Assignment: Read Chapter 5 in your text.

Purpose of Classification:

1. A system of classification is necessary to keep the species in order. An alphabetical file could be used, but taxonomists have found that it is better to arrange the multitude of animals into ever larger and more comprehensive groups based on their similarities and differences. Once the species are named, described, and classified, it is possible to keep track of the hundreds of thousands of facts about each one.

2. The storage and retrieval of all the information known about each group from species to kingdom. The keys to the data in the classification are the names of the species and groups.
   Every time you wish to learn something about an animal you look under its name. For this reason we say that the scientific name is the key to the retrieval of all our knowledge about an insect - life history, seasonal and geographic distribution, control, parasites and predators, morphology, physiology, etc. Insofar as classification reflects relationships among organisms, it provides a means of predicting the distribution of characters among organisms.
   Every time someone publishes something about an insect, information is put into the classification system under the name of a species or group.

3. A good classificatory system, based on relationships, then will have a predictive value. If you do not know the identity of an organism, but you know who it is related to, you often predict some of the characteristics about your organism from information known about its relatives.

Hierarchial Classification - we do use a hierarchial style of classification. What this means is that similar species are grouped together in a genus, similar genera are then grouped together into a family, similar families are grouped together in an order, and so on.

If you remember from our last lecture, we learned that Linnaeus established four taxonomic categories: Class, Order, Genus, and Species. We also learned that Latreille added the category Family, and Haeckel added the category Phylum. These 7 (including kingdom) categories are considered obligate categories, that is all animals will have a name in each of these categories. We often do use a number of other categories, most of which are established simply by adding either of the prefixes sub- or super- to existing categories:

- Kingdom: Animalia
  - Phylum (there are about 12) - insects in Arthropoda
    - Subphylum - Uniramia
      - Class - Insecta
        - Order - Hemiptera
          - Suborder - Heteroptera
            - Superfamily - Pentatomoidea
              - Family - Pentatomidae
                - Subfamily - Pentatominae
                  - Tribe - Pentatomini
                    - Genus - *Thyanta*
                      - Species - *calceata*

These are the main categories, but there may be more (Superorder, subspecies, etc.).

<u>Taxonomic category</u> - one of the levels of taxonomic hierarchy used above (e.g. Family).

<u>Taxon</u> (taxa, pl.) - group of organisms classified together (e.g. Apidae - bees).

It is important for you to realize that classifications are not constant, immutable things, but rather are continually changing as new and more information is learned about the organisms in the classification. It is like any other science - the classification is like a hypothesis (in need of testing and validation) and we try to find more information to either verify the classification or to find reasons to adjust it. This is why not all people agree on the same classification of different groups. Different workers will use different characters to form their classifications, or they will interpret these characters in different ways.

As I mentioned previously in our lecture on history, during the 1800's it became obvious that a set of rules were needed for systematic work. Many workers were changing names for no apparent reason, newer names were being used instead of the original older names, and other problems were causing quite a mess.

By the turn of the century the systematic community had begun to meet and discuss these rules that were desperately needed. Through a series of meetings of the General Assembly of the International Union of Biological Sciences a book called the International Code of Zoological Nomenclature was published and has been modified several times. This is a copy of the code - essentially the bible for animal systematists. The botanists have their own international code.

It used to be that if you had an important systematic problem, you would have to refer the problem to the International Commission on Zoological Nomenclature, and they would have to make a ruling. This was a long process that probably wasn't necessary in most cases. Now a few more rules have been established, and many of these problems can now be solved by the individual workers in a normal publication (still has to go through the peer review process).

The main goal of the international code is to provide a set of rules that will maintain stability in systematics. We do not want to see many unnecessary name changes and the chaos it may bring. The code is based on the law of priority. This means that if there are two names for a single species the oldest (or first described) name should be used. This applies only back to 1 January 1758 with the publication of the 10th edition of Systema Naturae by Linnaeus (one exception: Clerck's 1757 publication). So for most systematics projects the literature must be searched back to 1758.

There has been, however, a recent movement to use modern catalogs as a new starting point for each group which has a modern catalog. For example, I have published a catalog on the family Tessaratomidae. Supporters of this idea would say that they would follow whatever I published plus papers more recent, even if I might have missed some important. Fortunately, it does not appear that this is going to happen.

In order for the scientific name of a species to be acceptable under the Code, it must meet certain criteria:

1) In must be a binomial (species) or trinomial (subspecies).

2) It must be a Latin or latinized word, but may be derived from any language or from the names of people or places; most names are derived from Latin or Greek words, and usually refer to some characteristic of the animal or group named.

