

Option B –  
Medicine and Drugs  
IB Chemistry

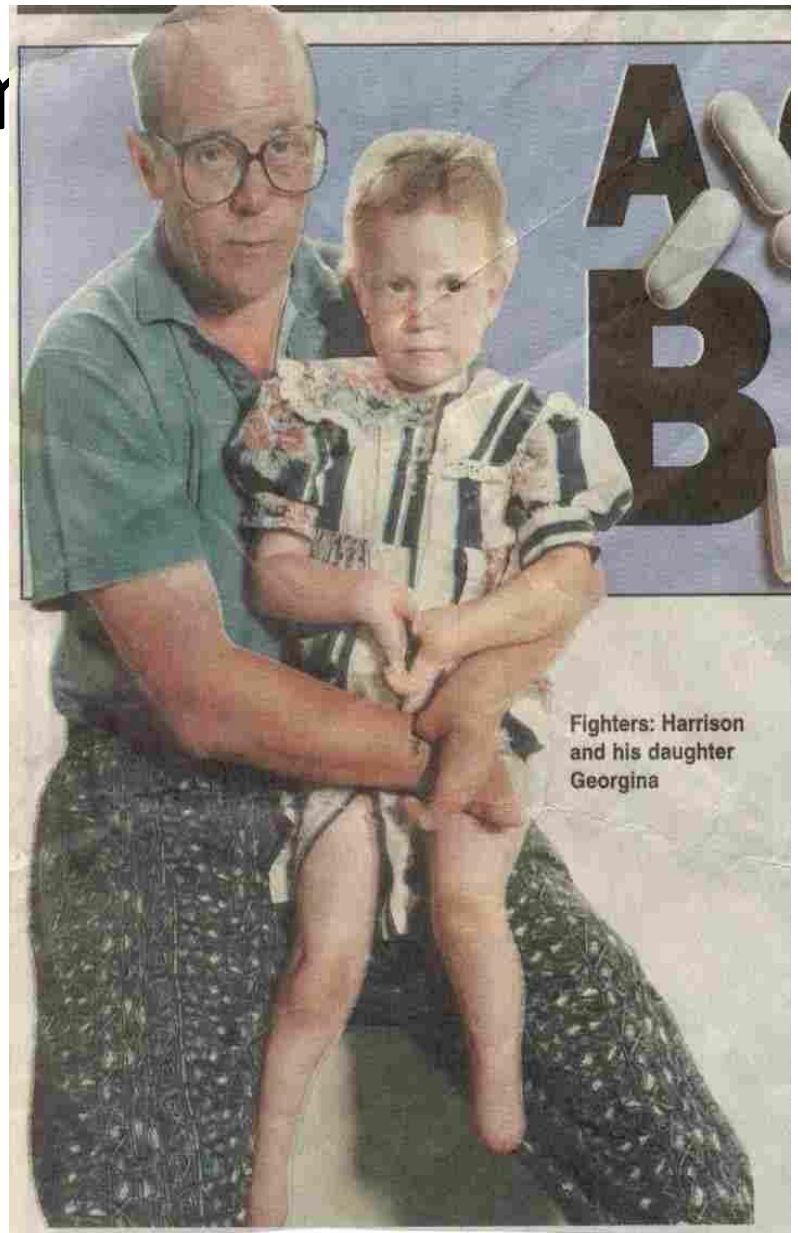
# Pharmaceutical Products

- **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**

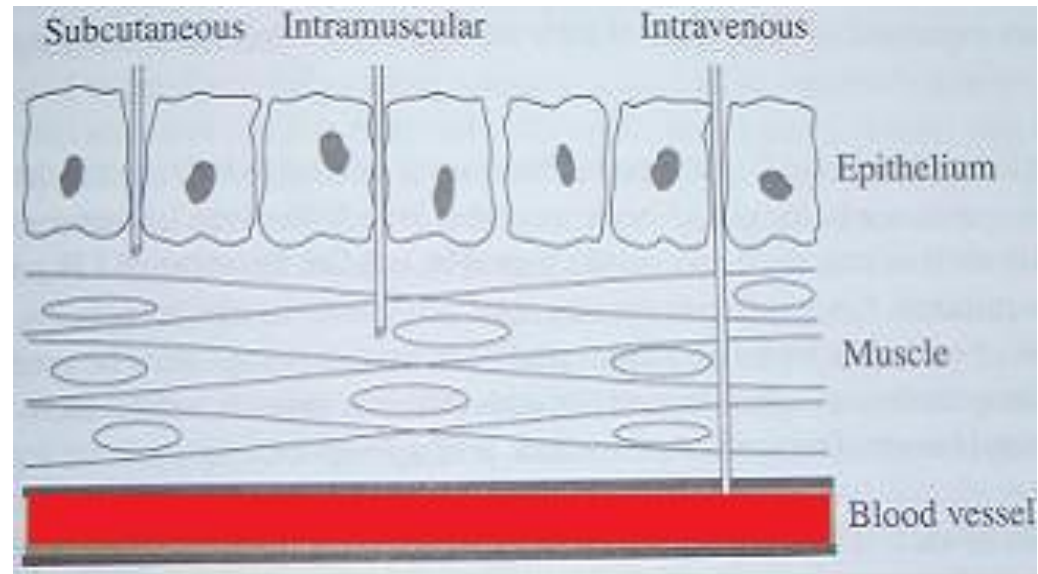
- Effective if a drug cannot be taken orally or if a drug is pH sensitive

- **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 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

