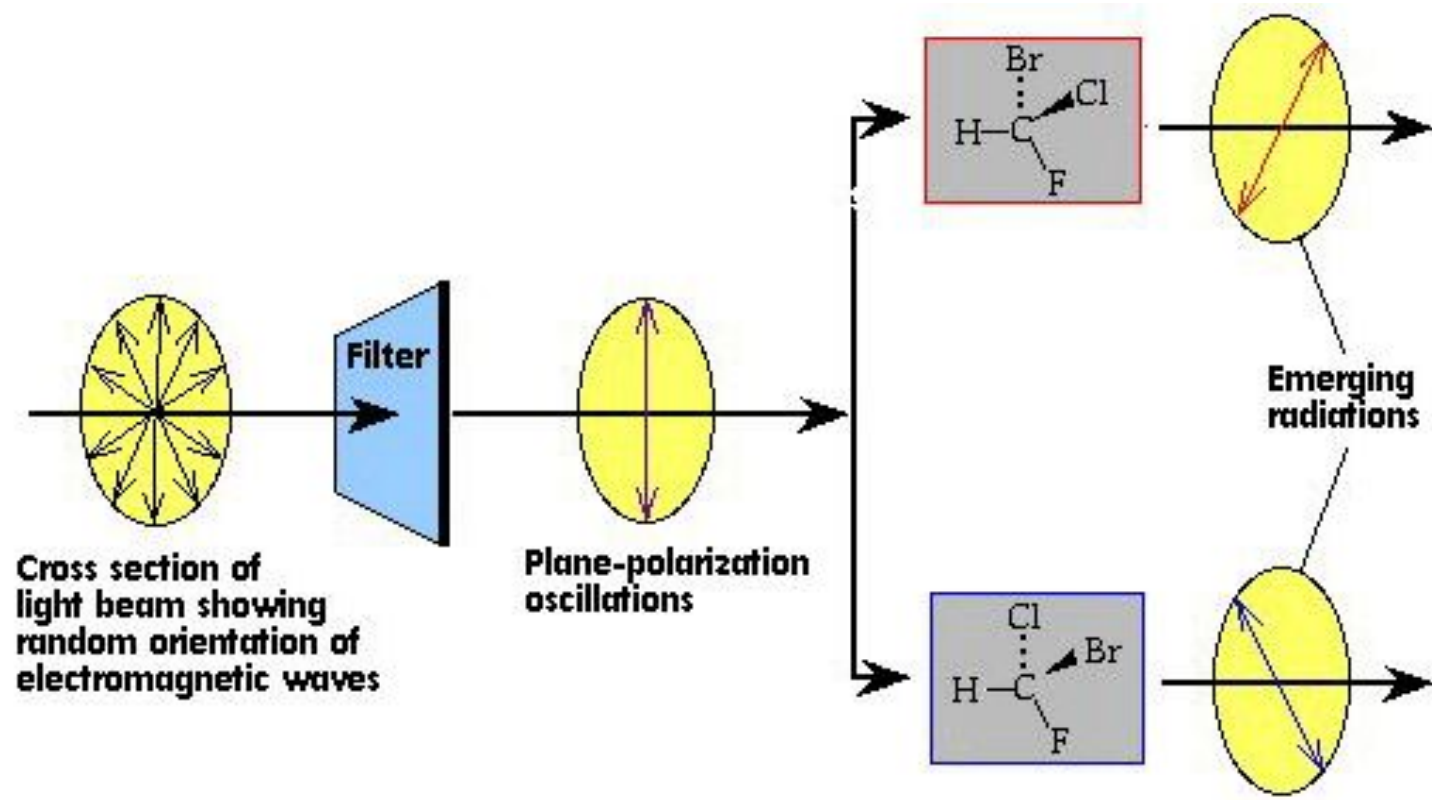
cis - isomer
chemotherapeutically active



trans - isomer
chemotherapeutically inert

- Square planar molecule, NH₃ groups are either on same side of the square or opposite sides

- Optical isomers:
 - Different from geometric isomers:
 - The molecules are chiral (asymmetric, meaning that there are four different groups around a central atom)
 - The isomers are non-superimposable mirror images of one another
 - Each isomers differs in its optical activity (the ability to rotate the plane of polarized light)
 - One isomer (enantiomer) rotates the plane of polarized clockwise (+ form), the other rotates it counterclockwise (- form)



