Chapter 6
Amines and Amides

Chapter Objectives:

- Learn to recognize the amine and amide functional groups.
- Learn the IUPAC system for naming amines and amides.
- Learn the important physical properties of the amines and amides.
- Learn the major chemical reactions of amines and amides, and learn how to predict the products of amide synthesis and hydrolysis reactions.
- Learn some of the important properties of condensation polymers, especially the polyamides.

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CHEM 2353 Fundamentals of Organic Chemistry
Organic and Biochemistry for Today (Seager & Slabaugh)
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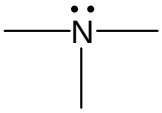
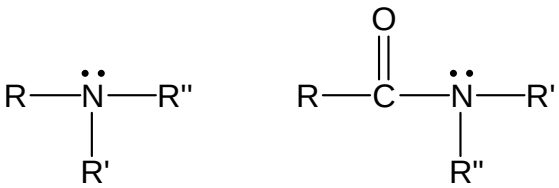
Nitrogen-Containing Functional Groups

- Nitrogen is in Group V of the periodic table, and in most of its compounds, it has three single bonds and one lone pair:



- In this chapter, we will take a look at two functional groups which contain nitrogen atoms connected to carbons: the **amines** and the **amides**.

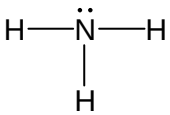


Amine **Amide**

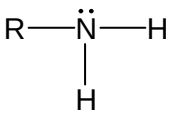
Classification and Nomenclature of Amines

Amines

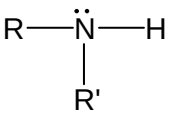
- Amines and amides are abundant in nature. They are a major component of proteins and enzymes, nucleic acids, alkaloid drugs, etc. (*Alkaloids* are N-containing, weakly basic organic compounds; thousands of these substances are known.)
- **Amines** are organic derivatives of ammonia, NH_3, in which one or more of the three H's is replaced by a carbon group.
- Amines are classified as **primary** (**1°**), **secondary** (**2°**), or **tertiary** (**3°**), depending on *how many carbon groups are connected to the nitrogen atom*.



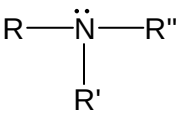
Ammonia



1° Amine



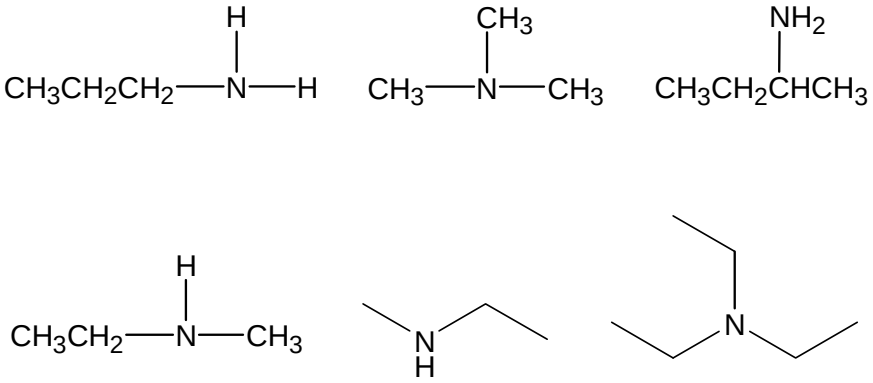
2° Amine



3° Amine

Examples: Classifying Amines

- Classify the following amines as primary (1°), secondary (2°), or tertiary (3°).



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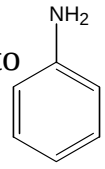
Nomenclature of Amines

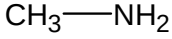
- **Simple 1°, 2°, and 3° amines:** common (trivial) names are obtained by alphabetically arranging the names of the alkyl substituents on the nitrogen and adding the suffix **-amine** (e.g., ethylmethylamine).
- **Amines in the IUPAC system:** the "e" ending of the alkane name for the longest chain is replaced with **–amine**. The amine group is located by the position number. Groups that are attached to the nitrogen atom are located using "N" as the position number. More complex primary amines are named with —NH_2 as the *amino* substituent.
- **Aromatic amines:** named as derivatives of the parent compound **aniline**. Substituents attached to the nitrogen are indicated by using "N-" as the location number.

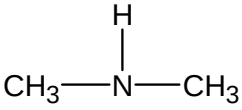


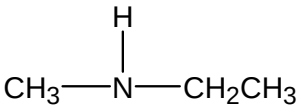
aniline 6

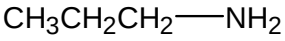
Examples: Nomenclature of Amines

- Provide common names for the following 2° and 3° amines; for 1° amines, provide common and/or IUPAC names where possible.









Examples: Nomenclature of Amines

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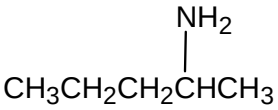

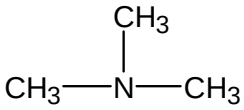

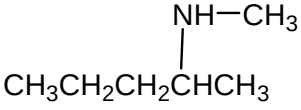

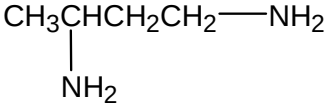

Examples: Nomenclature of Amines

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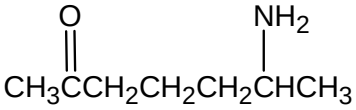

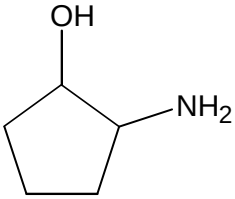

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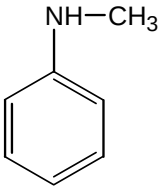
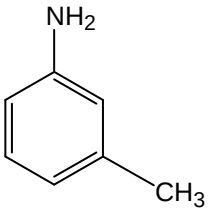
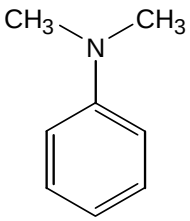
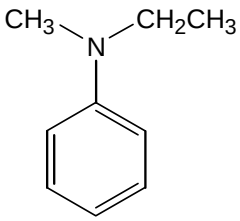
Examples: Nomenclature of Amines

- Provide names for the following aromatic amines.









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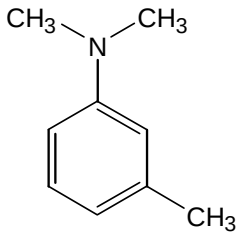
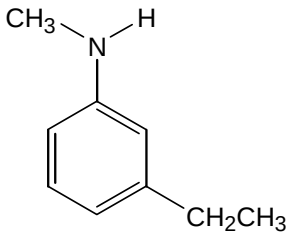
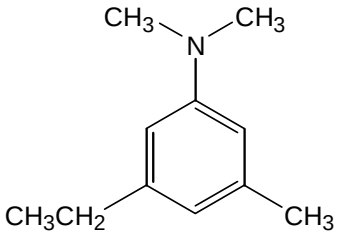
Examples: Nomenclature of Amines

- Provide names for the following aromatic amines.







Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - ethylisopropylamine

  - tert-butylamine

  - 2-pentanamine

Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - N-methyl-2-propanamine
  - 1,6-diaminohexane
  - 3-amino-1-propanol

Examples: Nomenclature of Amines

- Draw structural formulas for the following molecules:
  - N-methyl-2-chloroaniline
  - N,3-diethylaniline
  - N,N-dimethylaniline

Physical Properties of Amines

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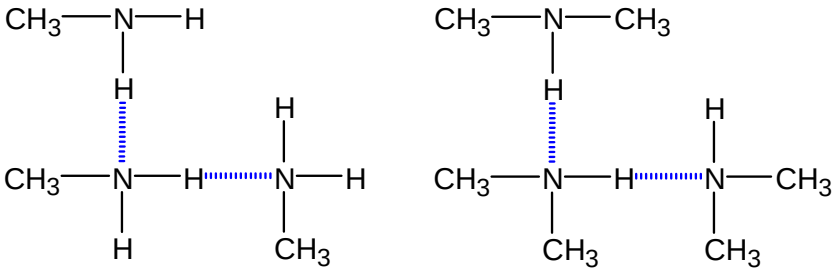
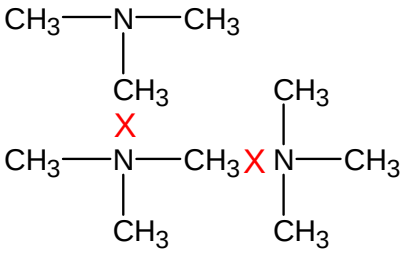
Physical Properties of Amines: H-Bonding

- 1° and 2° amines can hydrogen bond to each other:



- 3° amines cannot hydrogen bond to each other:



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Physical Properties of Amines: Boiling Points

- Nitrogen is less electronegative than oxygen, so the N—H bond is not quite as polar as the O—H bond.
  - Hydrogen bonds from N—H's are not as strong as those resulting from O—H's.
  - Hydrogen bonding between 1° and 2° amines is not as strong as those found in alcohols or carboxylic acids.
- 1° and 2° amines have lower boiling points than alcohols of similar molecular weight.
- 3° amines, since they do not hydrogen bond to each other, have boiling points similar to hydrocarbons of the same molecular weight.

Physical Properties of Amines: Boiling Points

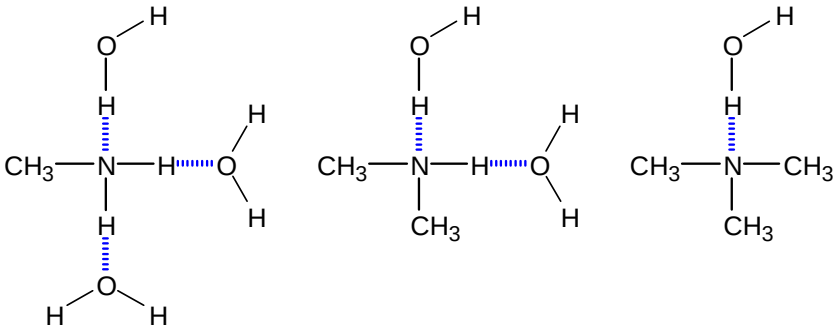
Boiling Point:

Carboxylic acid
Alcohols
1°/2° Amines
3° Amines/Alkanes

Name	Molecular weight	Boiling point
Acetic acid	60.0 g/mol	118°C
1-propanol	60.1 g/mol	97°C
propyl amine	59.1 g/mol	48°C
ethylmethylamine	59.1 g/mol	36°C
trimethylamine	59.1 g/mol	2.9°C
butane	58.1 g/mol	-0.5°C

Physical Properties of Amines: Water Solubility

- 1°, 2°, and 3° amines can all form hydrogen bonds with water.
- Low-molecular weight amines are generally water-soluble.



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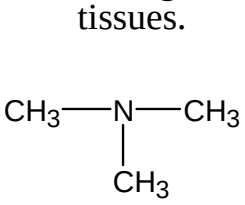
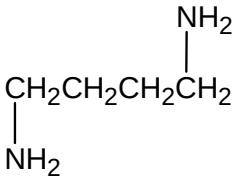
Physical Properties of Amines: Odor

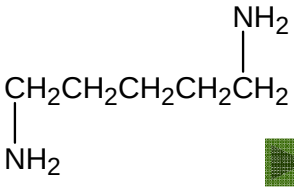
- Low molecular-weight amines tend to have sharp, penetrating odors similar to ammonia
- Higher molecular-weight amines often smell like rotting fish, and are often found in decaying animal tissues.



