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Photo Credit: Joy Okazaki

East Meets West
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Conifer Society Voices

Cover Photo: Kubota Garden - Venue ACS National Meeting

WE'VE MOVED!

The Society's National Office has moved from Maryland to North Carolina. Our new contact information is:

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Where Do New Plants Come From?

by Glenn Herold

Editor's Note: Don Howse invited additional comment in his article, "Changing Genes–Brooms, Sports, and Other Mutations" beginning on page 38 in our Winter 2007 issue. Here is Glenn Herold's follow-up. Both Don and Glenn are regular contributors.

Plants new to the horticulture industry originate either from seedlings that have been selected out, from mutations on existing plants, or from cultivariants. Though new species continue to be found and introduced, this is a rare occurrence. Today, the plants introduced into the industry are more likely to come from differences within a plant population, rather than from a new population. There are very few places on earth, especially in the temperate world, which have not yet been combed for new plants. The challenge now is to search the existing populations for the unusual.

Variations in seedlings may either be as a chance occurrence, selected from a specific parent, or produced through controlled pollination. An example of a chance occurrence is *Pseudotsuga menziesii* 'Wycoff's Big Blue' Douglas fir, selected by Hugh Wycoff for its foliage color from thousands of seedlings grown on a Christmas tree farm. Attributed to the same discoverer is 'Wycoff's Dwarf' - a diminutive Douglas fir that also originated as a seedling. Seedling mutations are occasionally discovered in nurseries, but are usually found in the wild by people with a keen eye, such as Hugh Wycoff.

Seedlings selected from specific parents have also been introduced. Dr. Sidney Waxman, who did his work at the University of Connecticut, evaluated and selected many plants derived from the cones of witches' brooms. An example is *Pinus strobus* 'Sea Urchin' white pine, a tight dwarf form with bluish needle color. Iseli Nursery in Oregon has also done extensive work with seedlings of dwarf conifers. In 1986 they collected and sowed seed from *Chamaecyparis obtusa* 'Nana Gracilis' with the goal of finding a dwarf blue seedling of the species. Over 50,000 seedlings were grown from this crop, but no blue one was found. However, a tremendous variety of sizes and colors did emerge, ranging from large trees to miniatures and with foliage in various shades of green and yellow. Some of the original plants are still under evaluation, and may be named and introduced in the future.

Other seed grown plants are produced through controlled pollination. This method is common in the forestry industry, where they are constantly in search of larger, faster growing, and more uniform trees. Many of these are considered hybrids, where two parents with known desirable characteristics are crossed in an attempt to display both of these qualities in their progeny.

A cultivariant is a plant that displays a certain growth habit based on the position of the propagule on the mother plant. In other words, a cutting taken from a side branch of a pyramidal plant will tend to form a spreading plant. This tendency to grow in the same direction is called topophysis. Though its form is different than the mother plant, it remains genetically identical, and thus is a clone. Numerous species exhibit this phenomenon, including yews, spruces, and firs.

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Mutations are accidents of nature. The dictionary defines a mutation as a heritable alteration of the genes or chromosomes of an organism. So two things must occur - the genes must be altered, and that change must be passed on to succeeding generations. Essentially, a mistake occurs in the cell replication process, resulting in a recombination of genes. Most of these mistakes will never have outward expression, but a few make themselves known in various ways. One of these ways is as a witches' broom, where the growth rate of one part of a plant is significantly slower than the normal rate, resulting in an area of dense growth. The phrase witches' broom originates from the German word *hexenbesen,* which means to bewitch (*hex*) a bundle of twigs (*besom*). In medieval times, sweeping brooms were made from bundles of twigs, and occurrences that could not be explained were blamed on witchcraft. The term *hexenbesen* came into use as a way to explain this aberration in plant growth. Some still believe this.

It is not unheard of for a plant produced from a witches' broom to itself have a witches' broom. An example is *Picea abies* 'Little Gem', originating as a witches' broom on *Picea abies* 'Nidiformis', which itself was a broom on *Picea abies* (Norway spruce.) Other ways in which mutations may be expressed are: foliage color (*Picea orientalis* 'Skylands'); variegated foliage (*Chamaecyparis nootkatensis* 'Aureovariegata'); fixed juvenile foliage (*Chamaecyparis pisifera* 'Boulevard'); or a change in growth habit (*Pinus strobus* 'Pendula' or *Pinus strobus* 'Fastigiata'). It is these changes that provide the different shapes, colors, and sizes that give conifers their multi-season interest. Because of the different gene combinations possible in the plant genome, the number of possible variations in conifers is infinite.