- An equimolar mixture of both enantiomers (racemic mixture) will not rotate the plane and is said to be optically inactive
- Drugs from natural sources are usually chiral and are generally found as a single enantiomer
 - Ex. Penicillin V
 - Opposite enantiomer can only be produced artificially and is pharmacologically inactive

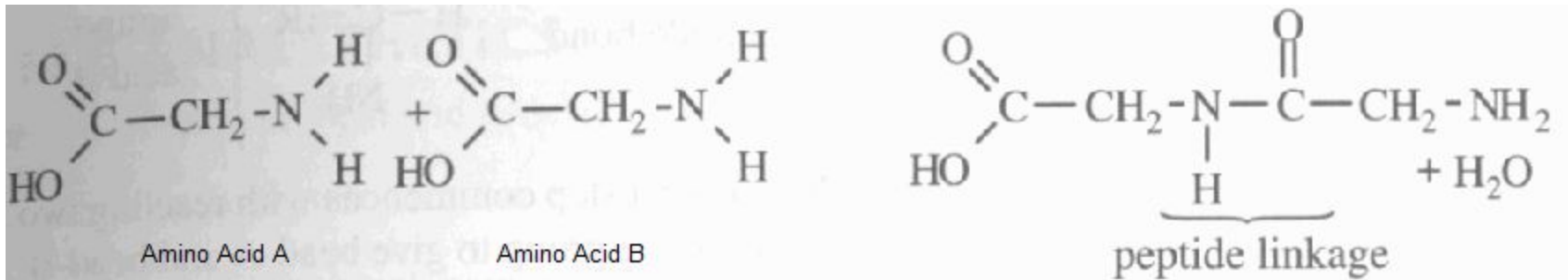
- Synthetic drugs, when chiral, are usually produced as racemic mixtures
 - Ex. : Ibuprofen
 - One enantiomer is pharmacologically inactive
 - Drug still produced as a racemic mixture to reduce costs
 - Thalidomide
 - One enantiomer alleviates morning sickness, the other can cause birth defects
 - Unknown before it was prescribed in the 1970's
 - Racemic mixture (“bad” and “good” enantiomers) can still be sold as a treatment for leprosy

- Synthesis of non-racemic mixtures is difficult, as both enantiomers are chemically identical in relation to non-chiral reagents
 - “chiral auxiliaries” (helping-hands) are used to produce a desired enantiomer from a non-chiral molecule
 - Attaches itself to non-chiral “building block” to create the stereochemical conditions necessary to force the reaction to follow a certain stereospecific path
 - Auxiliary can be removed and reused once the desired enantiomer has been formed
 - Eliminates the need to separate a racemic mixture