3) It must be given to a species or subspecies, although before 1961 it was often assumed that varieties, races, forms, and so on could also be named.

4) It must be based on actual specimens, fossils, or prior to 1931, the work of an animal (a gall). Can't name hypothetical or mythical animals (unicorn).

5) It must be accompanied by a description and desireably also by a differential diagnosis (characters which separate this species from close relatives). Once again this rule only took effect after a certain date. Prior to this date, only an indication of what the species was was necessary to fix a new name. For example, a picture with a name would be sufficient. [relate story of *Arocera* Showalter in National Geographic]

6) It must be properly published. It must be printed or duplicated in an approved manner and made available to other scientists (not label on museum specimen, a thesis deposited in library, or a talk at a meeting). After 1985, these should state whether or not names or nomenclatural acts are intended for permanent public scientific record. Now with the advent of the internet, the taxonomic community has to deal with electronic publication of names. Should a name published on the internet be considered valid? The new code does allow for this possibility, but a copy of the electronic publication must also be saved onto a CD, and copies of that CD must be deposited in several well-recognized institutions or museums. Publication on CDs is ok as long as it meets all of the other criteria, and that the CD is deposited as above.

Even though a name is available, it may be invalid if it is later found to be a synonym or homonym.

The scientific name of an organism is a binomial (species) or trinomial (subspecies). The full scientific name of an organism will always include the genus name and species name (also subsp. name if applicable). Generic names are always capitalized; species or subspecies names are never capitalized. The genus and species names should be written in italics (when italics are not possible, the names are underlined to indicate italics).

The names of species and subspecies should be followed by the name of the author(s) who originally described that name. The author's name(s) are not italicized and are not separated from the name by any punctuation mark. If the author's name appears in parentheses, it means that he described the (sub)species in some genus other than the one it is now placed. [note - botanists will also include the name of the person who moved the species from one genus to another]

The date of the name of a species is the date of the publication of the original combination.

A specific name can be used only once in a genus. If it is used more than once in a genus they are called homonyms. The more recently published name (junior homonym) then becomes invalid, and will require a different name; the older name (senior homonym) is still valid and useable.

If a species is divided into subspecies, the particular subspecies that includes the holotype of the species will have the same subspecies name as the species name.

Also, a genus will often be split into smaller groups of species called subgenera. The subgenus is treated like a genus name. Its first letter is always capitalized, it is written in italics, it is inserted between the genus and species names, and it is enclosed in parentheses.

The designation of types at the species level. There have been many different kinds of types defined. The following are the ones that I would like you to know:

1) holotype - a single specimen designated as "the type" of a species or subspecies by the original author at the time of the publication of the original description, or the single specimen on which such a taxon was based when no type was specified (is a primary type).

The designation of a single type specimen is very important in that it anchors the name forever to a single specimen. There may be more than one species in a type series, but if the name is tied to just one specimen then there should be less confusion. It is important to have a type designated, and not just rely on the published description. Often the description may be inaccurate, or new characters will be discovered later. When working on a systematics problem if there is even the slightest doubt about the identity of a given species, then the type should be examined to verify that you do have the species identified correctly. It is understood that the type specimen will probably not exhibit all of the characters of the species, so the author should describe not only the type but also give the range of variability of the other specimens.

2) paratype - a specimen studied by the author of the original description and so designated by him (does not qualify as a primary type).

3) allotype - a paratype specimen of the opposite sex as the holotype specimen, that was designated as the allotype by the original author at the time of the original publication.

4) syntype - each specimen of a type series from which neither a holotype or a lectotype has been designated.

5) lectotype - a syntype designated as the single name-bearing specimen subsequent to the original description of the species or subspecies.

6) paralectotype - each specimen of a former syntype series remaining after designation of a lectotype.

7) neotype - the single specimen designated as the name-bearing type of a species or subspecies for which no holotype, lectotype, syntype(s), or prior neotype is known to exist.

8) topotype - a specimen collected subsequent to the original description at the type locality of the species. (type locality = the location where the type was collected).

9) homotype - a specimen actually compared to the type of a species and deemed to be the same species as that type.

Of the above taxonomic categories only the species is relatively well-defined; the other categories are more or less up to the subjective decisions of those who work on the groups.

species (biological definition) - a species is a group of individuals or populations in nature that are capable of interbreeding and producing fertile offspring and that are reproductively isolated from other such groups. This is a general definition which will work for most species found in nature. It won't work for everything, however, and the literature is full of discussions on trying to find a definition that will work for all living things. This may be impossible. For example, the definition above will not work for some aphids which reproduce parthenogenetically. I will discuss these problems in more detail in just a few minutes. For our purposes, the definition given above will work for most things we encounter.