Trimethylamine
Responsible for the odor of rotting fish



1,4-Diaminobutane (Putrescine)
A poisonous oil present in rotting flesh; produced during the decomposition of the amino acid arginine; also partially responsible for the odor of urine and bad breath



1,5-Diaminopentane (Cadaverine)
A poisonous, viscous liquid present in rotting flesh; produced during the decomposition of the amino acid lysine; also partially responsible for the odor of urine and bad breath

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Examples: Predicting Physical Properties

- Arrange the following compounds in order of increasing boiling point. (All of the compounds have about the same molecular weight.)

propanoic acid, diethylamine, 1-butanol, ethyldimethylamine

Examples: Predicting Physical Properties

- Which member of each of the following pairs of compounds would you expect to have a higher boiling point?
  - 2-aminopropane *or* 2-aminohexane
  - triethylamine *or* 1-aminohexane
  - propanoic acid *or* diethylamine
  - 1-pentanol *or* 1-aminopentane

Some Important Alkaloids

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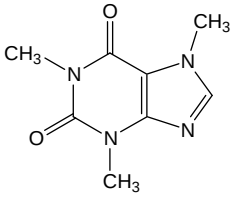
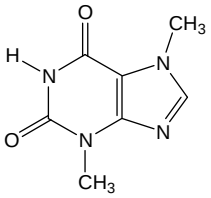
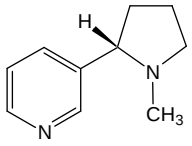
Important Alkaloids



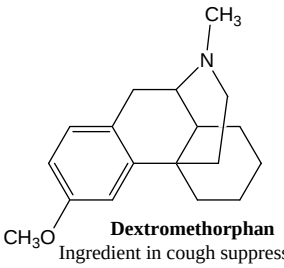
Caffeine
Found in the seeds of *Coffea arabica*, roasted coffee beans; inhibits the action of phosphodiesterase, an enzyme which inhibits cyclic adenosine monophosphate (AMP), which is responsible for forming glucose in the bloodstream



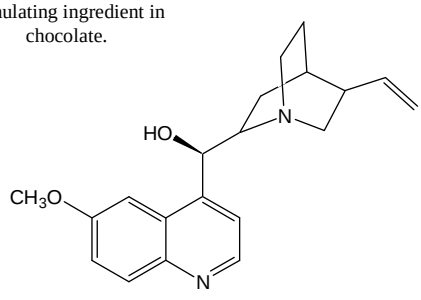
Theobromine
Found in the seeds of *Theobroma cacao*; the stimulating ingredient in chocolate.



Nicotene
Found in tobacco plants; mild stimulant in small doses; addictive, but not especially harmful itself



Dextromethorphan
Ingredient in cough suppressants.



Quinine
Antimalarial drug from *cinchona* tree

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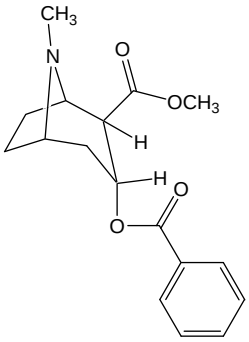
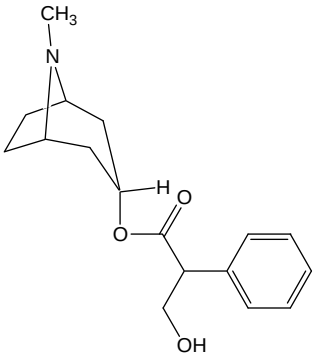
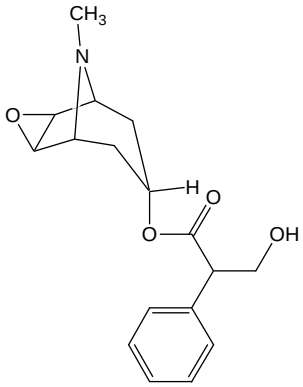


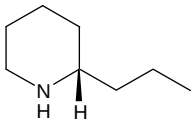
Cocaine
The form which is "snorted" is the hydrochloride salt; the free-base "crack" form is burned and inhaled, and reaches the brain in 15 seconds.



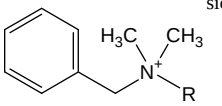
Atropine
relaxes muscles and reduces secretion of saliva during surgery; used to dilate pupils for eye examinations.



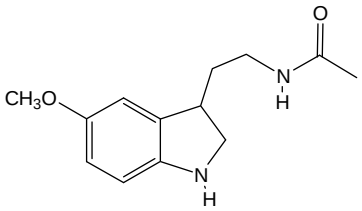
Scopolamine
used in treatment of motion sickness



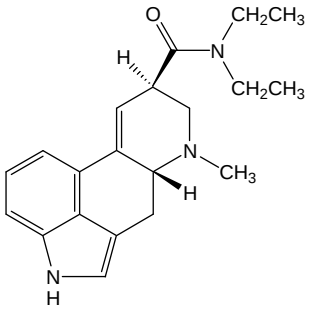
Coniine
Poison from hemlock



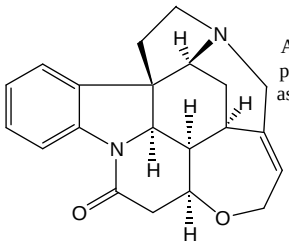
Zephiran chloride
(benzalkonium chloride)
Antiseptic compound that kills bacteria and fungi on contact



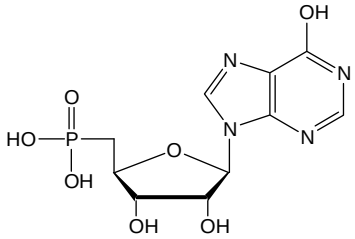
Melatonin
A naturally occuring hormone produced in the pineal gland; its production is triggered by the absence of light; causes drowsiness in humans at night, triggers birds to migrate, and signals dogs to shed their winter coats; sold as a treatment for jet lag.



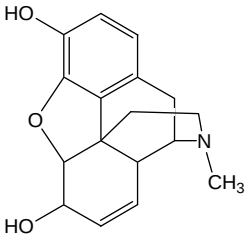
Lysergic acid diethylamide (LSD)
A synthetic hallucinogen from alkaloids obtained from ergot, a fungus which grows on rye



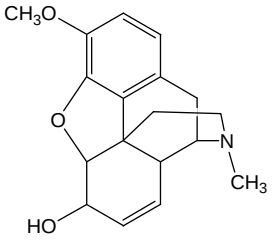
Strychnine
A poison from strychnos plant (*Nux vomica*); used as a rat and mouse poison



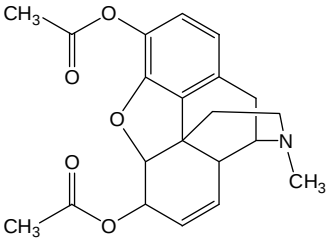
Inosine Monophosphate (IMP)
With monosodium glutamate (MSG), one of the major substances responsible for the flavor of meat



Morphine
Found in the opium poppy; a CNS depressant; very effective painkiller



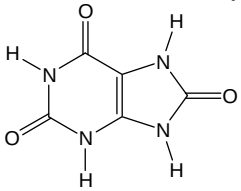
Codeine
Used in some cough syrups to depress the action of the cough center of the brain



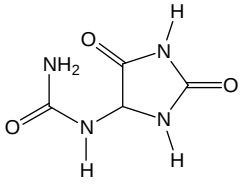
Heroin
More fat-soluble than morphine, and must be injected directly into the bloodstream, but crosses the blood-brain barrier more readily, causing it to be more potent than morphine

Nitrogen Wastes

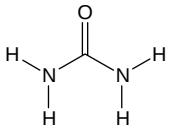
The disposal of waste nitrogen from the body is a problem which different species of animals have solved in different ways:



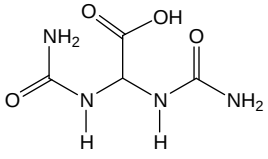
Uric acid
Birds, reptiles and insects excrete nigrogen wastes in the form of uric acid. Uric acid can be eliminated directly in the solid form, without being dissolved in water. It is produced in the body from foods and beverages rich in purines, such as claret and port. Lactic acid inhibits the removal of salts of uric acid in the urine; these salts instead deposit in the joints, causing gout. Dalmations have been bred to have black spots with no white hairs in them on their coats; however, the gene which determines the presence of white hairs is linked to the gene which codes the enzyme which breaks down uric acid into allantoin. Dalmations thus excrete uric acid instead of allantoin, and are very susceptible to gout.



Allantoin
Most mammals contain enzymes which metabolyze uric acid into allantoin.



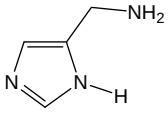
Urea
Urea is the major organic component of urine; about 25 g are excreted every day by humans. Cartilaginous fish and amphibians also excrete urea.



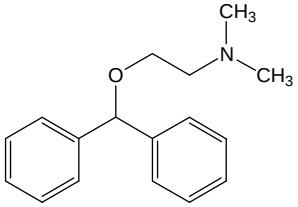
Allantoic acid
Marine vertebrates further metabolyze allantoin into allantoic acid.

$NH_4^+ X^-$
Marine invertebrates excrete ammonium salts.

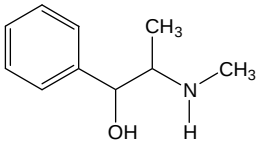
Antihistamines



Histamine
People who are allergic to pollen produce histamine, which causes blood vessels to dilate and leak, releasing fluid into surrounding tissues, causing watery eyes, sniffles, congestion, and other symptoms of hay fever (*allergic rhinitis*); also causes the symptoms of the common cold and swelling after insect bites.



Diphenylhydramine
an *antihistamine*; active ingredient in Benadryl; sometimes used in sleeping pills



Ephedrine / Pseudoephedrine
found in the Chinese ma-huang plant; a decongestant used in many cold remedies

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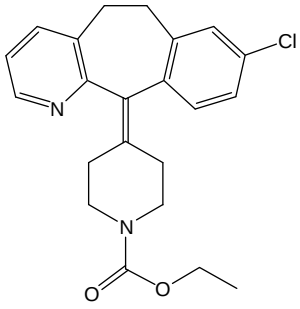
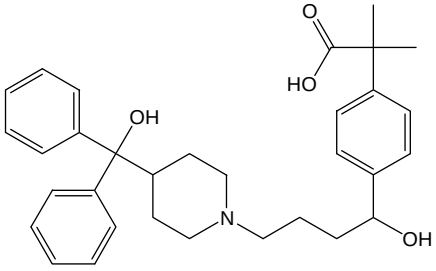
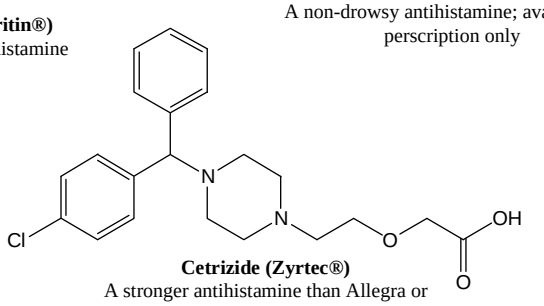
Antihistamines



Loratadine (Claritin®)
A non-drowsy antihistamine



Fexofenadine (Allegra®)
A non-drowsy antihistamine; available by perscription only



Cetrizide (Zyrtec®)
A stronger antihistamine than Allegra or Claritin, but causes drowsiness in some people

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Reactions of Amines

Bases

- A **base** takes a **proton (H^+)** from another species. A base produces **hydroxide ions**, **OH^-**, when dissolved in water:

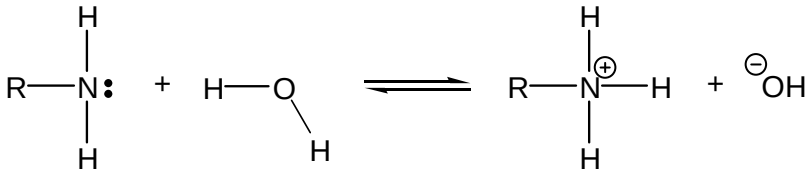
$$B + H_2O \rightarrow BH^+ + OH^-$$

- A **strong base** is one that *completely dissociates* in water (i.e., every molecule of the acid splits apart).
- A **weak base** is one in which only a small percentage of the molecules are dissociated at any one time.