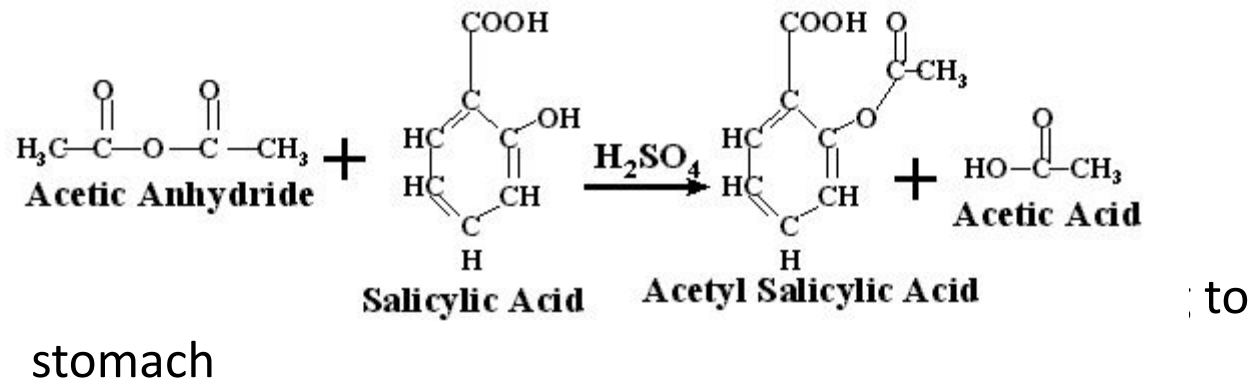
# Analgesics

## – 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:**

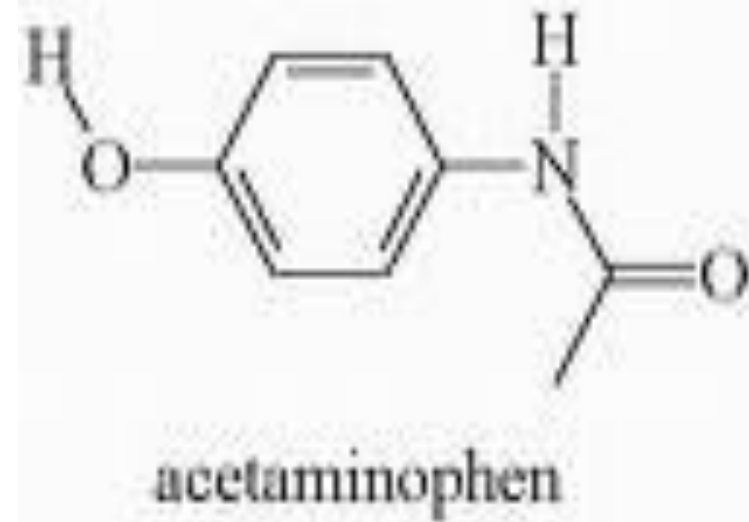
- Relief from minor aches and pains
- Fever reduction (antipyretic)
- Anti-inflammatory agent
- Anti-clotting agent

– **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**

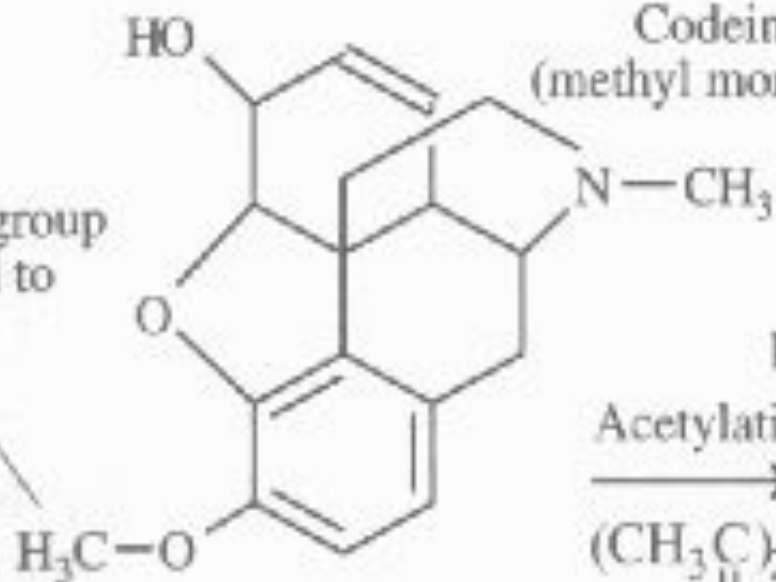
- **Codeine is about .5% of raw opium**

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

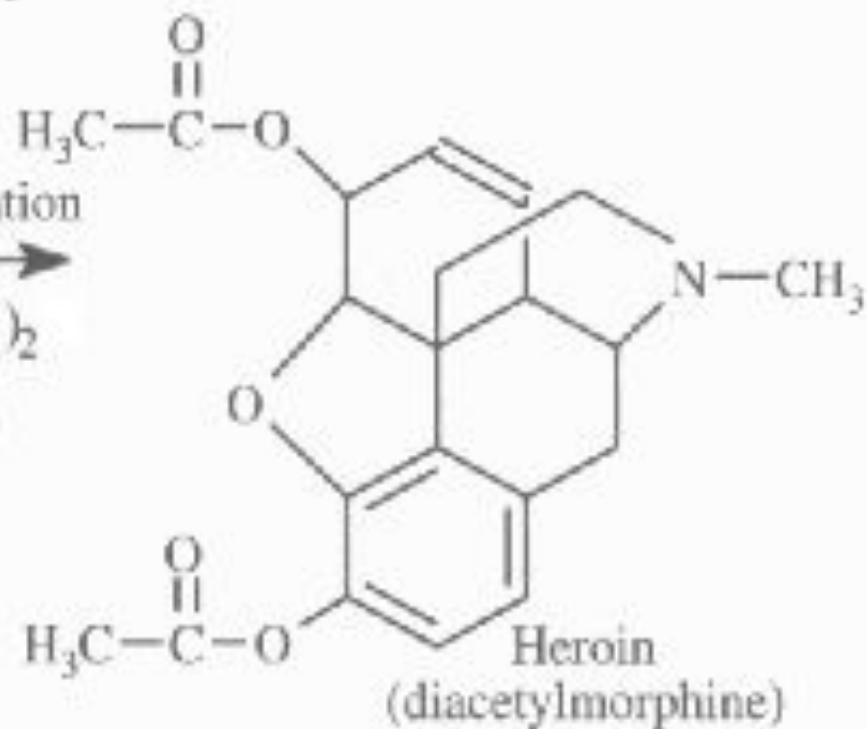
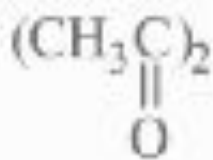


Codeine  
(methyl morphine)