Since it is nearly impossible in many cases for taxonomists to determine if two taxa will interbreed we often rely on other characters (morphology, geographic and seasonal distributions, habitat, hosts, life history, immature stages, cytology, physiology, behavior, etc.) to help us make our decisions on determining species.

Bear in mind that there will always be some intraspecific variation; that is, no two individuals (except possibly identical twins) are exactly alike. The differences between individuals of a population are usually slight and intergrading (e.g. size). If they are not, then there is usually certain characters in every group that are less subject to individual variation than others (e.g. genitalia).

Sibling species - These are pairs or groups of very closely related species which are essentially morphologically identical. It is nearly impossible to tell them apart, but they are reproductively isolated.

Polymorphic species - This is the opposite problem of sibling species. This is where you have a single species, but the variation is considerable. You may have what appear to be several completely different forms or morphs, but they all interbreed.

I now want to drop back and discuss in a little more detail the species concept.

Problems with the biological species concept:

1) Insufficient information - Sometimes we may not have enough information on such things as sexual dimorphism, age differences, polymorphism, or other variations, so it may be difficult to assign certain individuals or groups of individuals to a given species.

2) Uniparental reproduction - sometimes called asexual reproduction. This is a problem for entomologists because there are many insects which reproduce asexually. Fortunately among the insects, there are usually well-defined morphological discontinuities among these organisms and they seem to occupy unique ecological niches. That is, it is usually not too difficult to assign them to species.

3) Evolutionary intermediacy - Species continue to evolve. Those that are currently speciating or are not yet fully distinct are often called incipient species.

4) The paleontologists sometimes have problems with the time factor in what to call taxa. But this is really analygous to taxonomists dealing with extant taxa covering geographic ranges, some of which are continuous and some of which are interrupted.

5) Parasitic organisms and their host preferences sometimes give problems to taxonomists as to what constitutes a species.

Polytypic species - Almost all species (except perhaps those threatened with extinction) consist of several populations. When a taxonomist discovers new populations that are obviously different from other populations of that same species, he will often name the new population as a different subspecies. If a species has at least two subspecies it is said to be polytypic. Of course, the opposite is monotypic.

Subspecies - this is a geographic subdivision of a species. Mayr's formal definition is: "A subspecies is an aggregate of phenotypically similar populations of a species, inhabiting a geographic subdivision of the range of a species, and differing taxonomically from other populations of the species." Many workers do not believe that this is a valid category. My personal belief is that it is a valid category if certain rather strict conditions are met. First, the two populations must be consistently different. Even if you were not told where the specimens came from you would still be able to identify them nearly all the time. Secondly, the two populations should be nearly isolated from each other with only a small, narrow overlap in distributions. Thirdly, I would expect to see some, but not very many, intermediates between the two populations in that narrow zone of distributional overlap. One of the objections to the subspecies category is that it unnecessarily adds names to the literature. But in my view, subspecies are simply populations that are evolving towards becoming separate species and have not quite reached that point yet. At some point in time they will become separate species and will both deserve names anyway. Remember, once again, species are not constant objects either, but are in a constant change or evolving. This process is just too slow for us to see the changes during a lifetime.

So, if the different populations meet the above criteria, and have clear, distinct differences, they can be considered different subspecies. But what about minor differences. Some workers will designate subspecies on very minor differences - these are called splitters. Those at the opposite end of the spectrum are called lumpers. In the past, there has been a middle of the road rule of thumb to use in determining when to describe subspecies. This is called the 75% rule. If 75% of the individuals of one population differ diagnostically from 97% of a previously recognized subspecies then the new population can be named as a new subspecies. Personally, I think the actual percentage should be higher than 75%.

Sometimes the characters vary gradually from one population to the next (there is no sharp line where one population begins and the other ends). The term cline is used to refer to a character gradient where in a series of continuous populations a given character changes gradually.

Genus - a genus is a group of similar or related species. Mayr defines it as "a taxonomic category containing a single species, or a monophyletic group of species, which is separated from other genera by a decided gap." Similar definitions can be made for the other higher categories. As you can see, this is a very subjective definition. Each worker will have a different opinion on what species are similar enough to be grouped into a genus. This is true for all of the higher categories, above species.

Essentially, a higher taxon is an aggregate of related species separated from others by a discontinuity.

In thinking about the limits of higher taxa and their ranking, one should be aware of the evolutionary origins of the higher taxa. The higher taxonomic categories evolved from the species category. Higher categorical rank evolves through evolution, not lower rank through subdivision of higher categories.