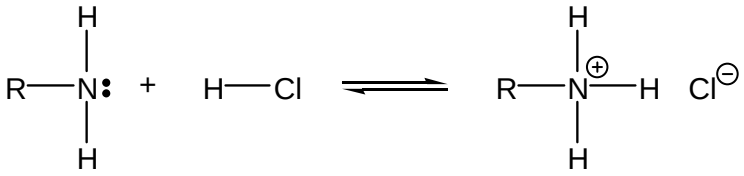
- **Acidic** solution: **pH < 7.00** ($[H_3O^+] > [OH^-]$)
- **Basic** solution: **pH > 7.00** ($[H_3O^+] < [OH^-]$)
- **Neutral** solution: **pH = 7.00** ($[H_3O^+] = [OH^-]$)

Chemical Properties of Amines: Basicity

- Amines are weak organic **bases**. They react with water to produce *alkylammonium ions* and hydroxide anions:



- and with acids to produce *alkylammonium salts*:



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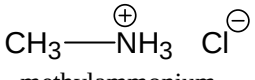
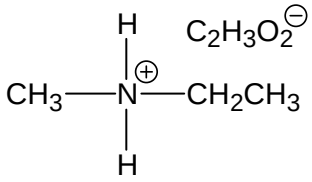
Alkylammonium Salts

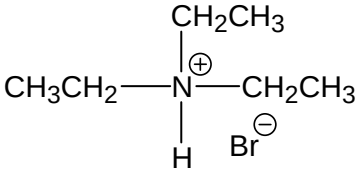
- Salts of amines are named by changing "amine" to "ammonium" and adding the name of the negative ion to the end of the word:



methylammonium chloride



ethylmethylammonium acetate



triethylammonium bromide

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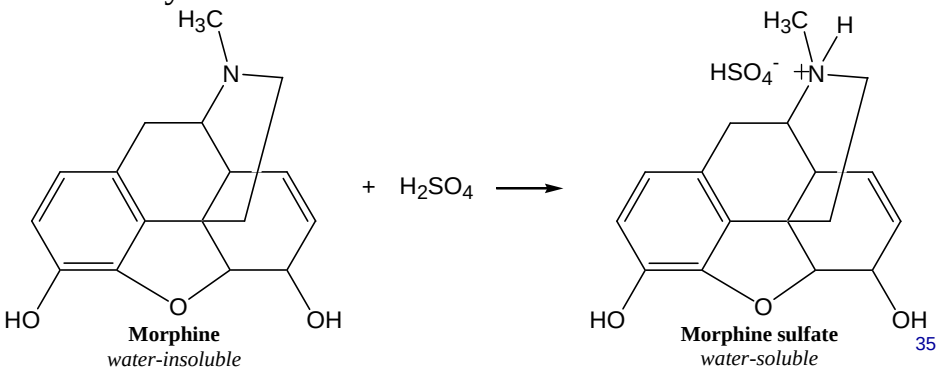
Alkylammonium Salts

- Salts of amines are generally white crystalline solids with high melting points.
- The ionic charges makes these salts more soluble in water than the neutral amines. Many amine-containing drugs are administered in the form of alkylammonium salts to increase their solubility in bodily fluids.



Morphine
water-insoluble

Morphine sulfate
water-soluble

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Chemical Properties of Amines: Basicity

- Ammonium salts may be converted back into neutral amines by a strong base:

$$R{-}NH_3^+\ Cl^- + NaOH \longrightarrow R{-}NH_2 + H_2O + NaCl$$

- Thus, by adjusting the pH of the solution, it is possible to influence whether an amine is present in the neutral form or as its ammonium cation form:

$$\underset{\text{amine}}{R{-}NH_2} + H_2O \underset{\text{base (high pH)}}{\overset{\text{acid (low pH)}}{\rightleftharpoons}} \underset{\text{alkylammonium ion}}{R{-}NH_3^+} + {}^-OH$$

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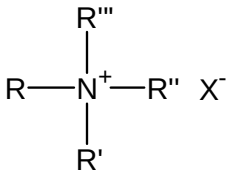
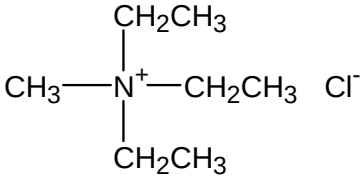
Quaternary Ammonium Salts

- In addition to salts of 1°, 2°, and 3° amines, it is possible to have amine cations which contain four alkyl groups attached to a nitrogen atom, which will *always* carry a positive charge, regardless of the pH of the surrounding solution. These are known as **quaternary ammonium salts**.



quaternary ammonium salt

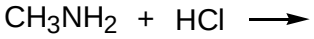


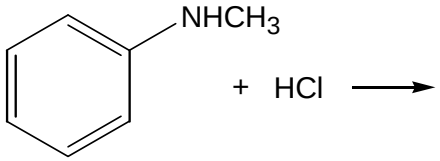
triethylmethylammonium chloride

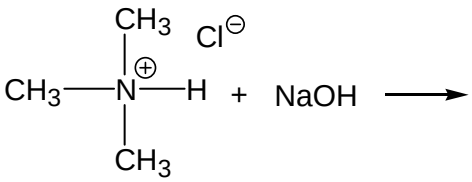
- These salts are present in many antiseptics and antibacterial agents.

Examples: Basicity of Amines

- Complete the following reactions:



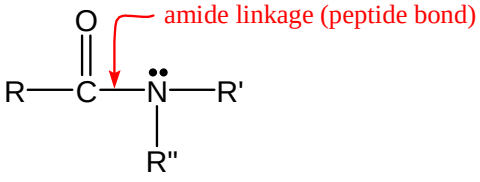




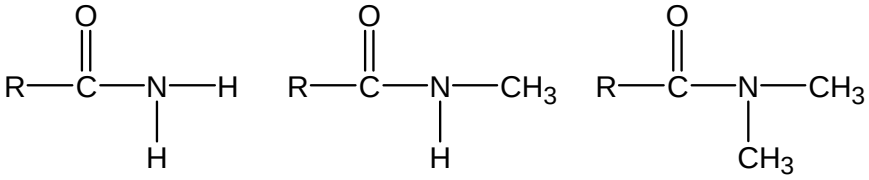
Amides

Amides

- **Amides** contain a nitrogen which is directly attached to a carbon in a carbonyl group:



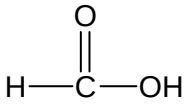
Amide



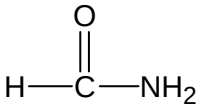
N,N-unsubstituted amide N-substituted amide N,N-disubstituted amide

Nomenclature of Amides

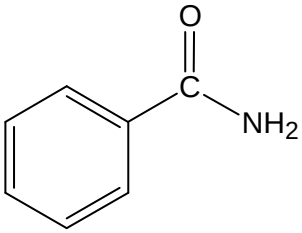
- Amides are named by changing the *-oic acid* ending of the corresponding carboxylic acid to **-amide**. If alkyl groups are attached to the nitrogen, they are named as N-alkyl substituents.



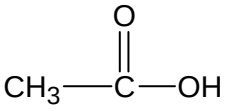
methanoic acid
(formic acid)



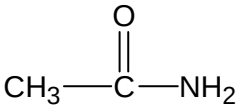
methanamide
(formamide)



benzamide



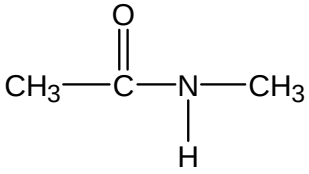
ethanoic acid
(acetic acid)

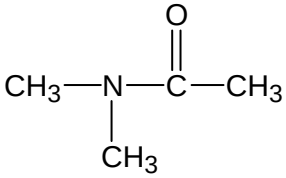


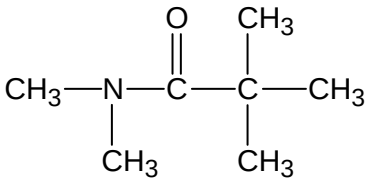
ethanamide
(acetamide)

Examples: Nomenclature of Amides

- Name the following compounds:

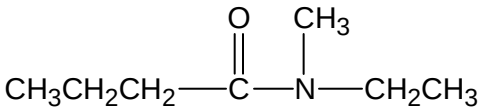


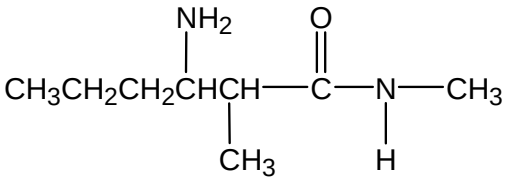




Examples: Nomenclature of Amides

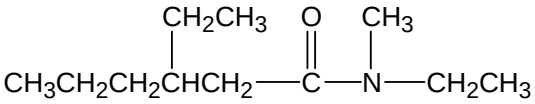
- Name the following compounds:

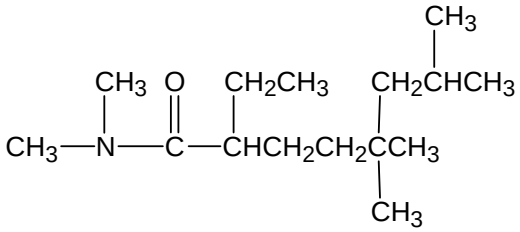




Examples: Nomenclature of Amides

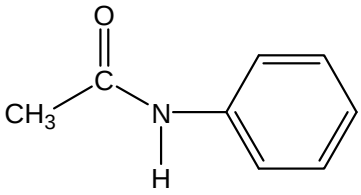
- Name the following compounds:

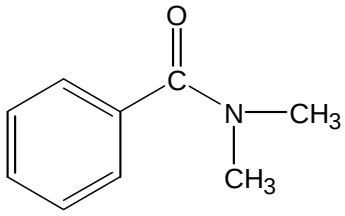




Examples: Nomenclature of Amides

- Name the following compounds:





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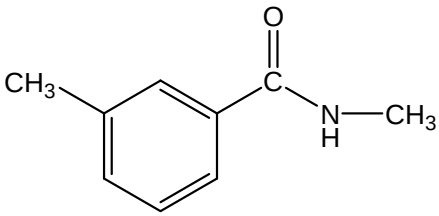
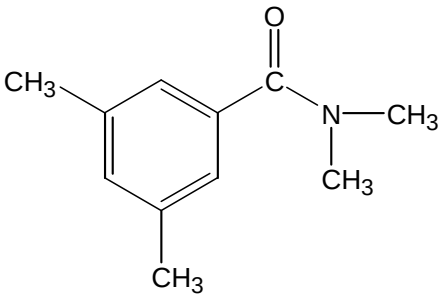
Examples: Nomenclature of Amides

- Name the following compounds:





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Examples: Nomenclature of Amides

- Draw structural formulas for the following molecules:
  - 2-methylpropanamide

  - N,2,4-trimethylpentanamide

  - N-ethyl-N-methylacetamide

Examples: Nomenclature of Amides

- Draw structural formulas for the following molecules:
  - N,2-diethylbenzamide

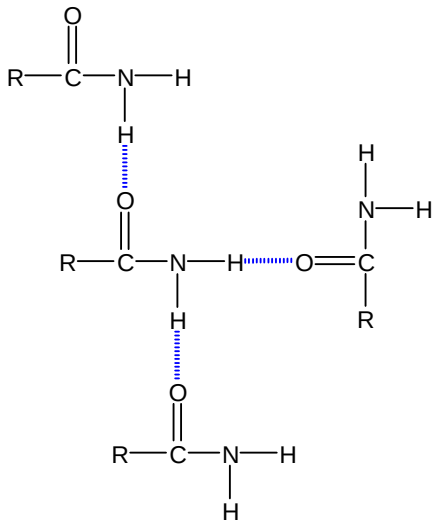
  - N,N,2,3,4-pentamethylbenzamide

  - N,N,4,4-tetramethylbutanamide (what's wrong with this name?)

