Evolution: The Darwinian Revolutions

BIOEE 2070 / HIST 2870 / STS 2871

DAY & DATE: **Monday 16 July 2012**
READINGS:
- **MacNeill/*Evolution: The Darwinian Revolutions* chapters 8 & 9**
- **Mayr/*The Growth of Biological Thought,* chapter 13, pages 571 to 627**
- **Ruse/*Darwin and Design: Does Evolution Have a Purpose?* chapters 9 & 10**

Lecture 6:00-7:50: **Species and Speciation**
Section 8:00-9:00: **Do species exist, and does it matter?**

• Essay #2 is due next Monday 23 July 2012:

Please submit it as a Word .doc attached to an email, and paste a copy into the body of the email (just in case).

• Research paper proposals are also due next Monday 23 July 2012:

If you have decided to submit a research paper instead of essays #2 and #3, you must submit an outline and list of proposed references, again as a Word .doc attached to an email, and paste a copy into the body of the email.

• Some of the readings for this section of the course are available at the course website:

Behe, M. (1998) Intelligent design as an alternative explanation for the existence of biomolecular machines (unpublished manuscript)

Dobzhansky, T. (1973) Nothing in biology makes sense except in the light of evolution. *American Biology Teacher*, March 1973, volume 35 pages 125 to 129

Kaviar, B. (2003) A history of the eugenics movement at Cornell. 2003 Tallman Prize winner. (unpublished manuscript)

MacNeill, A. (2011) *Evolution: The Darwinian Revolutions*, The Modern Scholar.

Mayr, E. (1982) *The Growth of Biological Thought: Diversity, Evolution, and Inheritance*, chapters 12 and 13

Provine, W. (1971) *The Origins of Theoretical Population Genetics*, chapter 5

Look for them in the "Course Packets" section of the course website at

http://evolution.freehostia.com/course-packet/

The password for the course packets is:

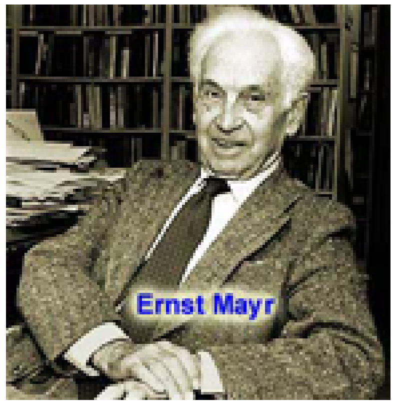
evolutioncp

Species and Speciation

Speciation is the evolution of new species from previously existing species. It is the source of all of the diversity in life on Earth. It is also the biggest mystery in evolutionary biology. People who think they have solved the problem of speciation haven't considered all of the various aspects of the topic.

As the title suggests, Darwin supposedly wrote about species in the *Origin of Species.* However, he didn't really write much about speciation, except to suggest that it was caused by natural selection.

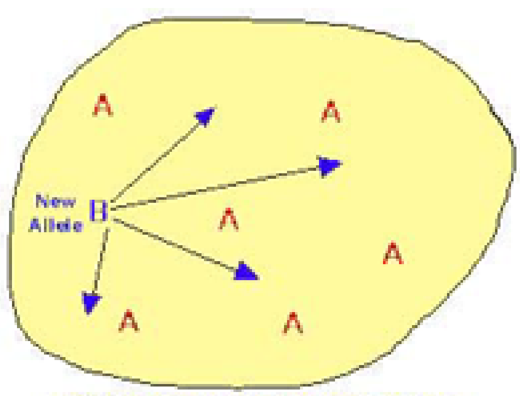
The recent history of ideas about speciation begins with the publication in 1942 of Ernst Mayr's magnum opus, *Systematics and the Origin of Species*.