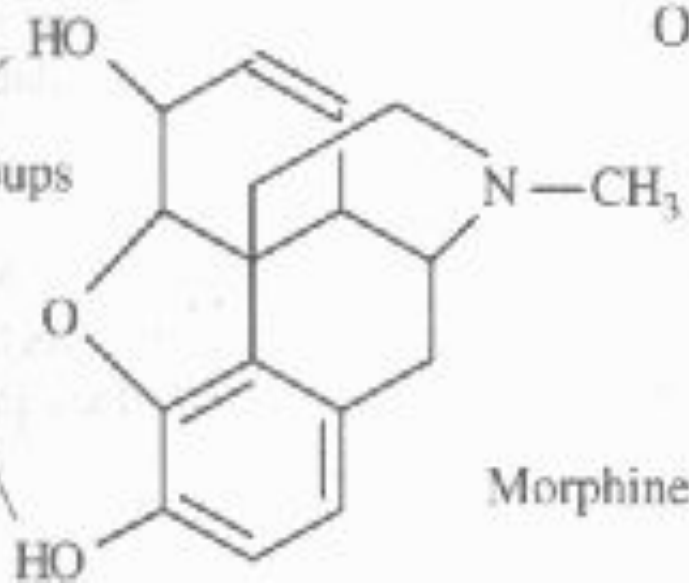
methyl group  
attached to  
oxygen



Acetylation



Two OH groups



Morphine

- **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 foggy, 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 cm<sup>3</sup> of blood
    - .08% is legal limit in US (.080 g per 100 cm<sup>3</sup> of blood)
  - Ethanol is easily absorbed from the stomach to the blood, where it is exhaled by the lungs (ethanol is fairly volatile)
 

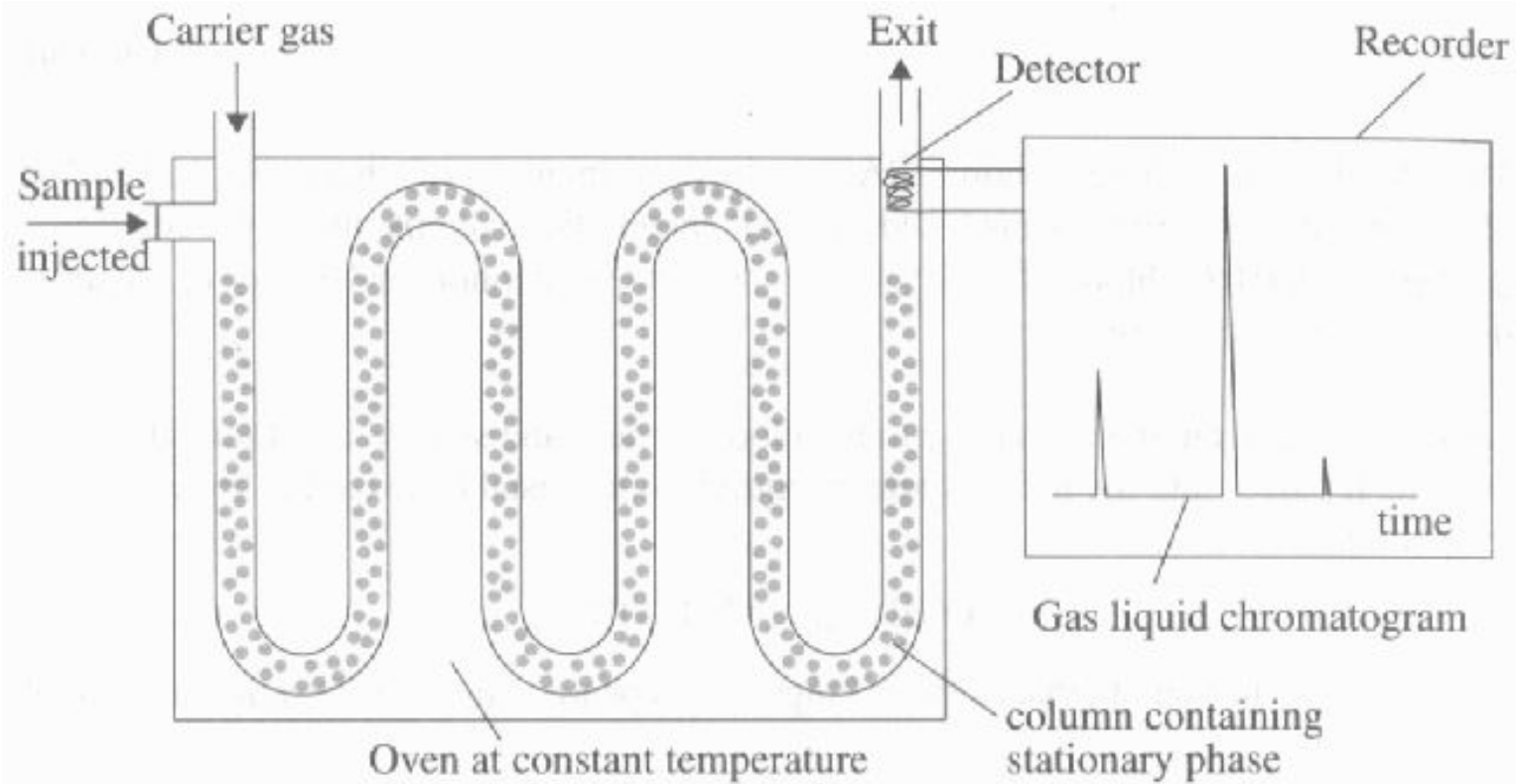
$$\text{C}_2\text{H}_5\text{OH}_{(l)} \rightleftharpoons \text{C}_2\text{H}_5\text{OH}_{(g)}$$