Physical Properties of Amides

Physical Properties of Amides

- N,N-unsubstituted amides can form a complex network of hydrogen bonds. They tend to have high melting points and also high boiling points.



Physical Properties of Amides

- N-substituted amides often have lower melting points and boiling points than N,N-unsubstituted amides because fewer hydrogen bonds can form.
- N,N-disubstituted amides cannot form hydrogen bonds, and have even lower melting points and boiling points.
- All amides can hydrogen bond with water, so low-molecular weight amides are water-soluble.

Boiling Point:

N,N-unsubstituted amides

N-substituted amides

N,N-disubstituted amides

Examples: Predicting Physical Properties

- Arrange the following compounds in order of increasing boiling point. (All of the compounds have about the same molecular weight.)

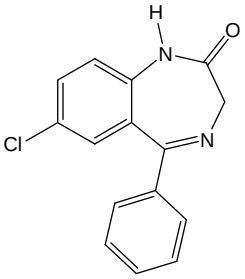
N-ethylethanamide

butanamide

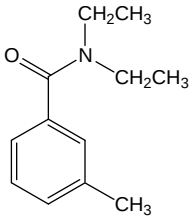
N,N-dimethylethanamide

Important Amides

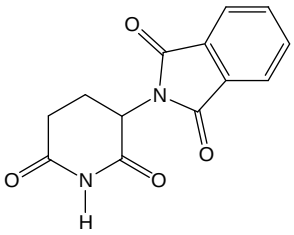
Important Amides



Diazepam (Valium)
A benzodiazepene tranquilizer; acts by enhancing the inhibitory neurotransmitter GABA; since it binds to the same protein as ethanol, combinations of valium and ethanol can be deadly

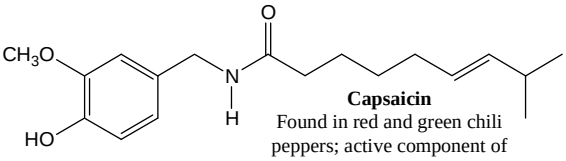


***N*,*N*-Diethyl-*m*-toluamide**
Active ingredient in OFF

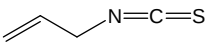


Thalidomide
Until 1956, a very popular, safe sedative; the largest market was for pregnant women who were experiencing morning sickness. However, it caused massive birth defects in women who used it in the early states of pregnancy, and was banned in Europe; it was never authorized for sale in the U.S.

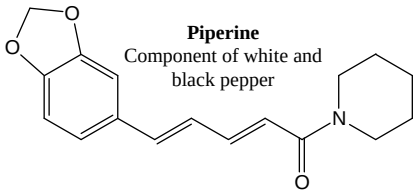
Hot Stuff



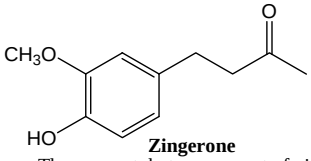
Capsaicin
Found in red and green chili peppers; active component of paprika



Allyl isocyanate
Used in horseradish flavor, mustard oil, pickles, salad dressings and sauces; mustard plasters, medications and fumigants

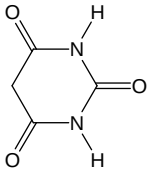


Piperine
Component of white and black pepper

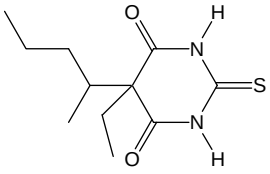


Zingerone
The pungent, hot component of ginger

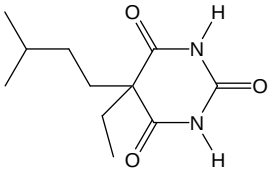
Barbiturates



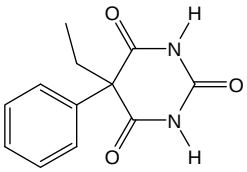
Barbituric acid
First synthesized by Adolf von Baeyer in 1864; barbiturates are soporifics, and are used as tranquilizers and anesthetics; many are also addictive, and overdoses can be fatal. (Other barbiturates include Seconal, Veronal, Phenobarbitol, Thiopental, Amobarbitol, etc.)



Thiopental (Pentothal)
An intravenous anesthetic

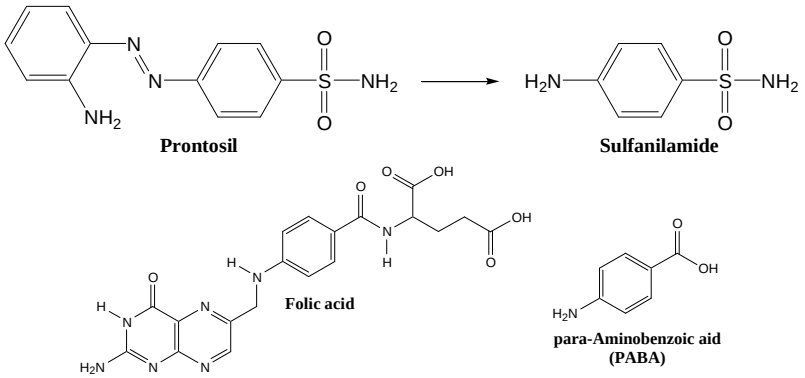


Amobarbital (Amytal)
Used in the treatment of insomnia



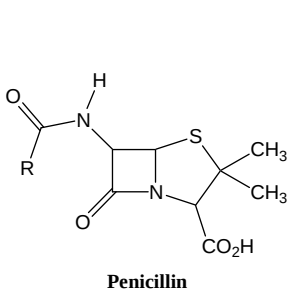
Phenobarbitol
Anti-seizure medication, sedative

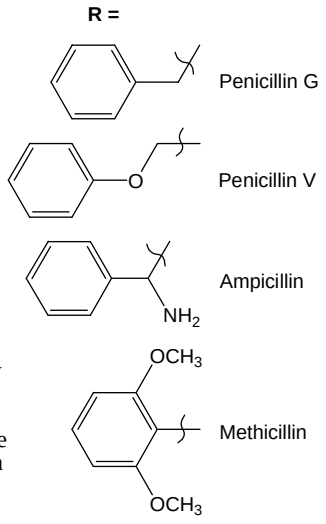
Sulfa Drugs



Sulfanilamide, the first **antibiotic**, was discovered by Gerhard Damagk (Nobel Prize, 1939), who observed the antibacterial action of the red dye Protonsil; further researched showed that it was the metabolic byproduct, sulfanilamide, which was the active form. It prevents bacteria from synthesizing folic acid, which they need in order to grow. Bacterial enzymes synthesize folic acid using *para*-aminobenzoic acid (PABA); sulfanilamide fits into the enzyme more tightly, blocking it from taking up PABA, and thus blocking folic acid synthesis. The bacterium cannot grow, and eventually dies. Humans obtain folic acid from their diet (an **essential vitamin**), so sulfa drugs do not harm people in this way (although they can cause allergic reactions).

Penicillin

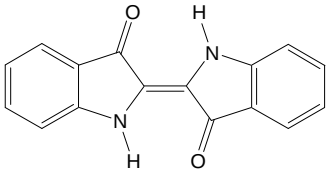




Penicillin is an antibiotic compound produced by the molds *Penicillium notatum* and *Penicillium chrysogenum*; it was discovered by Alexander Fleming in 1928 in a culture of bread mold. There are several varieties: Penicillin G and Methicillin are administered by injection; Penicillin V is an oral form which is not broken down in the stomach; Ampicillin is a broad spectrum penicillin which can be administered by injection or orally

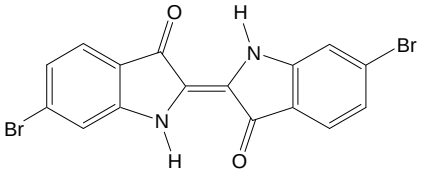
Molecules To Dye For

- **Dyes** are compounds that can be used to color other materials, such as clothing, paper, hair, etc.
- Many organic dyes contain a long series of double bonds that are close together. If the chain of double bonds is long enough, these molecules can absorb low-energy light in the visible region of the electromagnetic spectrum, resulting in colors that are visible to the human eye.



Indigo

A naturally occurring blue dye which has been used for thousands of years. It is obtained from an Indian plant (*Indigofera tinctoria*) and the European woad (*Isatis tinctoria*). Today, indigo can be made synthetically, and is used in dyeing denim to make blue jeans.

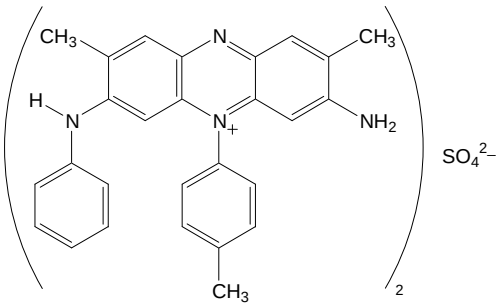


Tyrian purple

6,6'-dibromoindigo

Tyrian purple, or "royal purple," is a purple dye originally obtained from a species of mollusk (*Murex*) found near the cities of Tyre and Sidon in ancient Phoenicia. It took about 9,000 mollusk shells to obtain one gram of the dye, making it very expensive. This dye was used by royalty (hence the name "royal purple") and the Roman aristocracy.

Molecules To Dye For

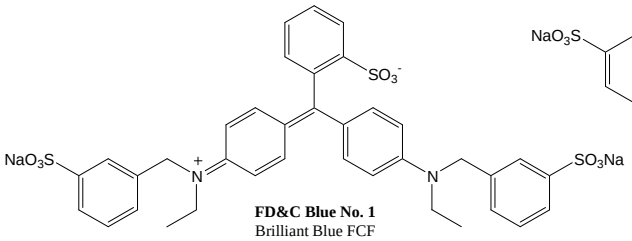


Mauve

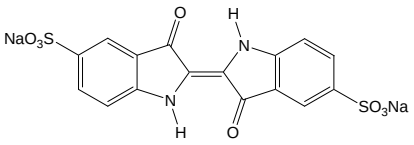
This is the first of the synthetic dyes. It was discovered by the 18-year-old English chemist William Henry Perkin in his home laboratory, while attempting to synthesize quinine (the only known treatment for malaria at that time). While cleaning up the sludge from one of his failed attempts, he noticed that the sludge was turning the water in his sink violet, and that cloth would pick up this purple color. Perkin patented his serendipitous discovery, and went into business making dyes, becoming so successful that he was able to retire at the age of 36 to focus his attention on chemical research.

