THE BRODIE CLUB

ROYAL ONTARIO MUSEUM OF ZOOLOGY

THE 972nd MEETING OF THE BRODIE CLUB

The 972nd meeting of the Brodie Club was held on Jan. 21, 2003 in Room 432 of the Ramsay Wright Zoological Laboratories of the University of Toronto.

Chairman: George Bryant
Secretary: Oliver Bertin
Attendance: 16 members and three guests
Enid Machin, guest of Ann Falls
Glenn Coady, guest of Fred Bodsworth
Kevin Seymour, guest of Jock McAndrews

NEW BUSINESS:

Ellen Larsen, a UofT zoology professor, was welcomed as a new member by Ann Falls.

Longstanding member Keith Reynolds has moved to a nursing home where he would welcome any letters or cards. He can be reached via his daughter at 638 Cowan Circle, Pickering L1W-3K7, tel: 905-509-1723.

Treasurer Jennifer Young asked any procrastinating members to forward their $10 annual membership fee to her, preferably by cheque payable to the Brodie Club. Her address is 310 Hidden Trail, Toronto M2R-3R8.

Jim Rising wondered whether members would like to move the starting time of meetings ahead to 7 pm. He welcomed comments from other members. He plans to present a motion at the next meeting.

Bertin recommended "Northern Cookbook," a useful and highly amusing cookbook, published by the federal Department of mmm in 1975mmm. It contains recipes for a wild range of Canadian flora and fauna, of which jellied moose nose attracted the most interest at the meeting.

SPEAKER:

Marc Johnson introduced the speaker, Anurag Agrawal, who came to UofT's botany department as an assistant professor in the spring of 2000. Prof. Agrawal took his undergraduate and master's degrees at Pennsylvania State University, before moving to the University of California at Davis for his PhD.

Offence-defence interactions between insects and plants

Prof. Agrawal exclaimed on the truly amazing world of herbivorous insects and the plants they feed on. There is a great diversity plants of all shapes and sizes, and a similar diversity of herbivores. Of the two million known and described species, one quarter are plants, one quarter are herbivorous insects, 25 per cent are predators or saprophagous insects and the remaining quarter include all the protozoans, other invertebrates and vertebrates. Only two per cent of described species are protozoans, while 15 per cent are invertebrates and just four per cent are vertebrates.

To rub it in to the bird-watchers in the Brodie Club, Agrawal noted that the 10,000 species of known birds are a mere drop in the bucket compared to the one million insects. As for mammals, there hasn't been a new species for five years, when a find was made in Madagascar.

Plant biomass dominates the world, and photosynthesis represents 99 per cent of the energy on earth. "It is the life blood of the food chain," he said.

As plants evolved, so did the animals that feed on them, leading to a co-evolution of plants and animals. Agrawal described this co-evolution as a long-term evolutionary adjustment of one species in relation to another.

"It is an arms race," he said. "We see an arms race in adaptation and counter-adaptation on the part of insects and plants," an adaptation so important it may have led to an explosion in the diversity of plants and animals.

One characteristic of this arms race is the defence mechanism that some plants use to drive off predators. Caffeine and nicotine are two plant toxins that target particular insect receptors in hopes of driving off predators. He referred to these toxins as "secondary plant compounds" because they play a secondary role in the life of a plant, secondary to the primary roles of growth and reproduction.

Plants also use mechanical defences. Some African species, for instance, employ spines that make it difficult for a giraffe to browse on their leaves.

Agrawal has paid particular attention to the relationship between two species of plant and their insect predators. The common milkweed is an abundant plant species in southern Ontario that is a favourite food of the caterpillar of the Monarch butterfly, one of the more common butterflies in the region.

Milkweed plants are considered very toxic, yet they attract a wide range of insects through all stages of their life. Despite this, insects eat the leaf, stems, roots, flowers, seeds and sap. Monarch butterfly caterpillars are one of the most successful of the milkweed predators because it has evolved with the plant just as in Agrawal's arms race.

The butterfly lays its eggs on the surface of the leaf. The caterpillar hatches on the leaves and is immediately confronted with a forest of hairs that is designed to drive it off. But the caterpillar has developed a mechanism to neutralize these hairs. It grazes the hairs on a small area of the leaf, exposes the leaf surface and promptly begins to feed. Many caterpillars never succeed in penetrating the plant's first defence, the hairs, because the caterpillar is exposed to its own predators and to the elements during the time it takes to clear the hairs.

Once the caterpillar starts to chew on the leaf, it encounters the plant's second line of defence, a sticky, white latex that is held by the plant under pressure. When the caterpillar takes its first bite, the latex oozes out, giving the caterpillar a mouthful of latex. The latex also pushes it away and glues it to the leaf, leaving the caterpillar do die.

Agrawal noted that the latex is a secondary plant compound. Apart from defence, it has no known function.

Agrawal noted that larger caterpillars -- those that have successfully survived the hairs and the oozing latex – have developed a way to de-activate the pressure in the latex, allowing them to eat at their leisure. To do this, the caterpillars chew a notch in the leaf stem just above the base of the leaf. The heavy leaf breaks the stem and the latex oozes out, lowering the pressure of the latex in the rest of the leaf, bypassing the plant's defence mechanism. The caterpillar can then proceed to the leaf itself and have a meal.