    - 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



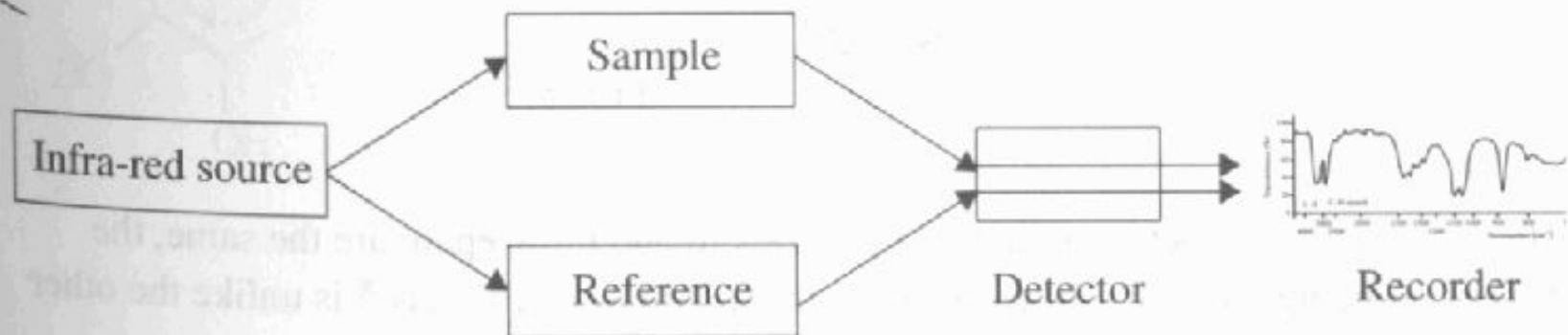
- Gas Liquid Chromatography
  - More precise than breathalyzer
  - Uses a stationary phase (non-volatile liquid or solid support) and a mobile phase (inert gas, like  $N_2$ )
  - Breath components ( $CO_2$ ,  $H_2O$ , and alcohol vapor) are injected into the machine and partitioned (divided) between 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 ( $1/\text{wavelength}$ )
- 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

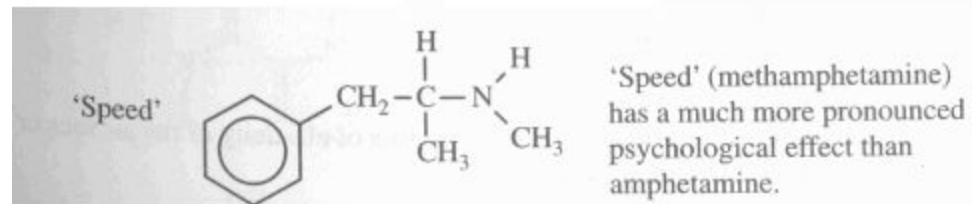
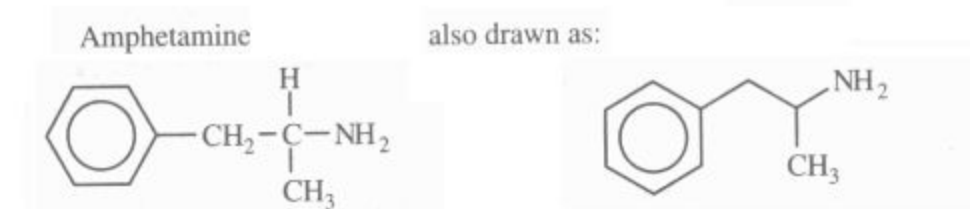
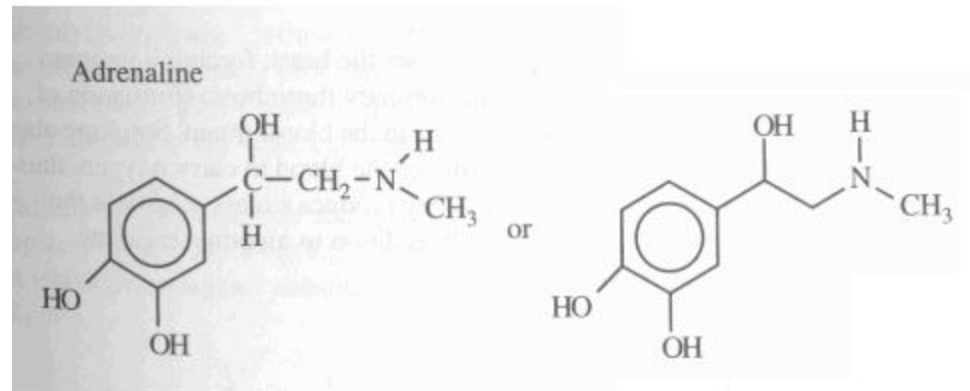
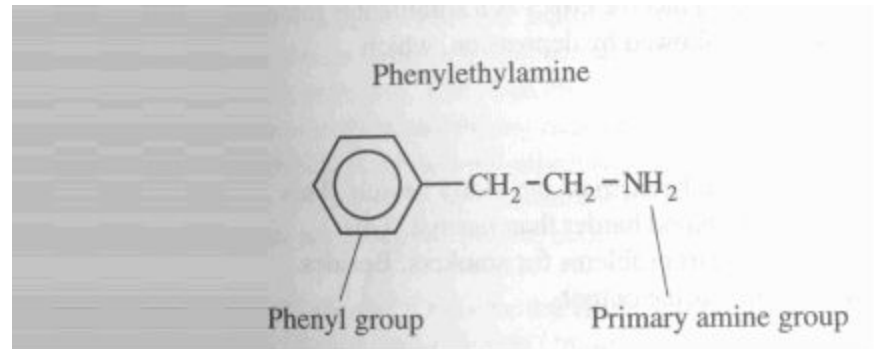
- Stimulate brain and central nervous system
  - Cause increased alertness and awareness
  - Include amphetamines, nicotine, and caffeine