In it, Mayr attempted to answer two questions: What is a species? and How does speciation occur? Evolutionary biologists are more than happy to define species. Indeed, there are almost as many definitions of species as there are evolutionary biologists. By far the most widely used definition is Mayr and Theodosius Dobzhansky's biological species concept, which defines species essentially by reproductive isolation: to be members of the same species, organisms must be capable of interbreeding and producing fertile offspring under natural conditions. Therefore, organisms that can't do this (*i.e.* that are reproductively isolated from one another) are *not* members of the same species.

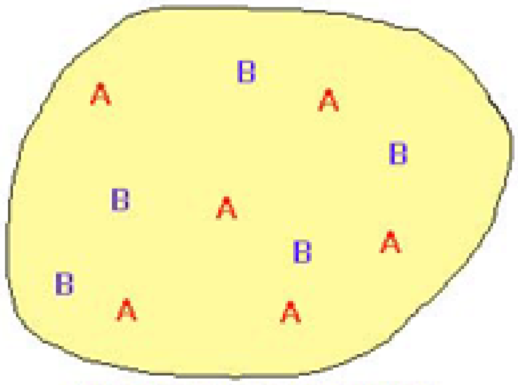
A Simplified Model of Allopatric Speciation

According to Mayr's theory, speciation can occur whenever a small subset of a large, interbreeding population becomes reproductively isolated from that large population. Consider a simplified model of such a large population:



Original Panmictic Population

Since this population is freely interbreeding (by definition), any new allele that appears within this population (i.e. via mutation of an existing allele or acquisition of a new allele from another population via gene flow) can potentially spread throughout the population.

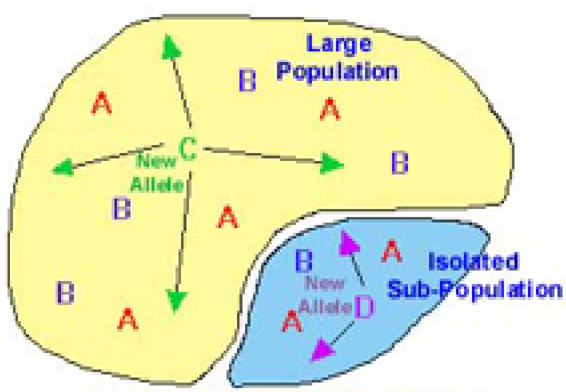


Later Panmictic Population

- **If the new allele is a deleterious mutation (as most mutations are), it will be removed from the population; rapidly and completely if the mutation is dominant, or slowly if the mutation is recessive (recall that, according to theory at least, once a deleterious mutation reaches a sufficiently low frequency in a population, it can be completely removed as the result of random genetic drift).**

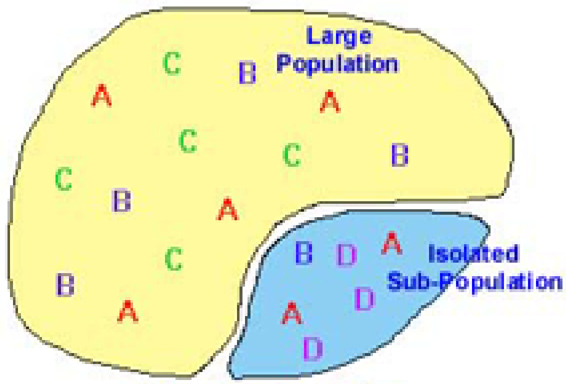
- **If the new allele is either neutral (as often happens) or beneficial (as rarely, but occasionally happens), then it will tend to spread throughout the population, so long as all individuals are freely interbreeding.**

However, if a small sub-population of this original population is reproductively isolated from it (i.e. there is reduced or negligible gene flow between the larger population and the smaller, isolated sub-population), then any new allele that occurs in either population will not spread to the other:



Effects of Geographic Isolation

Therefore, the longer these two sub-populations are kept reproductively isolated from each other, the more different alleles will accumulate in each. Eventually, the accumulation of such non-identical genetic elements can result in partial or complete genetic incompatibility between the two sub-populations, and they then qualify as two species (according to Mayr's biological species concept).