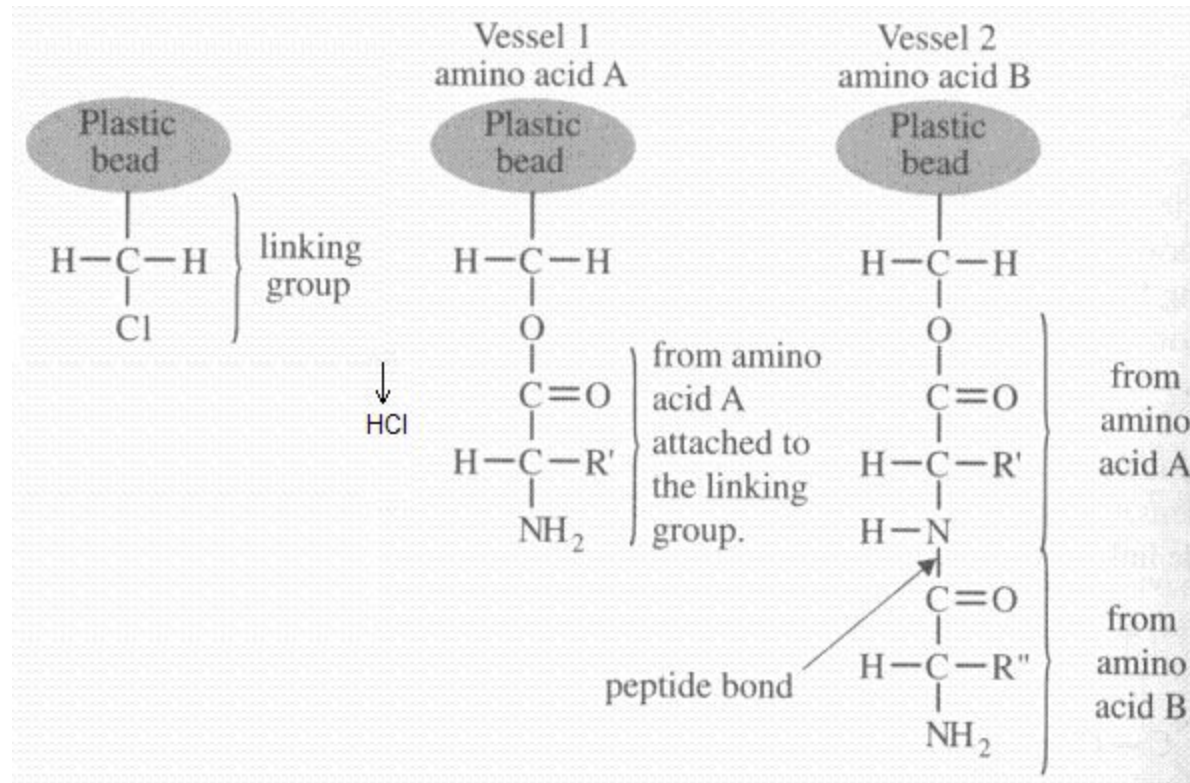
- Combinatorial chemistry
 - As drug R & D is very costly and time-consuming, most drug research begins with a “lead compound,” (not lead as in metal, but “lead) whose main structure is left unaltered but other parts are changed to produce more effective drugs.
 - Combinatorial chemistry (combi-chem) involves creating a large number of molecules and quickly testing them for desirable biological activity
 - Sometimes compounds are “virtually tested” by computer simulation
 - Combi-chem involves reacting a set of starting materials in all possible combinations
 - Uses same methods as basic organic synthesis, but uses technology and computers to make very large libraries of related chemicals
 - Increases the chances of finding better drugs

- Libraries of a vast amount of related compounds are produced using robotics to perform repetitive work (ex. adding a fixed volume of a substance to a collection of chemicals) (parallel synthesis)
 - Products of these reactions are then tested, without animals, by studying their effects on enzymes

- Combi-chem began in the 1960's
 - Most importantly: Solid-phase synthesis:
 - Peptide bond is created between two amino acids through a condensation reaction:



- Solid-phase synthesis allows for the rapid creation of a large number of polypeptides by employing the use of plastic beads