The higher taxa have ecological significance. That is, for example, all species in the Cerambycidae are wood borers, and all members of the family Picidae are woodpeckers. If properly classified, each higher taxon should be a <u>monophyletic unit</u>. That is, it evolved from a single phyletic ancestor. A taxon is a group of relatives.

A genus also has a type, but in this case it is not a single specimen, but rather a single species. This means the name of a genus or subgenus is anchored to a particular type of species, specimens of which can be examined if there is a question as to the characters of the genus or subgenus. All the species in a genus must resemble the type species of that genus more closely than they resemble the type species of other genera. Although no one species can be "typical" of a group of species assigned to a genus, the generic type serves as a fixed point for the generic concept. The species which serves as the type of a genus is, in turn, tied to type specimens, so the genus is firmly anchored. It is only the extent or limits of the genus that are arbitrary.

The name of a genus can be used only once in the animal kingdom. If a genus is divided into subgenera, the subgenus that includes the type species of the genus has the same subgenus name.

Family - a group of similar or related genera.

- the family level includes the following categories: tribe, subfamily, family, and superfamily. Linnaeus didn't recognize the family category, but most of his genera have been elevated to family. With only 312 genera in 1758, there was no need for a category between genus and order. Latreille first applied the family concept to insects. He divided all insects into families, which he characterized but did not name. Subsequent authors used French common names for families and later used common names based on the included genera. Kirby (1813) first suggested uniform ending -idae (Greek plural meaning like). Formalized in Code and extended (after 1916) to standardized endings for other family level taxa.

- Families generally have easier to recognize characters and are easier to identify than lower taxa. Families are commonly world-wide in distribution unlike many genera which are usually confined to one or several adjacent continents.

- Families, similar to genera, also usually have most of its species occupying similar habitats, etc.

- Just below the family level is the subfamily; and just above the family level is the superfamily. These categories may be elevated or lowered between any of these categories. It is useful to group related genera into subfamilies and related families into superfamilies to remind you of similarities of characters, life histories, habits, etc.

- The type of a family is a particular genus, which serves as a fixed point for the family concept. There is no mention in the original rules of nomenclature of how the type genus is selected. Strickland (1843) suggested the earliest known or most typically characteristic genus - this grew out of Latreille's method of selecting a Linnaean genus which represented a general type of animal. Subsequent workers loosely followed this principle, selecting typical, or, as we now know, atypical genera. Early 20th century workers advocated the "oldest genus type principle" which caused terrible confusion. Most taxonomists did not favor this proposal and follow the recommendation that the first family name proposed and formed from a valid generic name shall stand even if no type genus was designated.

- The names of categories from tribe through superfamily have standard endings (added to root name of type genus), and hence can always be recognized as referring to a particular category:

superfamily -	- oidea
family -	- idae
subfamily -	- inae
tribe -	- ini

Determining the root of a generic name not always easy (Aphidae vs. Aphididae)

<u>Synonym</u> - I mentioned this word earlier, but now I need to define it. A synonym is one of two or more names for the same taxon. The oldest name (the one first described) is often called the senior synonym while the others are called junior synonyms. Because of the law of priority we consider the senior synonym to be the valid name. [note priority works by first in year, and then unless the first revisor decides differently, the first in a work, and the first on a page]

Spodoptera Guenee, 1852:153
  Laphygma Guenee, 1852:156
  Prodenia Guenee, 1852:159

Cleis Mulsant, 1850
  Pseudocleis Casey, 1908

the brownbanded cockroach -
- from 1900-1960 was known as *Supella supellectilium* (Serville, 1838)
- now name is *Supella longipalpa* (Fabricius, 1798)

<u>Homonym</u> - I already defined this term, but will mention it again. This is one of two or more identical but independently proposed names for different taxa at the same level. There cannot be two (or more) species or subspecies with the same name in a given genus; there cannot be two (or more) genera in the animal kingdom with the same name, etc. You can have the same species or subspecies name used if they are (and always have been) in different genera. Also the same names can be used if they are in different taxonomic categories. For example, the same name can be used for both a genus and a species.

Because of the large number of animal taxa and the vast amount of zoological literature, errors in naming (homonyms and synonyms) are often difficult to discover. As they are discovered, we often must make changes to the existing nomenclature. It is also sometimes difficult to determine the date of publication of some names which can be important in determining priority.

A couple of other terms:

- <u>tautonym</u> - this is where the genus name and the species name are identical. This is more common in botany than in zoology. It is actually discouraged in most cases, but some examples do exist:

  Carbula carbula is a species of Pentatomidae.

- <u>patronym</u> - this is when a taxon is named after an individual. There are many species named after Linnaeus or Fabricius. This is fairly common, but it is usually better if the taxon can be given a more descriptive name rather than naming it after a person or a place.