Allopatric Speciation

If we accept Mayr 's definition of a species, then the key to speciation is anything that will cause reproductive isolation. This is fine when the cause is geographic isolation: that is, when organisms are so far apart that the probability of their mating with each other is effectively zero. In technical terms, this is called "allopatry" (from the Greek prefix *allos*, meaning "other" and the Latin word *patria*, meaning "country" or "homeland"). Speciation that results from allopatry is therefore allopatric speciation.

Central to Mayr 's concept of speciation via allopatry is the idea that reproductive isolating mechanisms (that is, the things that result in reproductive isolation) are incidental: they are not the result of natural selection. In this, Mayr is following Darwin's lead, who stated in the *Origin of Species* that natural selection cannot possibly produce increasing degrees of hybrid sterility or reproductive incompatibility.

- **Darwin, while on the voyage of *HMS Beagle*, observed that British sailors very avidly mated with women wherever the ship put in to port, including in Australia, where they mated with Australian Aborigine women. British scientists later asserted that such matings did take place, but that no offspring were produced, an observation that implied that British men and Aborigine women were members of separate species (an idea that dovetailed with the prevailing racism of the time). However, later investigation showed that offspring were produced by such matings, but were systematically killed by the Aborigines.**

Are we locked into the idea that speciation is the result of "incidental factors" which cannot be the result of selection? As Darwin first pointed out, when evolutionary biologists observe reproduction between individuals of different species, they observe the whole range of reproductive compatibility, from full hybrid fertility to full hybrid sterility/inviability. This would seem to undermine the biological species concept and the concept of allopatric speciation, but does it? Just what is a species? And, how does speciation occur in most natural populations?

Species Concepts

Here is a short list of criteria that have been used to define species (there are more):

Morphology (i.e. appearance): Classically, this what has been used most often to define species. However, what if two individuals that have been classified as members of different species are capable of interbreeding? This has happened repeatedly, as naturalists have learned more about organisms in nature.

Reproductive Incompatibility: As has been noted previously, this is the most commonly used criterion today. However, there are organisms that appear virtually identical, yet are reproductively sterile if they mate. And, conversely, there are groups of organisms that are all reproductively compatible, yet include individuals with widely divergent morphologies.

Behavioral Isolation: Some biologists have proposed that species should be distinguished primarily by whether or not individuals recognize the mating displays and/or signals of other individuals; if they do, they are members of the same species. However, this definition is obviously very limited; how would one apply it to plants, or fungi, or bacteria, or any other organism that doesn't actively display and/or mate with another organism?

Niche Exclusivity: In ecology, the niche of an organism is the totality of its interactions with the various components of its environment; a species can therefore be defined as a group of organisms inhabiting essentially the same niche. This concept is reinforced by Gause's Law: two species cannot simultaneously inhabit the same niche in the same ecosystem. However, if one uses this definition of species, one is using an essentially circular definition: a species is what inhabits a certain niche, which is defined by the species which inhabits it, etc. *ad infinitum*... Furthermore, it is very problematic to define the boundaries of a niche in nature; again, the usual way to do this is to inventory all of the interactions between the members of an already-defined species, and then call that the species' niche - circularity again.

Phylogeny (i.e. shared derived characteristics): This species concept is based on the same criteria as cladistic classification: the absence or presence of shared derived characteristics. However, phylogenetic lines can change without branching; does this mean that the organisms at widely separated parts (*i.e.* times) of such a line are members of the same species? Furthermore, what if two branches fuse together (i.e. hybridize); how should we classifying the resulting species?

Why are there so many different definitions of what constitutes a "species?" One reason is that each definition fits the "needs" of different groups of evolutionary biologists.