FD&C Dyes

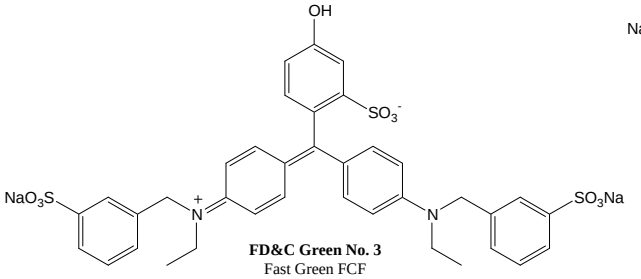
These color additives are approved by the Food and Drug Administration (FDA) under the Federal Food, Drug, and Cosmetic Act (FD&C, 1938, amended 1997) for use in foods.



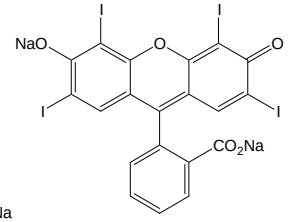
FD&C Blue No. 1
Brilliant Blue FCF



FD&C Blue No. 2
Indigo Carmine, Indigotine

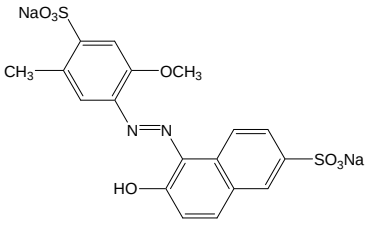


FD&C Green No. 3
Fast Green FCF

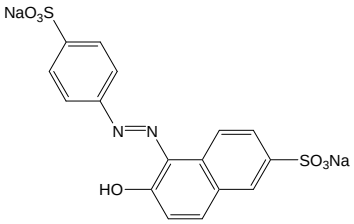


FD&C Red No. 3
Erythrosine

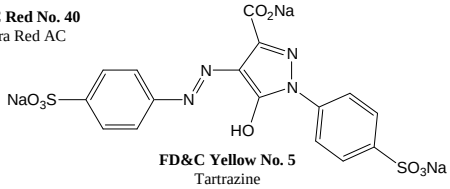
FD&C Dyes



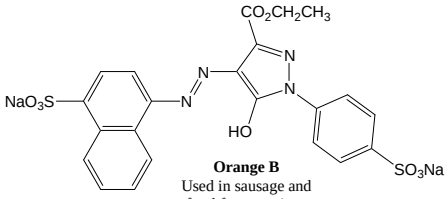
FD&C Red No. 40
Allura Red AC



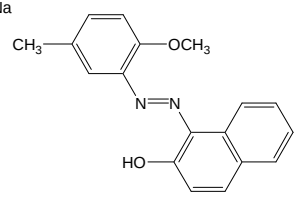
FD&C Yellow No. 6
Sunset Yellow FCF



FD&C Yellow No. 5
Tartrazine

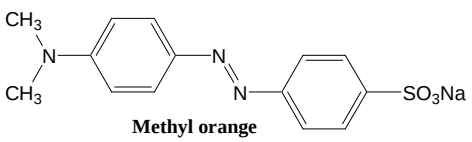


Orange B
Used in sausage and frankfurter casings

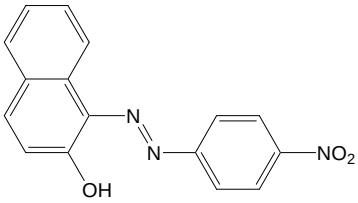


Citrus Red No. 2
Used to color orange skins

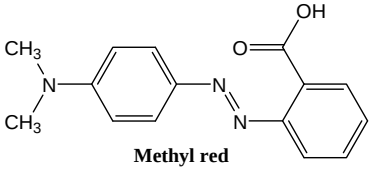
Molecules To Dye For



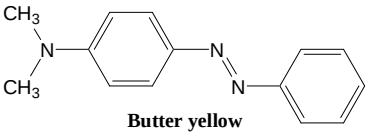
Methyl orange



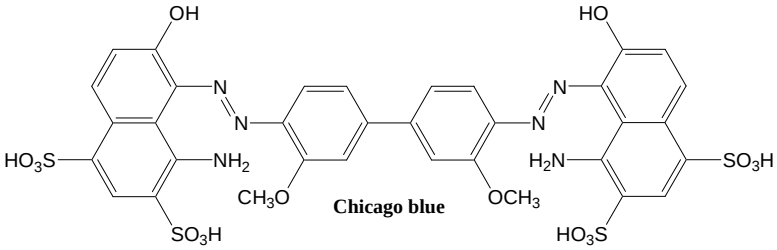
Para red



Methyl red



Butter yellow



Chicago blue

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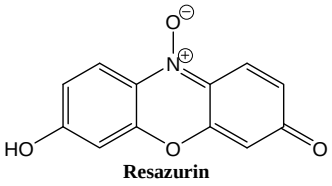
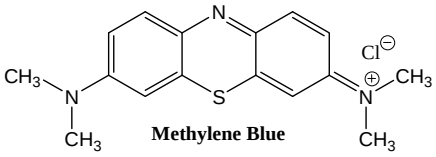
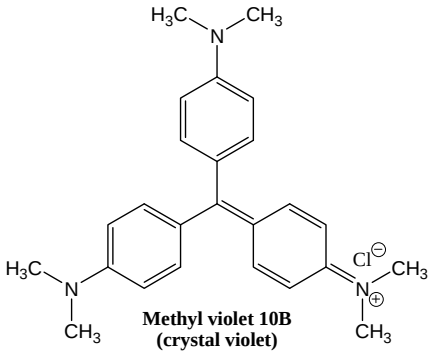
Molecules To Dye For



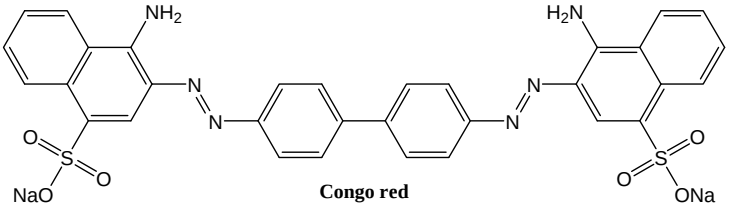
Resazurin



Methylene Blue



Methyl violet 10B (crystal violet)



Congo red

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Reactions of Amides

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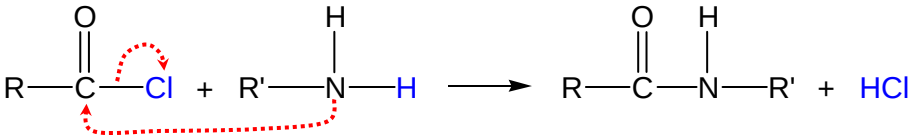
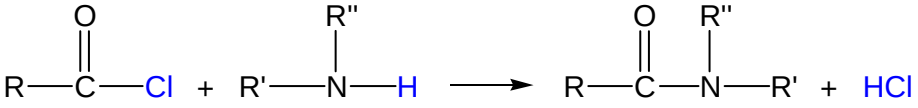
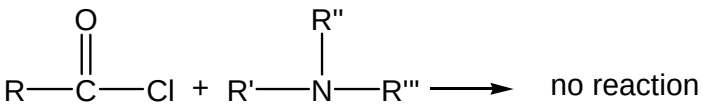
Amide Formation

- Amides are formed when acid chlorides react with 1° or 2° amines; 3° amines cannot form amides:







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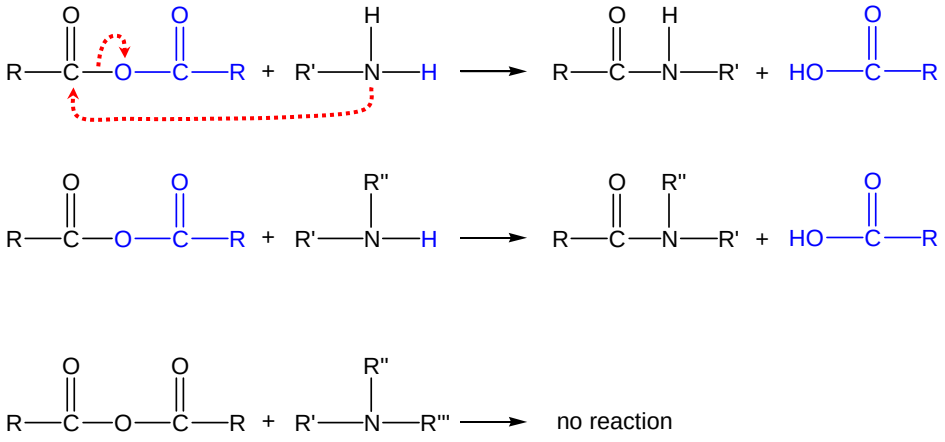
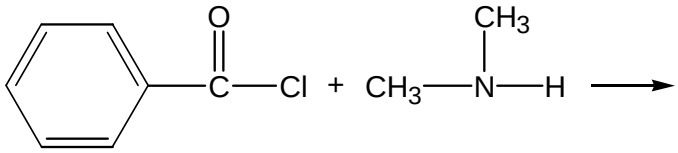
Amide Formation

- Amides are also formed when acid anhydrides react with 1° or 2° amines.



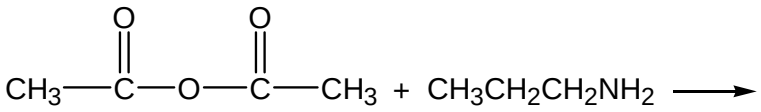
Examples: Formation of Amides

- Complete the following reactions:



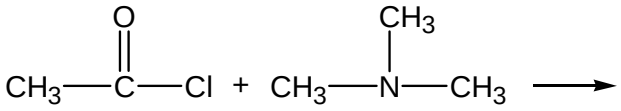
Examples: Formation of Amides

- Complete the following reactions:



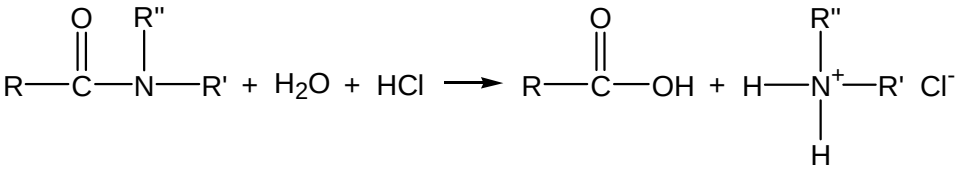
Examples: Formation of Amides

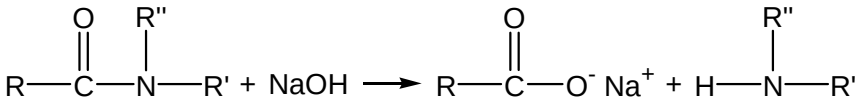
- Complete the following reactions:



Chemical Properties of Amides

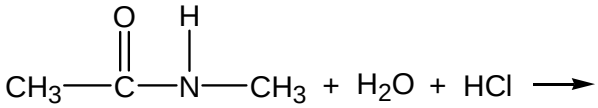
- Unlike amines, amides are not basic.
- Amide hydrolysis can take place under acidic or basic conditions:

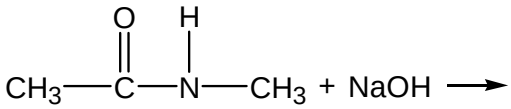




Examples: Reactions of Amines and Amides

- Complete the following reactions:





Condensation Polymers: Polyamides

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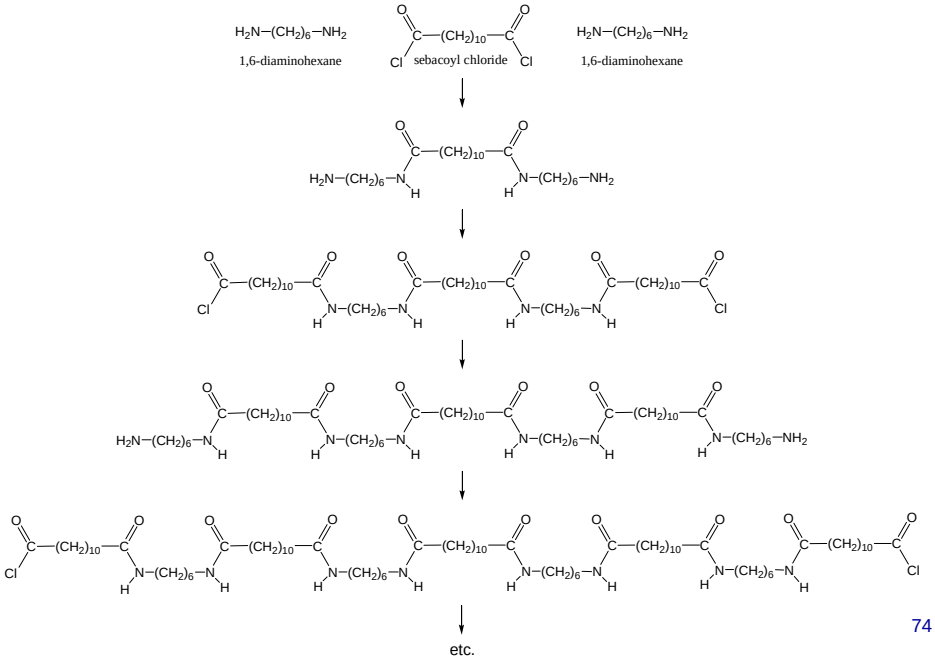
Condensation Polymers: Polyamides



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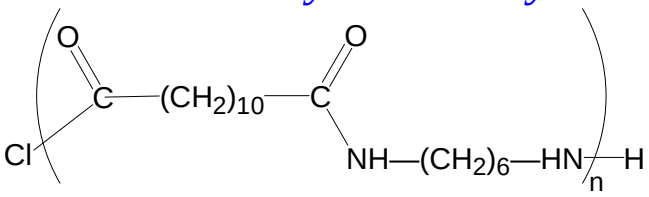
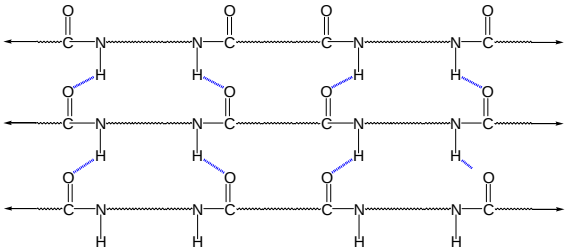
Condensation Polymers: Polyamides

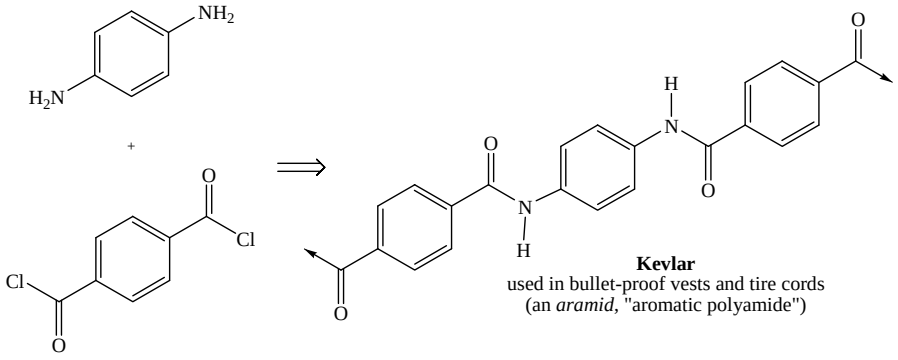


Nylon-6,12
a **polyamide**

Discovered by Wallace Carrothers at DuPont in 1934; polymers average about 10,000 g/mol; 3 billion pound of Nylon made per year; 60% used for nylon fiber in home furnishings (carpet); also used in textile fibers, tire cord, rope, parachutes, paint brushes, Velcro, electrical parts, medical applications (sutures, etc.)

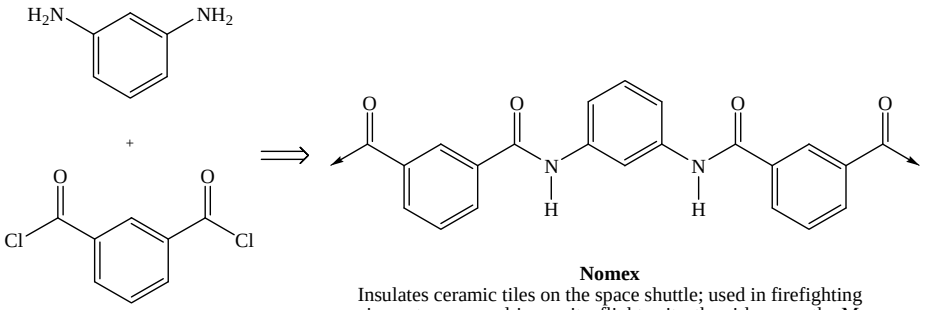


Polyamides



Kevlar
used in bullet-proof vests and tire cords
(an *aramid*, "aromatic polyamide")

Polyamides



Nomex
Insulates ceramic tiles on the space shuttle; used in firefighting equipment, race car driver suits, flight suits, the airbags on the Mars Pathfinder, Spirit, and Opportunity rovers (less strong than Kevlar, but has excellent thermal, chemical, and radiation resistance)

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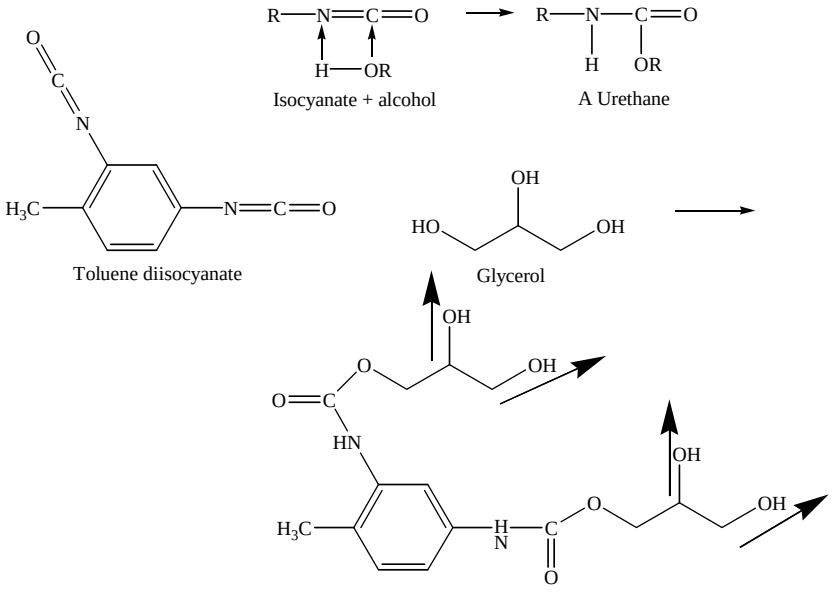
Polyurethanes



A **Polyurethane**

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Neurotransmitters

Neurotransmitters

- **Neurotransmitters** are small molecules that carry nerve impulses from one neuron to the next.
- Neurons consist of the main cell body (the **soma**), long stemlike projections (the **axons**), and short fibers connected to the soma (the **dendrites**).
- Neurons are not connected directly to each other, but are separated by a small gap called a **synapse**.
- When an electrical current originating in a neuron reaches the **synaptic terminals** at the end of the axon, the terminals release neurotransmitter molecules into the synapse; these molecules diffuse across the synapse and bind to receptors on the dendrites of the next neuron, stimulating an electrical current, which travels along that neuron until it reaches the next synapse, and so on until the nerve impulse reaches the brain.

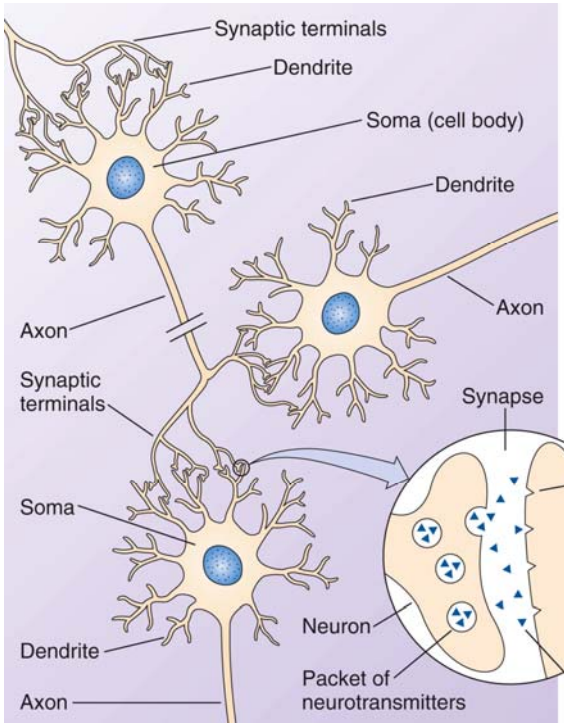

Figure 6.5 A nerve cell and the transmission of a nerve signal.

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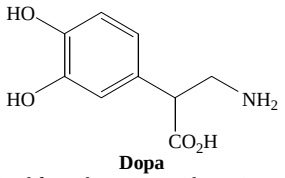
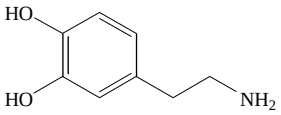


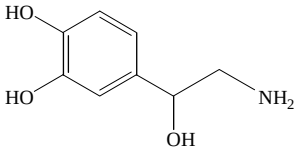
Dopa

Synthesized from the amino acid tyrosine; used as a treatment for Parkinson's disease, which is caused by a breakdown of dopamine-based neurons that control the brain's motor system (dopamine cannot be administered directly because it does not cross the blood-brain barrier; however, the L-form of dopa does)



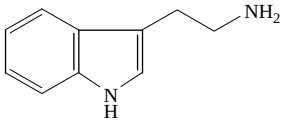
Dopamine

Synthesized from dopa; used as a treatment for low blood pressure



Norepinephrine (NE)

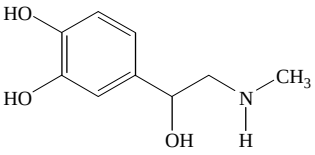
Synthesized from dopamine; an excess of NE in the brain is related to feelings of elation or manic states; low NE levels are linked to depression; the stimulant action of epinephrine and NE in some cells can be reduced by *beta blockers*, which are used to treat cardiac arrhythmias, angina, and hypertension



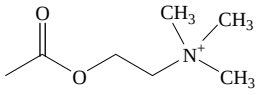
Serotonin

Synthesized from the amino acid tryptophan; influences sleeping, body temperature, and sensory perception; drugs that mimic serotonin are used to treat depression, anxiety, and obsessive-compulsive disorder; serotonin blockers are used to treat migraine headaches and nausea resulting from chemotherapy

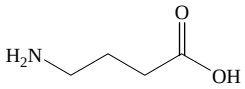
82



Epinephrine (Adrenalin)
More important as a hormone than a neurotransmitter; synthesized in the adrenal glad; release of adrenalin into the bloodstream in response to pain, anger, or fear increases blood glucose levels, and provides a sudden burst of energy (fight-or-flight response); increases force of heart contractions (raising blood pressure); also a vasoconstrictor; used in local anesthetics to keep the anesthetic from being washed away