- 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

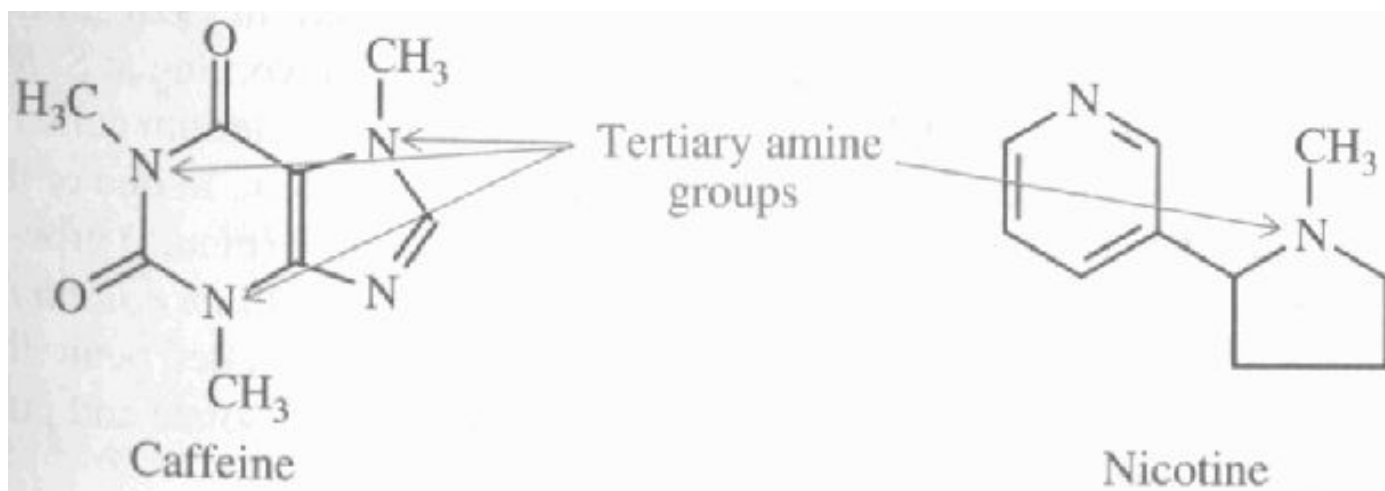


- Smoking can also lead to
  - Lung cancer
  - Cancer of the larynx and mouth
  - Heart and blood vessel disease
  - Emphysema
  - Chronic bronchitis
  - Air pollution
  - Fires!!
  - Stained fingers and teeth
  - Bad breath
- Very easy to develop dependence on nicotine compared to alcohol or barbiturates
  - 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):