- **For example, the phylogenetic species concept is preferred by systemitists and taxonomists; they generally reject the biological species concept as being unusable for systematic classification.**

Again, there are almost as many definitions of what constitutes a species as there are different branches of biological science. However, most of these can be subsumed under one of four broad species definitions:

- **Biological Species Concept,: species are defined by reproductive isolation (*i.e.* members of different species cannot successfully exchange genetic material). According to this definition,**

species have reproductive isolating mechanisms which prevent interbreeding. The problem with this definition is that it really only works with animals, and even then not with all of them (it seems to work best with birds). In particular, it is completely useless for defining species of asexually reproducing organisms (of which there are very, very many).

- **Phenetic Species Concept (also called "Numerical Taxonomy"): species are defined by a quantitative analysis of their characteristics, as determined via comparisons of empirically quantified characteristics. Formerly very popular, this technique relied on computer/numerical analysis of similarities and differences in empirical (*i.e.* observable) characteristics. However, there is no intrinsic mechanism that defines which characteristics are important (from an evolutionary standpoint) and which are accidental/irrelevant.**

- **Phylogenetic Species Concept (*i.e.* cladism): Very similar in some ways to the evolutionary species concept, this concept is based on the presence or absence of shared derived characteristics. If two organisms share the "same" set of derived characteristics, they are considered to be members of the same species. However, cladism is not necessarily tied to any form of descent with modification; for example, it can just as easily be used to classify office furniture as living organisms. Furthermore, this concept is highly dependent on detailed information about the characteristics of organisms; these characteristics are quantified, and then the results are used to construct a cladogram, the "fit" of which is either accepted or rejected using statistical analysis. As in all such analyses, if there isn't enough data to perform such an analysis, an organism simply can't be classified. Recent attempts to clear up some of these difficulties using purely molecular genetic analyses have been confounded by the discovery that widely divergent organisms share very similar DNA sequences. Does this mean that they are closely related? Why or why not, especially if one's criterion is only the absence or presence of shared derived characteristics?**

- **Species Recognition Concept: As described earlier, this concept depends on mating behavior - organisms are members of the same species if they recognize each other's mating displays and behaviors, and successfully mate. Again, this is only applicable to animals, and not even to many of them. And, there are many cases in which organisms from widely divergent species will attempt to mate with each other. Males, in particular, are not very "picky" about whom they will mate with, and will attempt to exchange genetic material with members of widely divergent species (or even kingdoms, in the case of orchid wasp-mimics).**

The "Species Problem" is that none of these concepts really help in the understanding of species or speciation. As noted above, the definition of what constitutes a species varies from discipline to discipline in biology. However, if you ask the local people in a particular area what species of animals and plants they recognize, they will get very close to the same set of "species " as those recognized by professional systematists. So, are these "real" species?

Darwin (as usual) may have had a more useful definition of what constitutes a species than most modern systematists. According to Darwin,

- **"To sum up, I believe that species come to be tolerably well-defined objects, and do not at any one period present an inextricable chaos of varying and intermediate links…" (*Origin of Species,*1st ed., pg 177/Wilson, pg 563, emphasis added)**

But is this true?

The Origin of the Specious

We have been wrestling with the concepts of species and speciation, trying to determine which (if any) of the various species concepts are most useful, and which mechanism of speciation is the most important in nature. But all of this has been predicated on the assumption that species actually exist outside of the human imagination. Is it possible that all of this has been an exercise in futility, a kind of "origin of the specious?"

Consider the fact that nearly all of the people whose opinions on the subject we have been studying have themselves studied animals almost exclusively: Darwin, Dobzhansky, Gould, Mayr, Simpson *et al*. Not really surprising: after all, we're all animals and most interested in ourselves. Furthermore, the most widely applied definition of a species, the so-called "biological species concept " was most forcefully advocated by Ernst Mayr in *Animal Species and Evolution*. Might there be something peculiar about animals that predisposes people who study them to frame the question of what a species is in such a way as to inevitably get the biological species concept as the answer?