Voucher specimens - specimens preserved as a standard of reference to substantiate what organisms were used in a given piece of research. If a question arises as to the species used in past research projects, the voucher specimens can be examined to confirm or adjust published identifications. Thus a scientific publication will have greater value and a longer life. This practice also saves duplicating experiments and may allow bringing together the results of different pieces of research on the same target organism but for which different species names are used. Publication of papers in ESA journals now require a statement as to where voucher specimens are deposited.

- From 1-10 good specimens of each sex and/or developmental stage should be preserved. Standard methods of mounting and preserving should be used. The labels should bear proper detailed data, plus a light green label should also be attached indicating that it is a voucher specimen - this label should have a project or research number or publication that the specimen refers to. The publication should indicate where voucher specimens are deposited (should be a recognized museum).

Common Names - there are in general 3 categories of common names:

1) Names in the ordinary language of the people of a region. Examples: stinging worm, waterbug, fish bait farmer, etc. The Mexican bean beetle entered the U.S. in 1800's and devastated beans - it was called bean ladybird, bean beetle, bean bug, spotted bean beetle, and even yellow peril in reference to the yellow larva. It is common for a wide-spread species to receive many such names, especially in different parts of its range. For example, the European water lily has 15 English common names, 44 French, 105 German, and 81 Dutch for a total of 245 common names.

2) names in general entomological use such as those in textbooks or those used in such groups as butterflies and moths. These are often not standardized.

3) Standardized common names - names which are officially adopted like scientific names. In many cases the names adopted were those in general entomological use, e.g. bollworm, chinch bug, Colorado potato beetle were in use prior to 1897. For species without common names, names were specially coined or made up, e.g. soybean looper for *Pseudoplusia includens*.

The list we use is "Common Names of Insects and Related Organisms" compiled and approved by the Entomological Society of America. Since 1925, they have appeared at 3-6 year intervals. It gives the scientific and common names of certain families and species of insects, spiders, and mites, a few snails, slugs, and La. red crayfish. (See Chapin, Fall, 1989 Bulletin) (Corrections & additions in ESA Newsletter with annual summary in Bull.)

A proposal form is filled out (economic importance, distribution, hosts, other insects to which name might apply, other common names), approved by 7 of 9 committee members, and then by ESA membership. Names usually have 2 parts, one indicating family or group, and the other a modifier: brown stink bug. The group name is written as separate word if it correctly indicates the proper higher group: house fly vs. butterfly, dragonfly, sawfly.

Need recognized in 1897, committee on nomenclature formed in AAEE in 1903, first names adopted in 1904. Compilation in 1908, next in 1925. Rules adopted in 1920's as to formation of names: separate, hyphenated, closed compound (clover hay worm, clover-hay worm, clover hayworm). No common names for groups of insects (spanworm, cabbage worm) until Metcalf proposed in 1942 that group name be written as a separate word when term was systematically correct, house fly & lady beetle, and combined with a modifying word when term was not systematically correct (firefly, cutworm). Common names for higher categories (particularly families) proposed in 1955. There have been 15 such lists, since the first compilation appeared in 1908.

Advantages of standardized common names:

1) Scientific names don't mean anything to the average person, and common names make it easier for the entomologist to communicate with him.

2) A standardized list helps all entomologists use the same common names for the same species.

3) Common names more stable than scientific names which are subject to change due to advances in our scientific knowledge and changes in nomenclature.

Disadvantages of common names:

1) Common names may imply that the species is easily recognized and that there are no close relatives to worry about, which is not true.

Tenebrionidae: red and confused flour beetles
Cucujidae: sawtoothed and merchant grain beetles
Many stink bugs are brown, only 1 is brown stink bug

2) Common names don't show relationships:

a. house fly & face fly are *Musca* spp.

b. armyworm is part of common name of species in 4 genera of Noctuidae (*Pseudaletia*, *Spodoptera*, *Faronta*, *Mamestra*)

c. webworm is used in 9 different lepidopterous families, including 7 different genera in one family

Arctiidae, *Hyphantria*; Gelechidae, *Dichomeris*; Glyphiterigidae, *Homadaule*; Noctuidae, *Celama*; Oecophoridae, *Depressaria*; Phaloniidae, *Aethes*; Pyralidae, *Crambus*, *Hellula*, *Herptogramma*, *Hymenia*, *Loxostege*, *Surattha*, *Tetralopha*; Tortricidae, *Archips*; Yponomeutidae, *Atteva*

d. shothole borer - Scolytidae
white oak borer - Cerambycidae
peach borer - Sesiidae