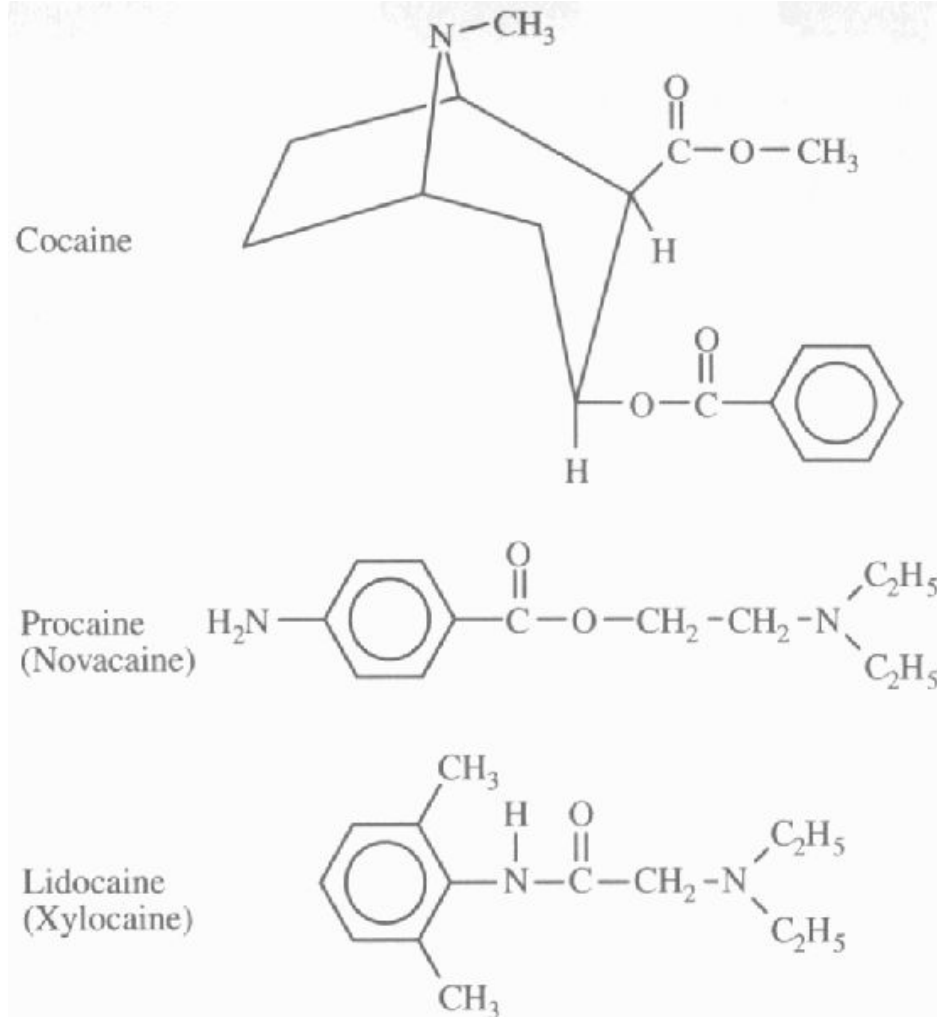
- “linking group” is attached to a plastic bead
- In vessel 1, amino acid A attaches to linking group, eliminating an HCl (Cl from linking group, H from OH group of acid portion of AA)
- Bead is placed in Vessel 2, where it attaches to amino acid B via a peptide linkage
- Process continues with any number of amino acids

- Procedure can be extended so that the first step reacts two amino acids, A and B, to produce bead A and bead B
 - These can be split into separate containers so that each now contains beads A and B, in a half and half mixture
 - In the second stage, one container is reacted with amino acid A to produce bead A-A and bead B-A
 - the other container is reacted with amino acid B to produce bead A-B and bead B-B
 - This two amino acid, two stage process produces 4 (2^2) amino acids (A-A, B-A, A-B, and B-B)
 - Starting with 3 amino acids in a 2 stage process would produce 3^2 (9) peptides, 10 amino acids in a 4 stage process would produce 10^4 (10,000 polypeptides) etc.
 - A large polypeptide library can therefore be quickly produced
 - Process can also be extended to other molecules besides peptides to produce very extensive chemical libraries

Anaesthetics

- Local vs. General
 - Local anaesthetics block pain in a specific area (injected under the skin or applied topically)
 - Cocaine, procaine, benzococaine, lidocaine
 - Block nerve conduction and decrease blood supply
 - Procaine and lidocaine do not affect the brain, but cocaine does

- Cocaine, procaine, and lidocaine all contain a benzene ring and a tertiary amine group



- Cocaine, besides acting as a local anaesthetic, can also stimulate the central nervous system
 - Only used medically as a surface application in oral surgery, extremely dangerous when injected because it is a vasoconstrictor
 - Produces a strong psychological addiction, although no physical dependence or tolerance
- Procaine gives prolonged pain relief and immediate loss of feeling prior to dental surgery
 - Applied through injection and is short-lasting
- Lidocaine produces loss of feeling and is applied topically
 - More potent than procaine
 - Itching and swelling are side effects

– General anaesthetics act on the brain and produce unconsciousness, which can be readily reversed

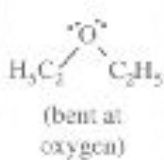
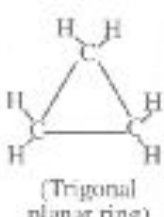

- Nitrous oxide (N_2O), diethyl ether ($\text{C}_2\text{H}_5\text{-O-C}_2\text{H}_5$), chloroform (CHCl_3), cyclopropane (C_3H_6), and halothane (CHClBrCF_3)