Seedling variations are often favored by plantsmen because they tend to be more genetically stable than bud sports or mutations. For over 20 years Dr. Waxman collected seeds from witches' brooms and grew seedlings from them. He discovered a high percentage of compact and dwarf forms among them and selected several to be named and introduced into the nursery industry. He discovered that almost 100% of the reproductive structures produced by witches' brooms are female. To produce viable seed, they must be pollinated, and the pollen is likely to come from a normal plant. Any seedling population will show variations in color, rate of growth, or growth habit. Whether in plants or animals, this variation is

Photo Credit: Anita Gould

This pathogenic witches' broom has succumbed to the fungal attack.

normal, but the progeny is usually similar to one or both parents. With one parent being dwarf and the other of normal size, however, one could expect a tremendous variety of progeny, and that is exactly what he found. Others have replicated Dr. Waxman's work and found the same to be true.

Pathogenic vs. Genetic Witches' Brooms

So far, we have talked about witches' brooms as being caused by mutations, but there are also a considerable number of witches' brooms caused by pathogens. Pathogenic brooms are found on sycamore, honeysuckle, hackberry, spruces, and many other plants. They may be caused by fungi, mites, aphids, viruses, or other pathogens. Plants propagated from this material do not retain their dwarf characteristics, but rather revert back to their normal growth habit when freed of the pathogen. Though of horticultural interest, they do not result in new clones. There is no change in the genetic material of the plant. One way to diagnose a witches' broom as being pathogenic is to note the frequency of brooms on trees of like species in the area. If the brooms are a common occurrence, it is likely to be pathogenic, for the discovery of more than one genetic broom in an area is rare.

Witches' brooms can form anywhere on a tree, from the very tip to close to the ground. They may be very small, discernable only to the trained eye, or dominate the tree. Occasionally, more than one genetic broom will form in a tree, but this is a rare find. Though it usually does not adversely affect the health of the tree, sometimes it can lead to tree

Photo Credit: Anita Gould

This spruce in Alaska has a mutagenic broom both at the top and near the middle of the tree.

decline. Perhaps a large broom diverts energy away from the rest of the tree causing it to suffer from poor vigor over time. This may, in turn, make it open to more opportunistic pathogens to invade the tree.

Plants propagated from witches' brooms may suffer a similar fate. For example, *Pinus sylvestris* 'Riverside Gem' develops into a dense, upright plant with a tight eight-foot conical habit. However, it rarely lives beyond 20 years.

Witches' brooms can form anywhere on a tree, from the very tip to close to the bottom.

One year it will be attractive and healthy, the next year it will be dead. Some broom hunters ("broomers") have found this to be true of brooms on the tree as well.

One explanation for the cause of witches' brooms lies in the hormone levels in the broom. The plant hormone cytokinin is found at a higher than normal level in witches' brooms. This hormone stimulates cell division and tends not to travel freely throughout the plant. On the other hand, gibberellins are present at reduced levels. This hormone is responsible for shoot elongation. Thus, the combination of the two encourages cell division, but discourages shoot elongation.

Broomers have their favorite hunting grounds. Brooms have been found in deserted woodlands, city streets, and rural roadsides. But most will tell you that their favorite place to look for brooms is in a cemetery. Some explain this by stating that solar reflection off of the monuments causes genetic mistakes in the dividing buds. Others simply state that the trees in cemeteries tend to be older, larger, and in an open space, making the broom easier to spot. No doubt those of medieval times have a different explanation. You decide for yourself.

Causes of Mutations

One thing that is agreed upon is that witches' brooms result from mutations. What is not proven is the cause of the mutations. One probable cause is stress, both pathological and environmental. Environmental stresses that injure the growing points of branches can also trigger the formation of brooms. An environmental stress that is thought to be important in broom formation is radiation. Radiation is around us at all times and may have an adverse effect on the process of cell division. Some broomers surmise that radiation is a major factor, for they tend to find a lot of brooms beneath power lines. If the radiation damages the division process at the right place and time, a mutation will result. The extent of the damage determines the expression of the mutation.