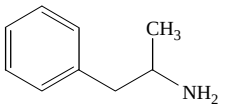


Acetylcholine

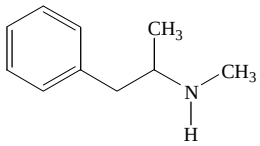


Gamma-aminobutanoic acid (GABA)
A *inhibitory neurotransmitter*

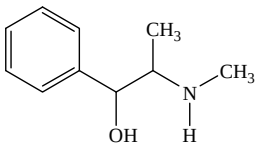
Pheynlephrines and Amphetamines



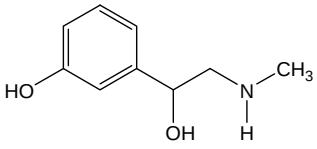
Amphetamine (Benzedrine)
a powerful nervous stimulant; raises blood glucose levels, increases heart rate and blood pressure



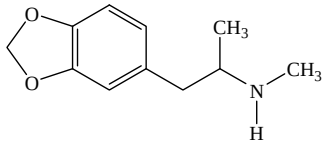
***N*-Methylamphetamine (Methedrine, "speed")**
Also a powerful nervous stimulant



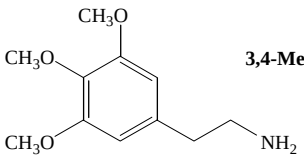
Ephedrine / Pseudoephedrine
found in the Chinese ma-huang plant; a decongestant used in many cold remedies



Phenylephrine
Common decongestant



3,4-Methylenedioxymethamphetamine (MDMA), "Ectasy"



Mescaline
Hallucinogen from peyote cactus

Amino Acids and Proteins

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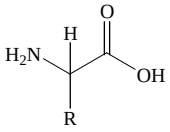
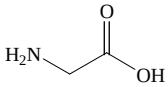
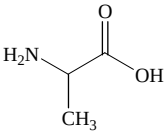
Amino Acids



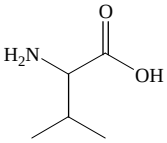
Amino Acids



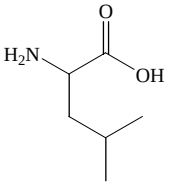
Glycine (Gly)



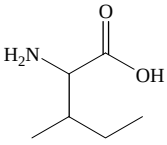
Alanine (Ala)



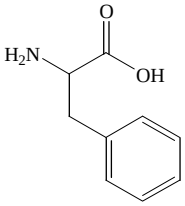
Valine (Val)



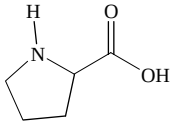
Leucine (Leu)



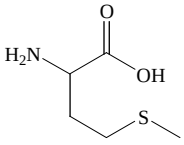
Isoleucine (Ile)



Phenylalanine (Phe)

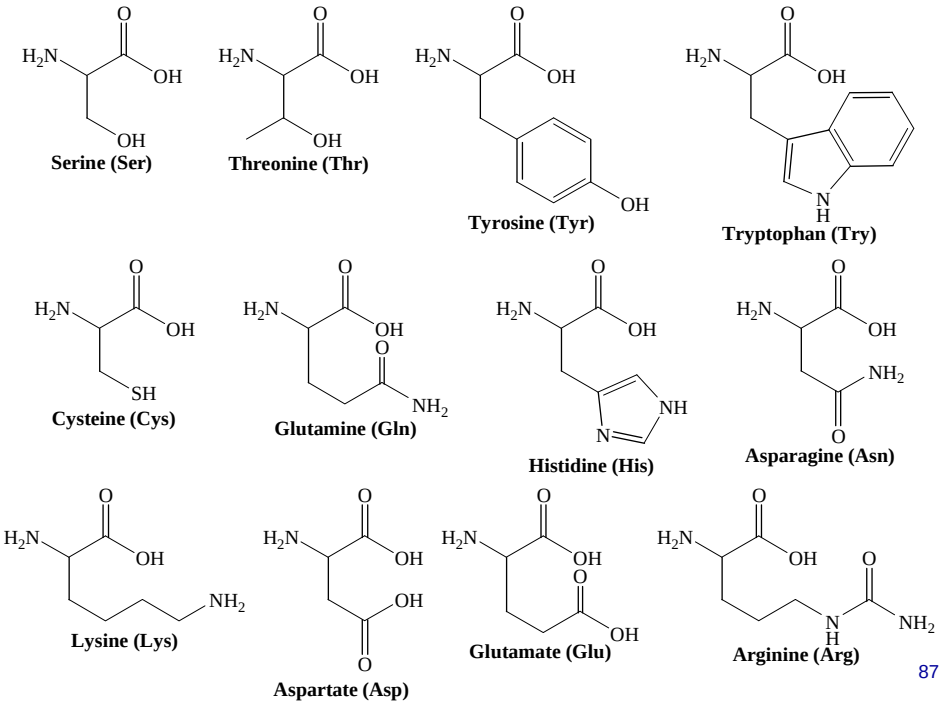


Proline (Pro)

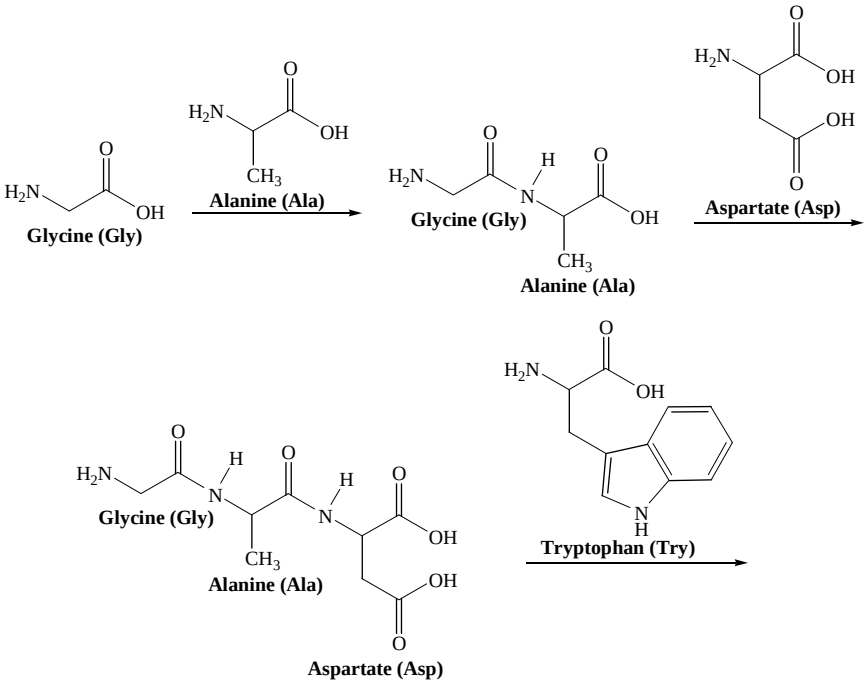


Methionine (Met)

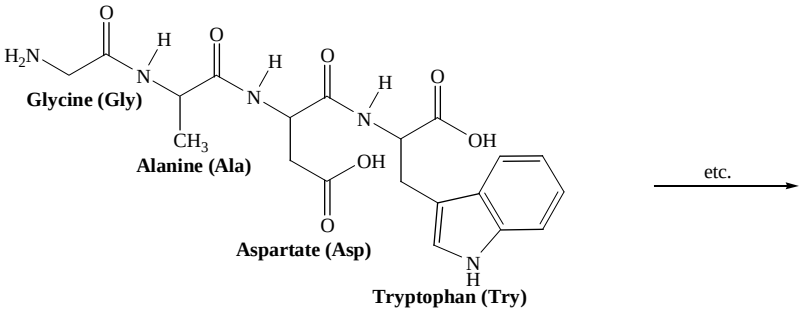
86


Serine (Ser)
Threonine (Thr)
Tyrosine (Tyr)
Tryptophan (Try)
Cysteine (Cys)
Glutamine (Gln)
Histidine (His)
Asparagine (Asn)
Lysine (Lys)
Aspartate (Asp)
Glutamate (Glu)
Arginine (Arg)

87

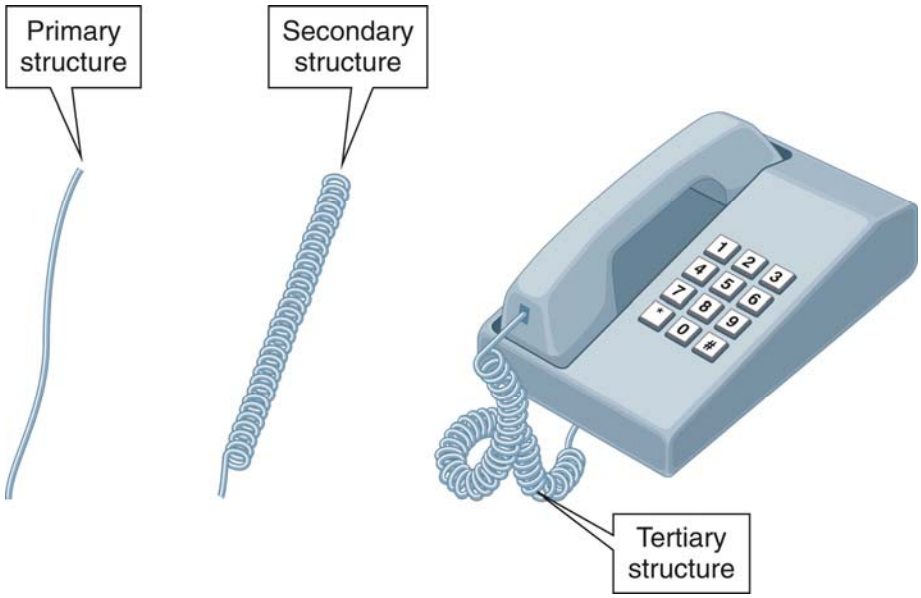

Glycine (Gly)
Alanine (Ala)
Glycine (Gly)
Alanine (Ala)
Aspartate (Asp)
Glycine (Gly)
Alanine (Ala)
Aspartate (Asp)
Tryptophan (Try)