In a word, yes: Lynn Margulis of the University of Massachusetts has argued forcefully for the following radical interpretation of the concept of "species":

- **There are no such thing as "species" among the most numerous and diverse organisms on Earth: the prokaryotes (commonly referred to as "bacteria") either don't have species at all in any commonly accepted sense, or they are all one huge "species."**

- **Horizontal gene transfer (*i.e.* gene transfer from organism to organism without sex, reproduction, and therefore "descent") hopelessly muddies the phylogenies of whole kingdoms of organisms (including many animals, and possibly including ourselves).**

- **In particular, the Protoctists (*i.e.* unicellular eukaryotes, also referred to as Protists) have such diverse and bizarre sexual and reproductive behaviors as to be all but unclassifiable (some have as many as eight "sexes"!)**

- **Nearly all fungi and many plants are generally indifferent to species boundaries.**

As sessile organisms, fungi and plants they can't be choosy about whom to mate with; whomever is nearby will do. This is particularly true for the fungi, who very rarely "go outside" – they live nearly their entire lives underground as widely distributed networks of tubular cells called hyphae. Orchids have been known to hybridize across not only species lines, but across genera and even families. And nearly all plants have the ability to reproduce asexually; indeed, some (like the dandelion) have given up sexual reproduction entirely and are therefore in essentially the same category vis-à-vis reproductive incompatibility as bacteria.

Pretty radical stuff, and a kind of "universal acid" for the biological species concept for anything except animals (but watch out for whiptail lizards). Lynn Margulis is admittedly a radical, but one with a solid track record. Her theory for the evolution of eukaryotes, called "serial endosymbiosis", was considered the ravings of a lunatic when she first proposed it in 1969. Now it is the most mainstream of orthodoxies. So, how about it: are non-animal species "real"? Consider the following:

The Taxonomy of Bacteria

(From: Margulis, Lynn and Sagan, Dorion (2002). *Acquiring Genomes: A Theory of the Origin of Species*, Basic Books, New York, NY, pp. 54-55.)

- **"For the numbers of living species…we have only crude estimates that may be wildly incorrect. Animals, probably because people are good at distinguishing beetles, dominate. Over 10 million – perhaps as many as 30 million – are thought to exist. Some 500,000 plants, 100,000 fungi, and 250,000 protoctists are suggested to be lurking in the woods and waters of this world. As for bacteria, although thousands have been named as species and no doubt thousands can be distinguished, the [biological] species concept doesn't apply. Although bacteria can be grouped on the basis of common features, these groups change so quickly that they are never fixed and recognizable like eukaryote species. Bacteria pass genes back and forth. All can simply reproduce, and thus at any given time have but a single parent. The intervention of sex…is a unidirectional affair. The genes pass from a donor to a recipient…but donors can change to recipients and vice versa in minutes. Furthermore the gene swapping is entirely optional…[I]ndeed bacteria are willing and able to "have sex" with naked DNA molecules that they absorb from the water in which they are bathed."**

- **"Life originated with bacteria; therefore we can say that the origin of life was concurrent with the origin of bacteria. But we agree with Professor Sorin Sonea and his colleague Lucien Mathieu, of the Université de Montreal, that bacteria do not have species at all (or, which amounts to the same thing, all of them together constitute one single cosmopolitan species). Speciation is a property only of nucleated organisms."**

The Taxonomy of Some Common Trees

So, perhaps taxonomists have been missing the forest for looking too closely at the trees? Consider these seemingly obvious tree species (you can see most of them by stepping outside this building and simply looking around):

SPECIES: *Acer saccharum*

COMMON NAMES :
- **sugar maple**
- **rock maple**
- **hard maple**

TAXONOMY :
The currently accepted scientific name of sugar maple is *Acer saccharum*. Sugar maple is highly variable genetically and taxonomic controversy abounds. Some taxonomists recognize two to six varieties, but others recognize these entities as forms or subspecies. Several ecotypes or races, each exhibiting clinal variation, have also been delineated.