A basic property of genetic material is the ability to exhibit variation over time. This is necessary to explain why individuals within a population are not all genetically identical. It can be both good and bad. Variation within a population is good. It allows a population to adapt to stresses and pressures that are placed upon it. The housefly survived DDT because of a mutant gene that gave it resistance to the pesticide. Douglas fir (*Pseudotsuga menziesii*) has two distinct geographic varieties. The Coastal variety (var. *menziesii*) is a zone 6 plant and typically has a yellow-green foliage color. The Rocky Mountain strain (var. *glauca*) usually has a bluish-green foliage color and is hardy to zone 4. Thus, one of the populations has genes that result in greater cold hardiness. While favorable to the survivability of a population, most mutations reduce the fitness level of an individual. So mutations are good for the population, but generally are deleterious for the individual.

Some mutations occur in regular body cells. These are known as somatic mutations. They are expressed only on the individual in which they occur. In plants, they may be expressed by a branch having a different growth rate, foliage type, or color. A slower growth rate or yellow color may eventually be swallowed up by the rest of the plant because of its reduced vigor, but if the mutant part is asexually propagated, it will result in a plant with different characteristics.

Other mutations occur in the cells that produce the gametes, or sex cells. These are known as gametic mutations. In most cases, such mutations will not even be noticed by the individual, but they will be passed on to the next generation. They may remain as recessive genes forever or expressed in the next generation. It all depends on the gene combinations.

Mutations may be spontaneous, occurring during the process of DNA replication, or induced through chemicals or radiation. The rate of spontaneous mutation varies with the organism. Those causing visible phenotypic variation have been measured to be in the range of 10^{-5} to 10^{-6} per gamete per generation in corn. In other words, a visible mutation occurs 1 in every 100,000 to 1 in every 1,000,000 times that cell division takes place. This may not seem like a lot, but when you add up the number of buds on a tree and the number of trees in a population, the frequency is significant.

Induced mutations are caused by materials called mutagens. Colchicine is sometimes applied to seedling populations of hostas in an attempt to induce tetraploidy. Seed lots of American elms and American chestnuts have been treated with gamma rays, X-rays, and ultraviolet rays in an attempt (unsuccessfully) to produce seedlings resistant to Dutch elm disease and chestnut blight, respectively. One cannot tell whether a mutation is spontaneous or induced, for the effect is the same. The process of mutation is also random. They do not automatically occur in response to a stimulus. Reverse mutations can also occur. If a mutation occurs once in a gene, there is a very small probability that the mutated gene could mutate back to its original form. We sometimes see this expressed in dwarf Alberta spruce (*Picea glauca* 'Conica'), where a branch grows with the vigor of a typical white spruce.

Mutations can affect individuals in a variety of ways. Among them are: a change in a morphological trait; nutritional or biochemical variation; a change in behavior (in animals - no one has yet demonstrated behavioral traits in plants!); or they may be lethal. It is the morphological differences that have been exploited, though nutritional variation might be important if it could be easily identified. An example of a lethal mutation is when the change prevents the expression of chlorophyll in a plant. If that change were to be asexually propagated, the plant would essentially starve to death.

There are two basic types of mutations – base substitutions and frameshift mutations. A base substitution involves the substitution of one base (adenine, guanine, cytosine, or thymine) for another. A frameshift mutation is the addition or subtraction of a nucleotide from a DNA chain. To illustrate, consider the following phrase, read as a triplet code like the genetic code: The fat cat ate the big rat. A base substitution might look like this: The fan cat ate the big rat, or: The fat mat ate the big rat. The sentence is still readable, but the meaning has been changed.

An insertion, on the other hand, results in a more significant change: The fan tca tat eth ebi gra t. Insertion of a single letter (the "n" in fat) causes the letters to shift and the genetic phrase to become unreadable. Likewise, a deletion will have a similar effect: The ftc ata tet heb igr at. Though both base substitutions and frameshift mutations are known as point mutations, because they occur at a single point on a chromosome, the effect is profoundly different.

Until we have a complete map of the genetic code of each organism, it is impossible to predict the effect of any given mutation. But it is the discovery of these changes that has made broom hunting challenging and exciting. And when one of these discoveries results in a desirable, unique plant, the discoverer is even more pleased. But when first discovered, the potential is not yet known. It's like the birth of a daughter. The parents are proud and excited when they first set eyes on her, but they do not realize the fruits of her upbringing for 20 or 30 years. Like raising a child, plant parenthood requires patience.

About the author: Glenn Herold is Professor of Horticulture at Illinois Central College in East Peoria. He is also curator of the Illinois Central College Arboretum which he founded in 1980. In addition to dwarf conifers, he is interested in woodland wildflowers, small maples and hostas. He, and his wife Terry, are members of ACS. He has served as vice president of the central region and is a past president of the Central Illinois Hosta Society.

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