- Some disadvantages:

- Nitrous oxide is not very potent
- Trichloromethane (chloroform) can lead to liver damage
- Ethoxyethane and cyclopropane are highly flammable
- Halothane is harmful to the ozone layer

A summary of the effects of some anaesthetics

Name	Formula	Structure	Advantages	Disadvantages
Dinitrogen oxide (nitrous oxide, laughing gas)	N_2O	$\begin{array}{c} \overset{\cdot\cdot}{N}=\overset{\cdot\cdot}{N}=\overset{\cdot\cdot}{O} \\ \text{(linear)} \end{array}$	Capable of inducing deep levels of anaesthesia (if adequate $[O_2]$ is maintained)	Low potency anaesthetic (not very efficient), induces a state of disinhibition and euphoria and is thus an abused drug
Trichloro- methane (chloroform)	$CHCl_3$	$\begin{array}{c} H \\ \\ Cl-C-Cl \\ \\ Cl \\ \text{(tetrahedral)} \end{array}$	Non-flammable	Leads to liver damage. Not a useful anaesthetic, its toxicity precludes widespread use. It has a narrow safety margin (i.e. a small difference between an anaesthetic and a lethal dose).

Name	Formula	Structure	Advantages	Disadvantages
Ethoxyethane (ethyl ether)	$(\text{CH}_3\text{CH}_2)_2\text{O}$	 <p>(bent at oxygen)</p>	Alleviates the pain involved in surgical procedures	Highly flammable; (prone to ignite and explode violently), ether has been replaced by safer anaesthetics that result in fewer side effects and are more stable, safe and non-flammable)
Cyclopropane	C_3H_6	 <p>(Trigonal planar ring)</p>	A very potent general anaesthetic administered by inhalation; used for all types of surgical operations	Forms explosive mixtures with air; highly flammable; can cause nausea vomiting and headaches
2-bromo-2-chloro-1,1,1-trifluoroethane (Halothane [®] trade name fluothane [®])	CF_3CBrClH	 <p>*Chiral carbon, an optically active compound.</p>	Widely used: a potent general anaesthetic for all types of surgical operations: non-flammable; produces rapid recovery; non-irritating to the respiratory tract	Induction to anaesthesia is slow; prolonged recovery. Potentially harmful to the ozone layer - capable of producing Cl and Br (chlorine and bromine free radicals) that can destroy the ozone layer; $\text{O}_3 + \text{*Cl} \Rightarrow \text{ClO*} + \text{O}_2$ See Option D.9

- Dalton's Law of partial pressures can be used to calculate partial pressures of component gases in an anaesthetic mixture
 - Ideal gas law says: $P_{\text{total}} V = n_{\text{total}} RT$
 - $P_{\text{total}} = P_a + P_b + P_c$
 - $n_{\text{total}} = n_a + n_b + n_c$
 - Example: Isoflourane, a halogenated volatile anaesthetic, is used with nitrous oxide to sustain anaesthesia during surgery. If the concentrations of isoflourane, N_2O , and O_2 are 2.0%, 70%, and 28% respectively, calculate the partial pressure of each gas in the sample at 25°C and 1.0 atm.
 - $P_{\text{isoflourane}} = 2\% \times 1.0 \text{ atm} = .02 \times 1.0 \text{ atm} = .02 \text{ atm}$
 - $P_{N_2} = 70\% \times 1.0 \text{ atm} = .70 \times 1.0 \text{ atm} = .70 \text{ atm}$
 - $P_{O_2} = 28\% \times 1.0 \text{ atm} = .28 \times 1.0 \text{ atm} = .28 \text{ atm}$
 - See examples on pg. 452 of LGB

Mind-altering drugs

- Psychedelic drugs or psychotomimetics (simulate madness)
 - Cause hallucinations and distortion of senses
 - LSD (lysergic acid)
 - Mescaline
 - Psilocybin (peyote mushrooms)
 - THC (tetrahydrocannabinol in marijuana)

– LSD

- Powerful hallucinogen
- Effect depends on:
 - Dose
 - Physiological condition
 - Psychological condition
 - Expectations
- Magnifies perception
- Destroys sense of judgment
- Produces flashbacks without taking LSD
- Does not produce physical addiction but can produce tolerance and psychological addiction