Florida maple (*A. barbatum*), chalk maple (*A. leucoderme*), and black maple (*A. nigrum*) hybridize and intergrade with sugar maple and are often included in the sugar maple complex. Some authorities recognize these taxa as subspecies of sugar maple, but most delineate them as discrete species. Sugar maple hybridizes with red maple (*A. rubrum*) in the field, and with bigleaf maple (*A. macrophyllum*) under laboratory conditions. *Acer senecaense* is a hybrid derived from an *A. leucoderme* x *A. saccharum* cross. *A. skutchii* is closely related to sugar maple and is treated as a subspecies by some taxonomists.

AUTHORSHIP AND CITATION :
Tirmenstein, D. A. 1991. *Acer saccharum* In: U.S. Department of Agriculture (2002, September), Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory Fire Effects Information System:
http://www.fs.fed.us/database/feis/plants/tree/acesac/introductory.html

SPECIES: *Quercus alba*

COMMON NAMES :
- **white oak**
- **stave oak**
- **ridge white oak**
- **forked-leaf white oak**
- **fork-leaf oak**

TAXONOMY :
The currently accepted scientific name of white oak is *Quercus alba*. Three varieties of white oak are commonly recognized:
- ***Quercus alba* var. *alba***
- ***Quercus alba* var. *repanda* Michx.**
- ***Quercus alba* var. *latiloba* Sarg.**

Some authorities recognize these entities as forms rather than varieties.

White oak is highly variable genetically, and many forms and ecotypes have been described. According to Fowells, "no definite races have been defined, but within such a tremendously diverse habitat, climatic races undoubtedly exist." White oak readily hybridizes with many other species within the genus *Quercus*, including swamp white oak (*Q. bicolor*), bur oak (*Q. macrocarpa*), chinkapin oak (*Q. muehlenbergi*), dwarf chinkapin oak (*Q. prinoides*), overcup oak (*Q. lyrata*), swamp chestnut oak (*Q. michauxii*), sandpost oak (*Q. margaretta),* chestnut oak (*Q. prinus*), English oak (*Q. robur*), Durand oak (*Q. durandii*), and post oak (*Q. stellata*). Hybrids, their common names, and purported origins are listed below:

- **Beadle oak X *beadlei* Trel. (*Quercus alba* x *michauxii*)**
- **Bebb oak X *bebbiana* (*Q. alba* x *Q. macrocarpa*)**
- **Deam oak X *deamii* (*Q. alba* x *Q. muehlenbergi*)**
- **Faxon oak X *faxonii* Trel. (*Q. alba* x *Q. prinoides*)**
- **Fernow oak X *fernowii* Trel. (*Q. alba* x *Q. stellata*)**
- **Jack oak X *jackiana* Schneid. (*Q. alba* x *Q. montana*)**
- **Saul oak X *saulii* Schneid. (*Q. alba* x *Q. prinus*)**

Saul oak was formerly known as *Q. alba* f. *ryderii* but is now considered a heterozygous hybrid form of white oak. Introgressive populations are locally common throughout much of the range of white oak. Hybrid swarms derived from complex mixtures of parental forms are particularly common on disturbed sites, at the margins of white oak's range, and where several oak species occur sympatrically.

AUTHORSHIP AND CITATION :
Tirmenstein, D. A. 1991. *Quercus alba* In: U.S. Department of Agriculture (2002, September), Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory Fire Effects Information System:
http://www.fs.fed.us/database/feis/plants/tree/quealb/introductory.html

SPECIES: *Salix nigra*

COMMON NAMES :

- **black willow**
- **swamp willow**
- **southwestern black willow**
- **Gulf black willow**
- **scythe-leaved willow**

TAXONOMY :

The currently accepted scientific name of black willow is *Salix nigra*. Recognized varieties are *S. nigra* var. *nigra*, *S. nigra* var. *altissima*, *S. nigra* var. *falcata*, and *S. nigra* var. *lindheimeri*. *Salix nigra, S. gooddingii*, and *S. amygdaloides* are closely related taxa commonly referred to as the black willows. The three species are not easily distinguished morphologically, and in fact, some authorities consider *S. gooddingii* to be *S. nigra* var. *vallicola* or *S. n*. var. *venulosa*. *S. amygdaloides* is sometimes considered to be *S. nigra* var. *amygdaloides*. For our purposes, however, these varieties will be considered as separate species. *S. nigra* hybridizes with *S. amygdaloides* (*S*. X *glatfelteri* Schneider); *S. alba* (S. X *hankensonii*); and *S. lucida* (S. X *schneider*).