88

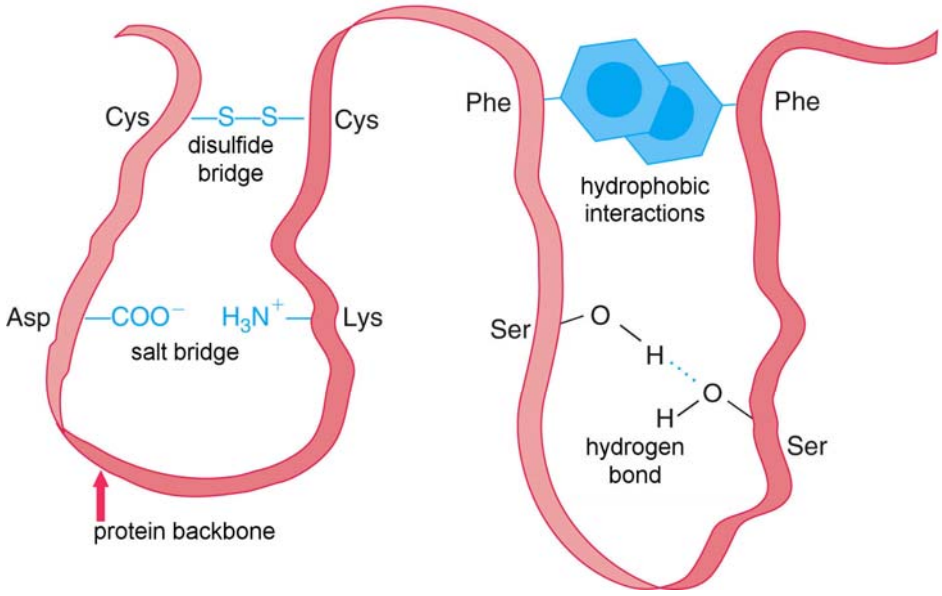


Gly—Ala—Asp—Try

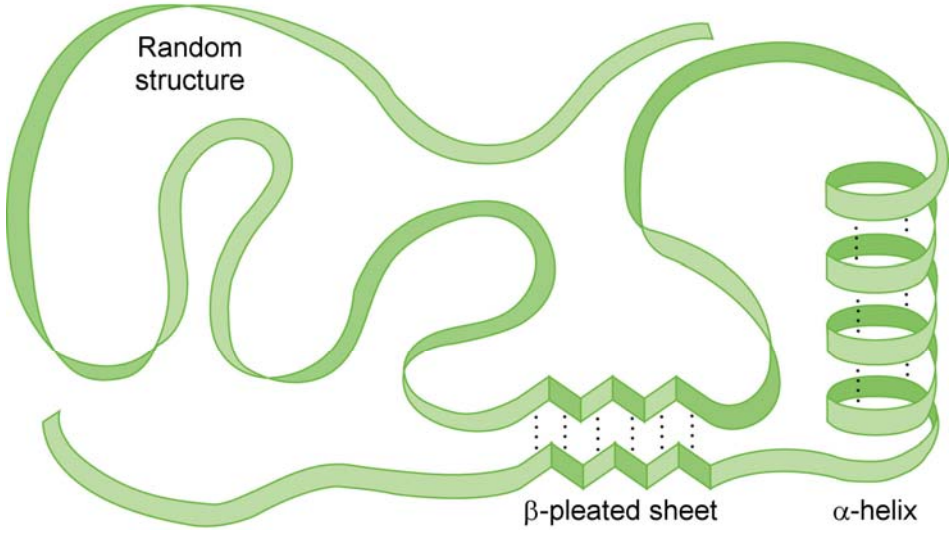
a **protein**
(a polyamide)
Instructions for making proteins
are encoded in DNA.



Three levels of structure in a telephone cord



R-group interactions leading to a protein tertiary structure



Segment of a protein showing α-helix, β-pleated sheet, and random coil structures

Some Hideously Complex Molecules

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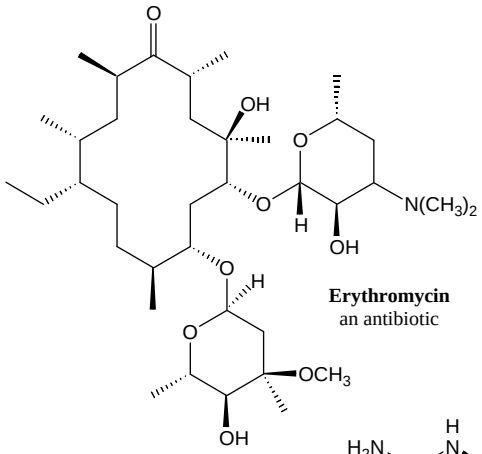
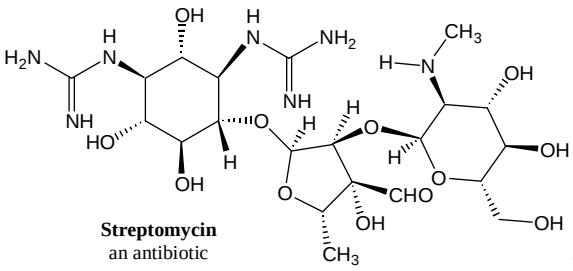
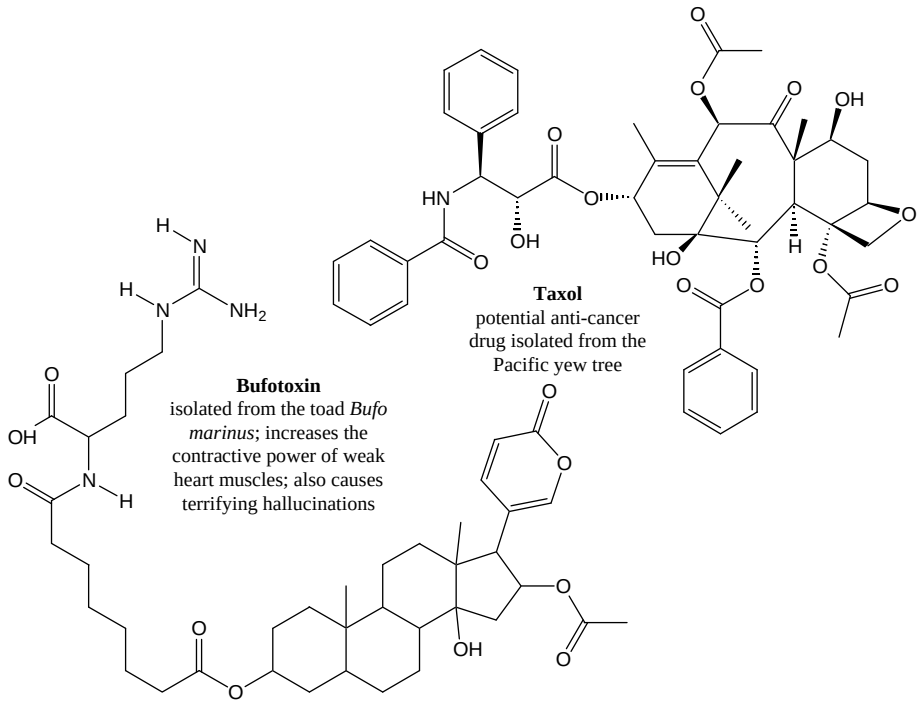


Erythromycin
an antibiotic



Streptomycin
an antibiotic

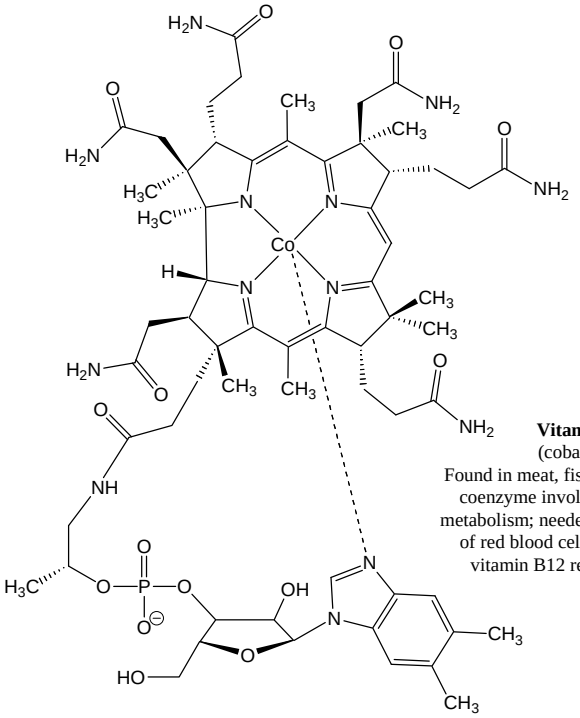
94



Taxol
potential anti-cancer drug isolated from the Pacific yew tree

Bufotoxin
isolated from the toad *Bufo marinus*; increases the contractive power of weak heart muscles; also causes terrifying hallucinations

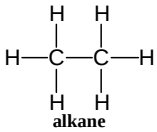
95



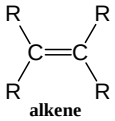
Vitamin B12
(cobalamine)
Found in meat, fish, eggs, and milk; a coenzyme involved in amino acid metabolism; needed for the production of red blood cells (a deficiency in vitamin B12 results in anemia)

96

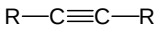
Functional Groups



alkane
(-ane)

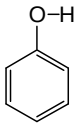


alkene
(-ene)

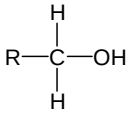


alkyne
(-yne)

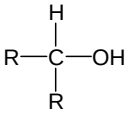
aromatic ring
(phenyl-, -benzene)



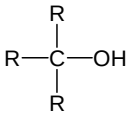
phenol
(-phenol)



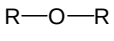
primary (1°) alcohol
(-ol)



secondary (2°) alcohol
(-ol)

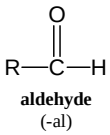


tertiary (3°) alcohol
(-ol)

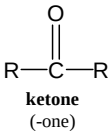


ether
(alkoxy-, -ether)

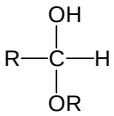
thiol



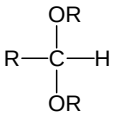
aldehyde
(-al)



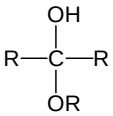
ketone
(-one)



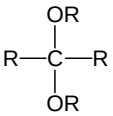
hemiacetal



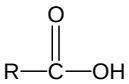
acetal



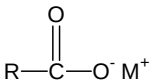
hemiketal



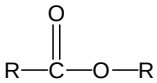
ketal



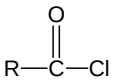
carboxylic acid
(-oic acid)



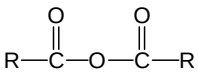
carboxylate salt
(metal + -oate)



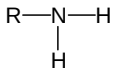
ester
(alkyl + -oate)



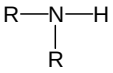
acid chloride



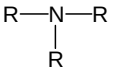
acid anhydride



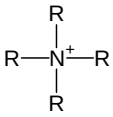
primary (1°) amine
(amino-, -amine)



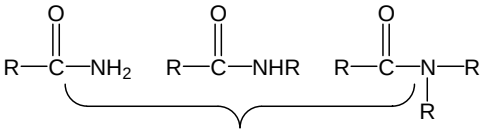
secondary (2°) amine
(-amine)



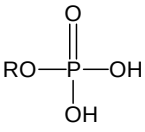
tertiary (3°) amine
(-amine)



quaternary ammonium salt
(alkyl ammonium + anion)



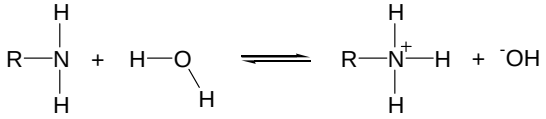
amide
(*N*-alkyl + -amide)



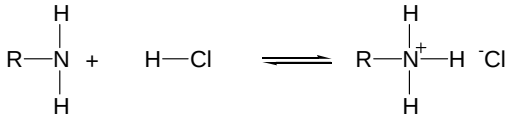
phosphate ester

Reactions of Amines and Amides

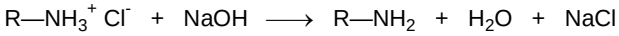
1. Reaction of an amine with water to produce an alkylammonium ion.



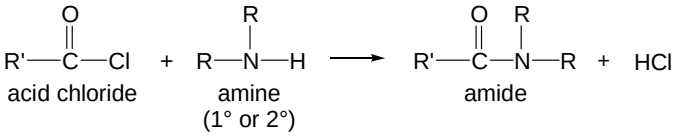
2. Reaction of an amine with acid to produce an alkylammonium salt.

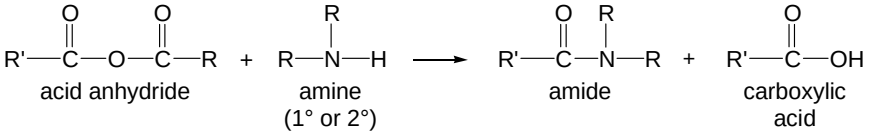


3. Conversion of an alkylammonium salt back to an amine.



4. Formation of an amide. (NR with tertiary amines.)





5. Hydrolysis of amides under acidic and basic conditions.