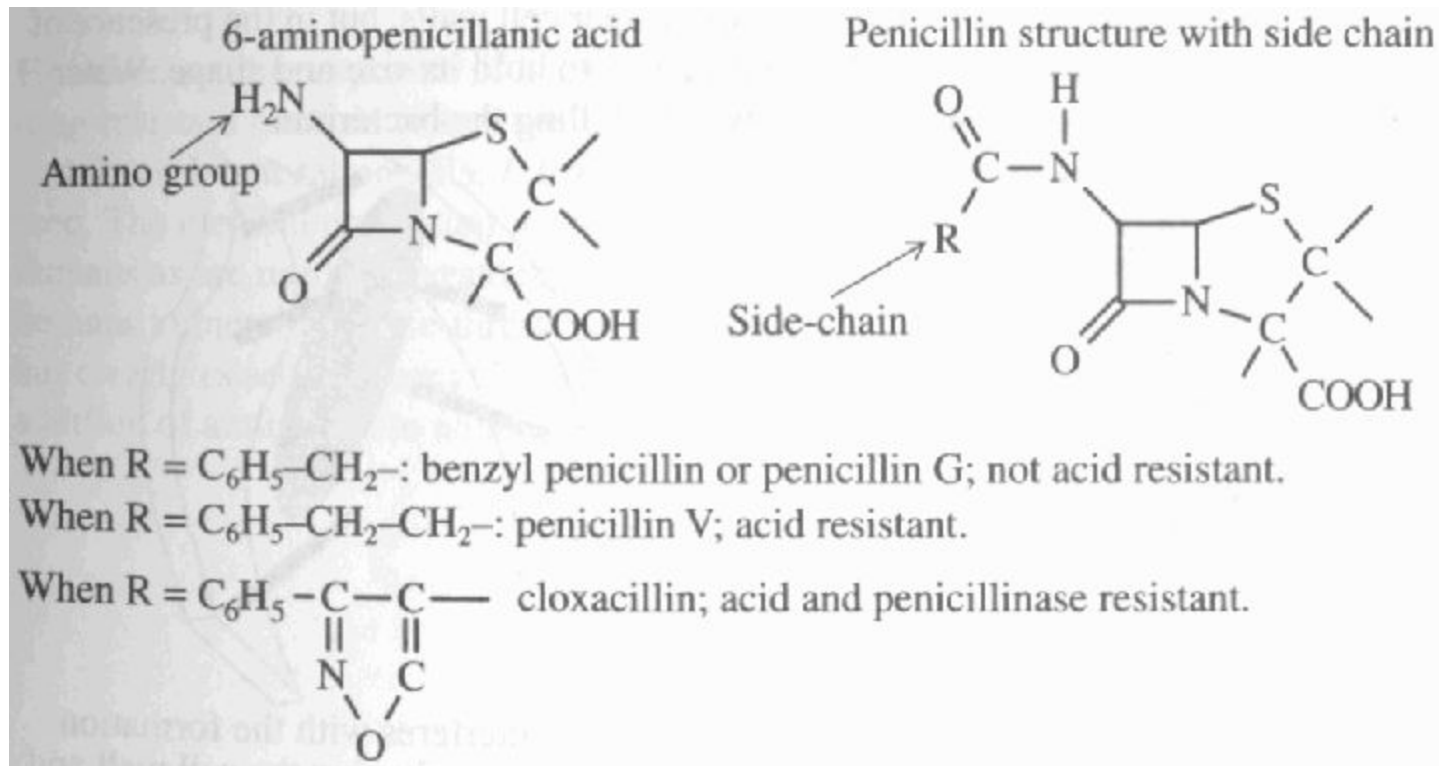
# Antibacterials

- 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

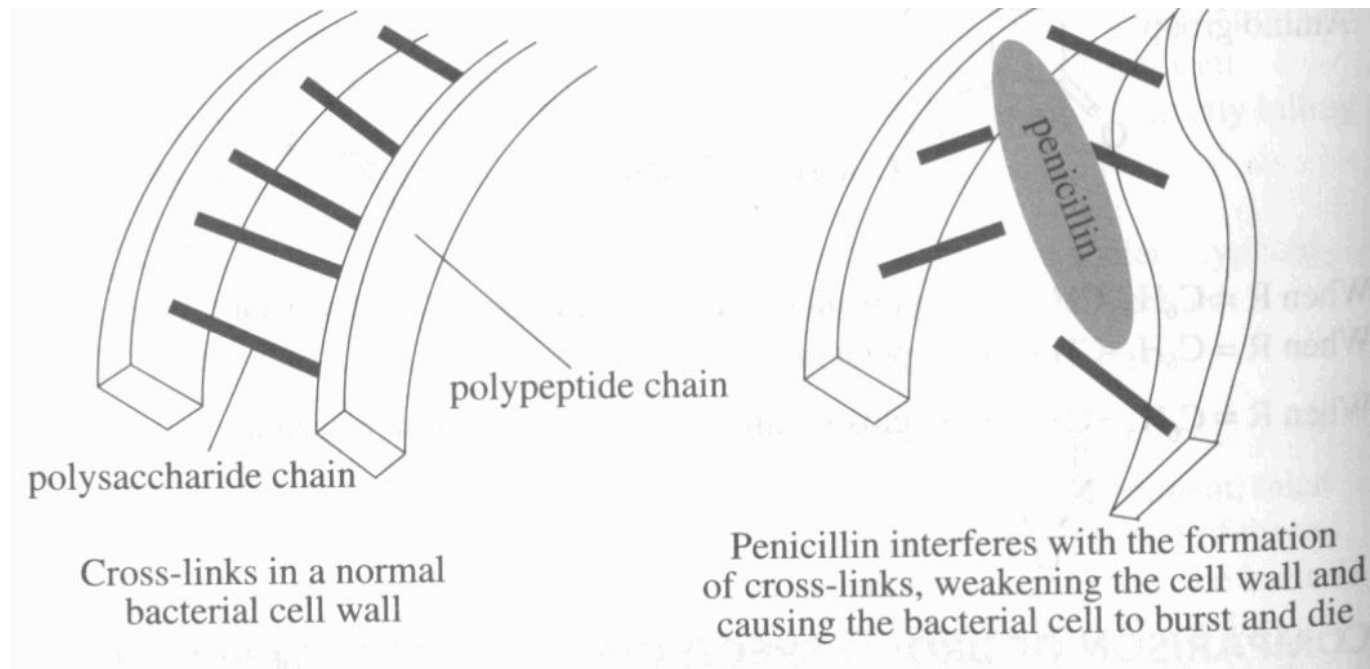
- Penicillins:
  - Produced from fungi (*penicillium* genus)
  - Accidentally discovered by Alexander Fleming, who noticed that bacteria did not grow around a spot of *penicillium notatum* mold on a culture plate
    - Fleming could not isolate the “penicillin,” and later gave up the research
    - Florey 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 ( $\text{NH}_2$ ) 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

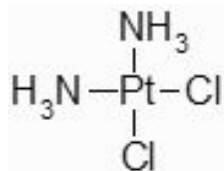
- Controlling viruses
  - Antibacterials may be effective if they block the transfer of genetic information, although few do
  - Vaccination is primary method of prevention
    - Patient is exposed to weakened or inert viral particles to stimulate immune system
      - Immune system produces antibodies, 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

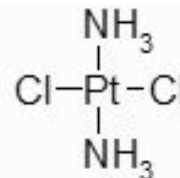
# Stereochemistry in Drug Action and Design (HL only)

- 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**

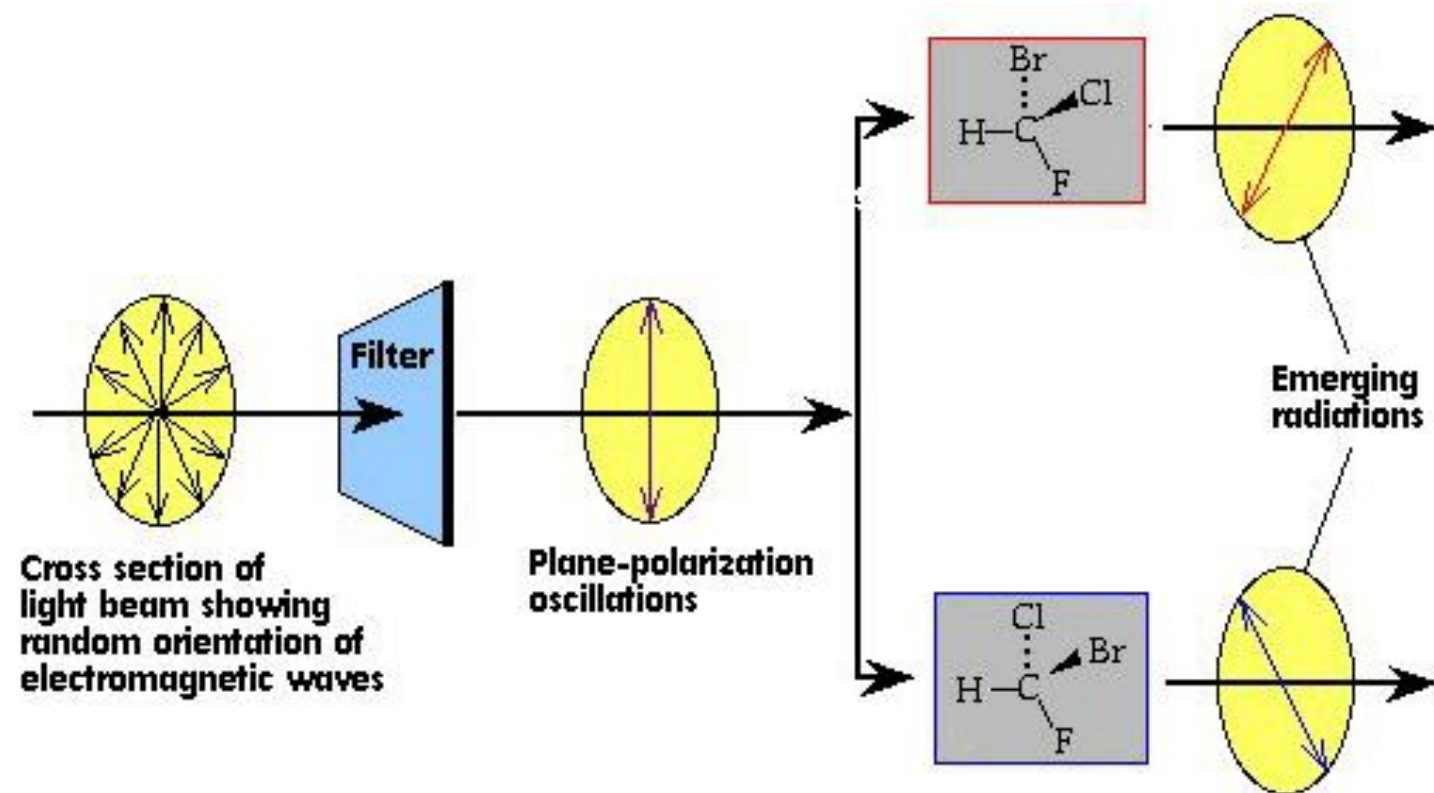


**trans - isomer**  
**chemotherapeutically inert**

- Square planar molecule, NH<sub>3</sub> 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