AUTHORSHIP AND CITATION :

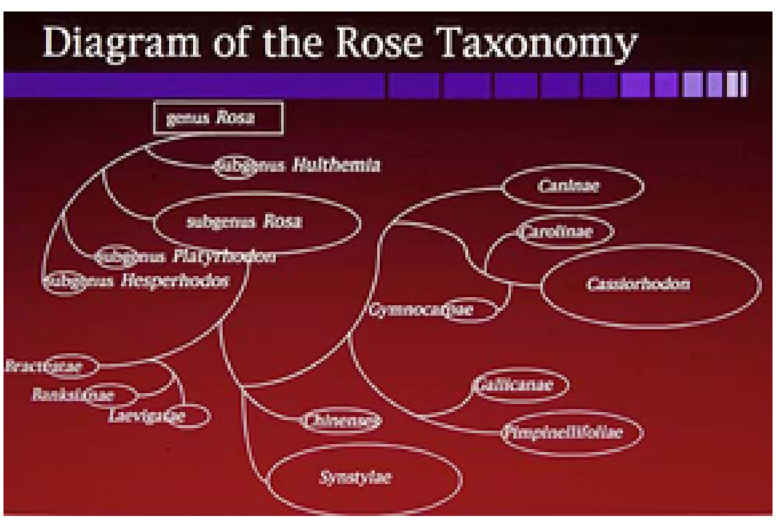
Tesky, Julie L. 1992. *Salix nigra* In: U.S. Department of Agriculture (2002, September), Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory Fire Effects Information System:
http://www.fs.fed.us/database/feis/plants/tree/salnig/introductory.html

The Taxonomy of Roses

Ah, but according to Gertrude Stein, "a rose is a rose is a rose", right? Well, check these out:

Relationships Among Some Species of Roses
(From: Ma, Y., Crane, C. F., and Byrne, D.H. (1997). Relationships among some *Rosa* species, *Caryologia*, vol. 50, n. 3-4, pp. 317-326)

- **"The genus *Rosa* is widely distributed and taxonomically difficult. The great majority of its 200 species hall into the ten sections of subgenus *Rosa*; the three other subgenera contain one to three species each. Morphological and ecological variation with subgenus *Rosa* is almost continuous because of wide adaptation, wide limits of crossability and hybrid fertility, and frequent human intervention in bybridization and dispersal. Polyploidy is frequent in sections Pimpinellifoliae, Gallicanae, Cinnamoneae, and Caninae of subgenus *Rosa* and essentially absent elsewhere among the wild species. Karyotype analysis is a traditional first step in the comparison of genomes among related species that are to be included in a breeding program."**



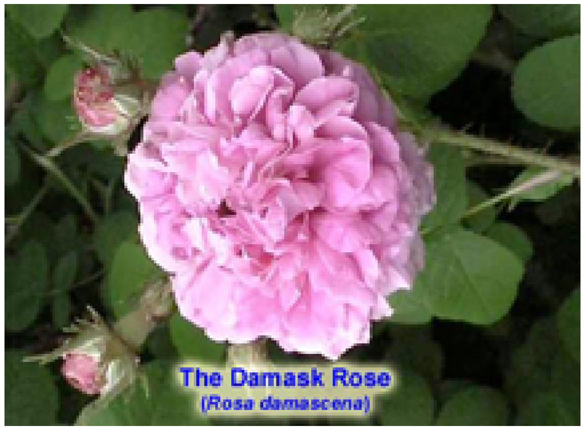
Chromosomes in Relation to Sterility in Roses
(From: Pal, B. P, (1972). ***The Rose in India*****, 2nd Ed. Maggs Bros, Ltd, New Delhi, RI)**