– Mescaline

- Produces color hallucinations
- Lasts approximately 12 hours

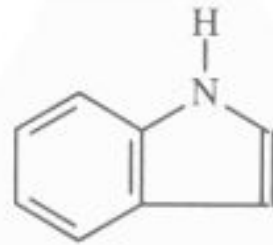
– Psilocybin

- Magnified perception
- Low doses produce relaxation, high doses produce effects similar to LSD

– THC (marijuana)

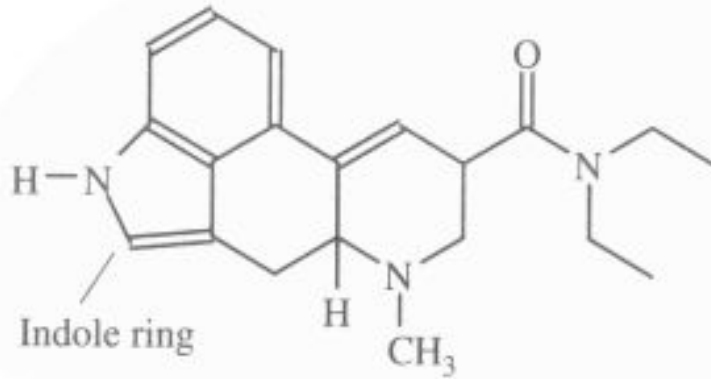
- Mild hallucinogen
- Causes silliness and excitement at low doses
- As dosage increases, perception changes and hallucinations result
- Can cause extreme anxiety, depression, uneasiness, panic attack and fearfulness in high doses
- Driving and other tasks requiring thinking are difficult
- Psychological dependence is possible

- LSD, mescaline, and psilocybin all contain a benzene ring (6 carbon); LSD and psilocybin contain an indole ring (6 carbon benzene ring fused to a 5-membered ring containing a secondary nitrogen)
- LSD is fat-soluble and easily diffuses into the brain
- Psilocybin mimics the structure of the brain hormone serotonin



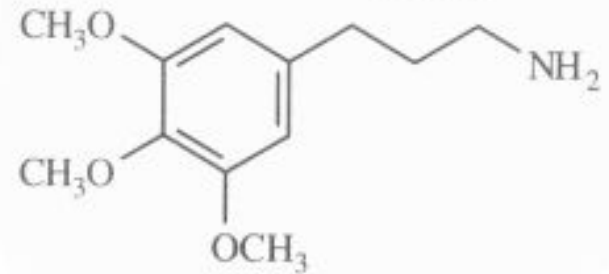
indole ring

Structure of LSD

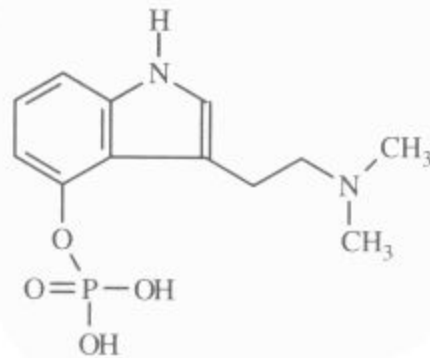


Indole ring

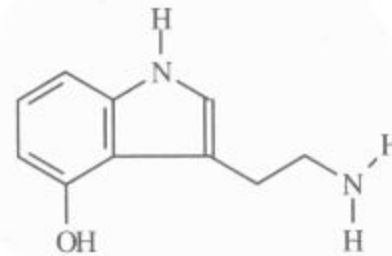
Structure of mescaline



Structure of psilocybin



Structure of serotonin



- Cannabis
 - *cannabis sativa*, contains pharmacologically active compounds (cannabinoids)
 - Legalization is a hotly contested issue
 - Arguments for:
 - Relieves symptoms from AIDS, cancer (allows for weight gain by suppressing nausea), and glaucoma (alleviates harmful pressure in the eye)
 - Arguments against:
 - Leads to respiratory ailments
 - Suppresses immune system
 - Decreases fertility
 - Causes brain damage and chromosomal damage leading to birth defects
 - “Gateway drug”
 - Users of marijuana and other drugs obtain them by illegal sources, leading to a host of crimes (prostitution, theft, murder, etc.)