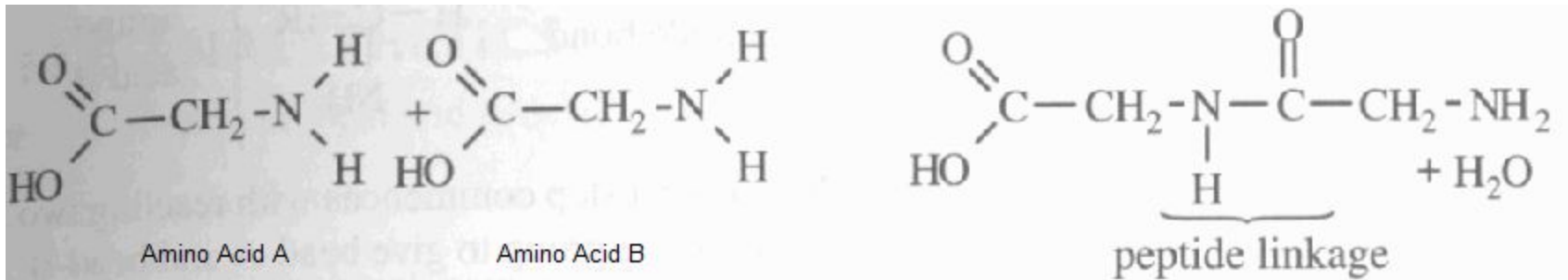
- Synthetic drugs, when chiral, are usually produced as racemic mixtures
  - Ex. : Ibuprofen
    - One enantiomer is pharmacologically inactive
    - Drug still produced as a racemic mixture to reduce costs
  - Thalidomide
    - One enantiomer alleviates morning sickness, the other can cause birth defects
    - 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 “leed) 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

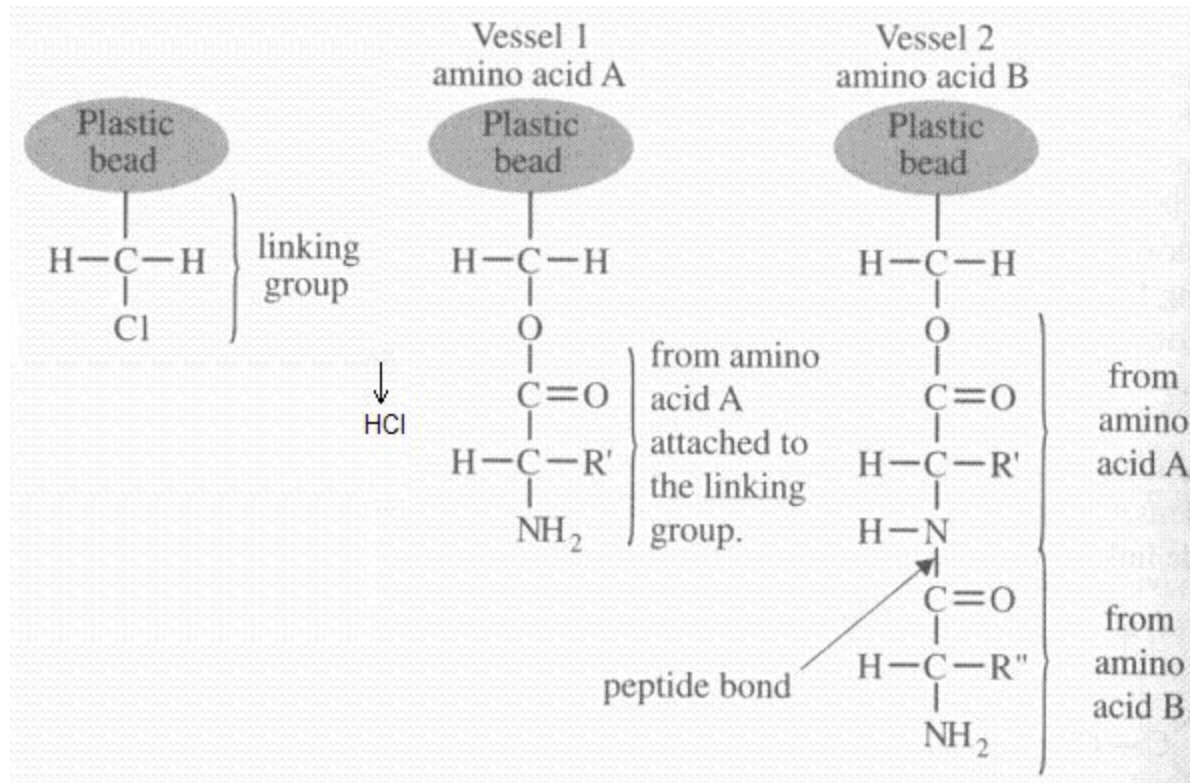
- Libraries of a vast amount of related compounds are produced using robotics to perform repetitive work (ex. adding a fixed volume of a substance to a collection of chemicals) (parallel synthesis)
  - Products of these reactions are then tested, without animals, by studying their effects on enzymes