- **"The basic number of chromosomes in roses is 7, and several important species of Asian origin, which have contributed significantly to the development of such famous groups as the Hybrid Perpetual and the Hybrid Teas, are diploids, having 14 chromosomes (7 maternal and 7 paternal). These include *moschata, gigantea, multiflora, wichuraiana* and *chinensis.* A number of Western species with which these Asian diploids crossed to yield several modern groups of roses are tetraploids, with 28 chromosomes. These, which had their chromosome number doubled during the course of their evolution, whose record we do not have, include *gallica, foetida* and their derivatives such as *damascena* and *centifolia."***

- **"One of the more important crosses involving these species of diverse geographical distribution was that between *gallica* and a variety combining in it the genes of *chinensis* and *gigantea.* The hybrid arising directly from this cross was a triploid, having 21 chromosomes, 14 from the European parent and 7 from the Asian. This imbalance made it sterile and restricted its utility; but plants with 28 chromosomes arose spontaneously from it. They were fertile and gave rise to the Hybrid Perpetuals with the further incorporation of some *damascena* genes."**

- **"A triploid origin has also been shown for the Hybrid Teas, which followed and replaced to a large extent the Hybrid Perpetual. The Hybrid Teas were derived from a cross between the tetraploid Hybrid Perpetuals and a diploid variety of the Tea roses which combines in it the genes of three Asian *(moschata, chinensis* and *gigantea)* and one European *(damascena)***

species. As in the case of the Perpetuals, tetraploid varieties were spontaneously obtained from the original triploid hybrid; this restored the fertility of the plant, making it possible to obtain many different combinations of genes in its progeny."



- **"The condition of triploidy resulting from the crossing of diploid and tetraploid parents, associated as it was with hybrid sterility, delayed the release of gene combinations which were destined to develop into our modern groups of roses. Not all triploid hybrids, however, had to wait for a change to the tetraploid level before their usefulness could be appreciated…There are also examples where a cross involving a diploid and a tetraploid skipped the expected condition of triploidy and gave rise to the tetraploid state directly through an abnormal behavior of the diploid parent, which passes its entire complement of chromosomes to its sex cells in place of only half the number, which is the normal practice."**

The Present State of Taxonomy of the East European Roses
(From: Schanzer, L.A. (2001) Biological Series, vol. 106, part 2, pp. 1-2)

- **"Critical overview of the taxonomic literature on the East European species of *Rosa* leads to the conclusion that this genus is still extremely inadequately studied as to species composition and relations. Quite a number of species, infra-, and superspecific taxa described so far do not make the taxonomy and nomenclature of the group any more clear. They moreover make any firm determination of most of the species perfectly impossible. Data available on chromosome numbers, interspecific crossings, and compatibility of West European species point to the necessity of such studies of East European species as well. The latter remain completely unstudied in these respects so far. On the other hand, sparse data on infrapopulational variability of *Rosa* suggest such studies to be important to understanding of many disputable questions of the *Rosa* taxonomy."**

Conclusion:

A rose by any other name would smell as sweet, but that doesn't help us with the classification of roses.

Perhaps Darwin's most important insight was his realization that species are not immutable, that they can intergrade over time in an "insensible series." But what Darwin didn't have the courage to say, and which evolutionary biologists in general don't have the courage to propose, is that there are really no such thing as "species" at all. Darwin should have realized this: he made it clear that natural selection happens at the level of individuals, never at the level of species. Evolutionary biologists have agreed with him, but have not taken the obvious next step: to declare that individuals living organisms are the *only* things that exist in the natural world, and that species (including animal species) may quite literally be figments of the human imagination.