Agrawal concluded that the insects that successfully graze on the milkweed tend to be specialists that have co-evolved with the plant over many generations. In effect, the plant and the insect have imposed genetic traits on each other.

Agrawal has done much of his field work at the Koffler farm west of Newmarket, a remarkable station that the Brodie Club visited in its field day in June, 2001. To test his hypothesis on the genetic contribution to the latex-Monarch defence mechanisms, Agrawal planted a field of milkweed using a variety of seeds of differing genetic background. Some milkweed varieties have low latex levels and some high. He charted the interaction between insect predation and the level of latex and found a clear negative correlation, proving his point. A similar test showed that plants that are genetically geared to have a high density of hairs on the leaves suffer lower predation. These tests indicate that evolution is modified by the members of the community.

Agrawal has also studied the co-evolution of defence reactions in the Brassica or cabbage plants and their prime predator, the Cabbage White butterfly. This butterfly species was imported from Europe and has become one of the more common butterfly species in southern Ontario. It feeds exclusively on the members of the Brassica, a group that includes cabbages, broccoli and mustard.

The butterfly lays eggs on the mustard plant, which turn into chrysalids which, interestingly enough, can change their colour to match their background.

Brassica use a chemical reaction to limit predation. The plants contain a harmless secondary compound called glucosinolate which is stored in the leaves. When the leaves are crushed, the glucosinolates are released and react with an enzyme that produces a toxic substance, mustard oil or isothiocyanate. This substance is found in mustard, horseradish and Japanese wasabi, pleasant condiments when eaten in small quantities on pork, beef or sushi, but a toxin which disrupts the sodium-potassium channels in insect predators.

Agrawal noted that wasabi traditionally comes from *Wasabia japonica*, but he said Japanese restaurants in Toronto typically use finely grated horseradish mixed with green food-colouring instead of the genuine product.

Agrawal noted that isocyanate is highly volatile. They act as toxins for a short time before vapourising, leaving the plant open to predation.

Unlike most other animals, Agrawal noted that Cabbage White butterflies – both larvae and adults -- are attracted to Brassica plants. To demonstrate this phenomenon, he drew a chart of glucosinolate concentration compared with the density of predators. He found a positive correlation with Cabbage White butterflies but a negative correlation with other species. That led him to conclude that specialist predators like the Cabbage White butterfly are untouched by the toxin while generalists are driven off. To double-check his hypothesis, Agrawal fed active horseradish powder to Cabbage White caterpillars, and they ate it happily. Then he fed deactivated horseradish to the caterpillars, and they positively thrived.

He also found that caterpillars store isothiocyanate in their bodies, making them distinctly unappetizing to their own predators.

QUESTIONS:

- Bertin recalled being told that elephants moving through a forest take one mouthful of each plant they encounter. Agrawal referred to this as the toxic dilution hypothesis. The elephants ingest a low dose of toxin from each plant, allowing them to have a full meal by the end of the day, without taking in a lethal dose of any one plant. Agrawal said grasshoppers and other generalists do much the same thing.
- McAndrews noted that parrots often detoxify their meals by ingesting clay, while turtles eat certain minerals and some butterflies eat sodium before a meal.
- Falls and Coady said one herbivore often release the volatile toxic, attracting other herbivores which can then feed in peace.
- McAndrews remarked on the remarkable specificity of some insect-plant interactions. Monarch butterflies will recognize and feed only on one species of plant, the milkweed.
- Bertin noted that aphids congregate on tobacco plants in large numbers. Agrawal said specialist aphids will feed on tobacco sap.

The speaker was thanked by Jean Iron.

NOTES & OBSERVATIONS:

Bryant recently visited Baja California, where he travelled 1,000 miles from top to bottom. He encountered the boojum tree on his journey, “a totally bizarre” species in its own family that resembles an upside-down carrot.

Falls and Tasker also went to Baja California where they saw 130 species of birds, including seven new ones. A White-throated Sparrow recently visited his yard for about a month.

Iron and Sandra Eadie saw a Northern Hawk-Owl near the Guelph Line on the south side of Hwy 401. This owl is typically found in the boreal forests near Hudson Bay.

Iron also saw a hybrid of a Redhead and a Canvasback duck. Coady said he may have seen the same bird.

Machin saw a Cooper's Hawk near Bayview Village in suburban Toronto.

Coady has seen Redhead ducks in increasing numbers every year, especially between Christmas and New Year's Day. He recently saw an estimated 8,000 to 10,000 birds in the Toronto area. He suspects they come up from Lake Erie when it freezes over.

Fred Bodsworth and George Fairfield saw a Fox Sparrow in north Toronto. It is an unusual bird that is rarely seen in winter.

Marc Johnson has been studying insects on Evening Primrose. He has counted about 150 species on the plant, both herbivores and insect predators.

NEXT MEETING:

The next meeting will be held at 8 pm on Feb. 18 in Room 432 of the Ramsay Wright Zoological Laboratories of the University of Toronto. The speaker will be David Mcleish, lake manager of the Upper Great Lakes Management Unit of the Ontario Ministry of Natural Resources. He will speak on *An Ecosystem Approach to Managing the Great Lakes*.

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