- 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





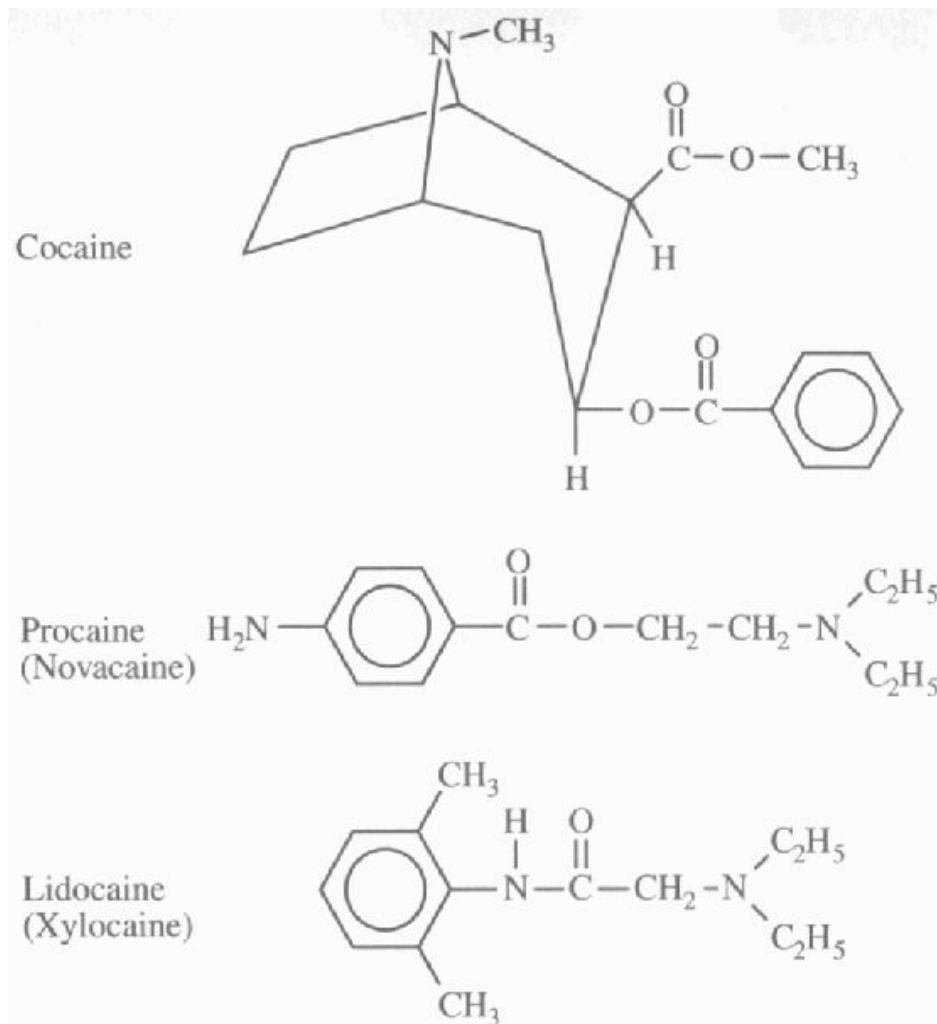
- “linking group” is attached to a plastic bead
- In vessel 1, amino acid A attaches to linking group, eliminating an HCl (Cl from linking group, H from OH group of acid portion of AA)
- Bead is placed in Vessel 2, where it attaches to amino acid B via a peptide linkage
- Process continues with any number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

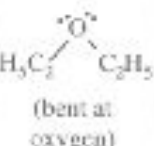
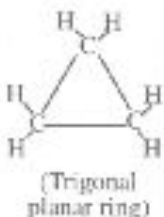
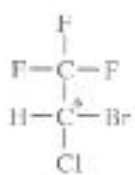
- Nitrous oxide ( $\text{N}_2\text{O}$ ), diethyl ether ( $\text{C}_2\text{H}_5\text{-O-C}_2\text{H}_5$ ), chloroform ( $\text{CHCl}_3$ ), cyclopropane ( $\text{C}_3\text{H}_6$ ), and halothane ( $\text{CHClBrCF}_3$ )

- 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)	$N_2O$	$\begin{array}{c} \ddot{N} = N = \ddot{O} \\ \text{(linear)} \end{array}$	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
Ethoxy-ethane (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)
Cyclo-propane	$\text{C}_3\text{H}_6$	 <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*)	$\text{CF}_3\text{CBrClH}$	 <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; $\text{O}_3 + \text{*Cl} \rightleftharpoons \text{ClO*} + \text{O}_2$ 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

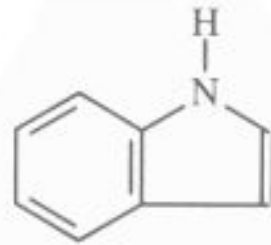
## – Psilocybin

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

## – THC (marijuana)

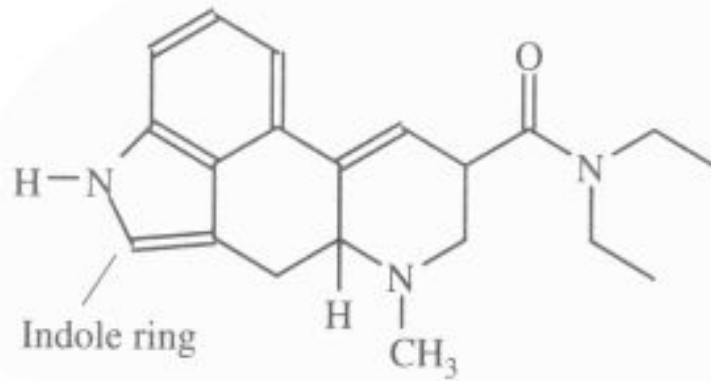
- Mild hallucinogen
- Causes silliness and excitement at low doses
- As dosage increases, perception changes and hallucinations result
- Can cause extreme anxiety, depression, uneasiness, panic attack and fearfulness in high doses
- Driving and other tasks requiring thinking are difficult
- Psychological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

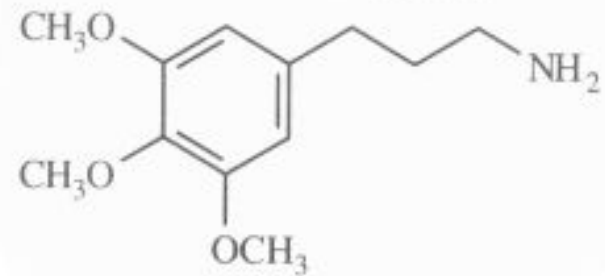


indole ring

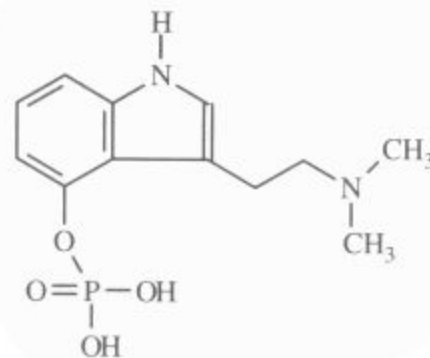
Structure of LSD



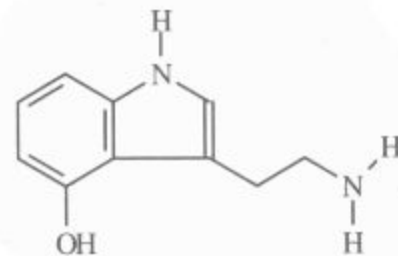
Structure of mescaline



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.)