used interchangeably, snowflakes are in fact intricate structures composed of smaller sub-structures called snow crystals, which are in turn derived from conglomerates of ice crystals. The ice crystals themselves are formed when water molecules aggregate into hexagonal structures. The hydrophilic properties of water naturally cause the water molecules to attract to one another in this six-sided formation, ice crystals nucleate around tiny particles in the air, such as salt or dust, to form snow crystals. As the snow crystals fall to the earth, additional snow crystals accumulate, ultimately form snowflakes. The distinctive morphology of the snowflake is shaped as the snow crystals pass through different air temperatures, wind patterns, and humidity levels. Changing any of these conditions can significantly modify the shape of the snowflake. Indeed, highly complex snowflake morphologies indicate correspondingly complex migration histories, and since no two snowflakes take the same path in their decent, it is highly unlikely that any two snowflakes will ever be alike (Nakaya 1954).

The mystery of the hexagonal morphology of snowflakes was finally solved three hundred years after Kepler first proposed the question as a challenge to the scientific community. Nature has long been a sense of intrigue for many, and thanks to the contributions of individuals like Kepler, Descartes, Hooke, Bentley, and Martin, E.B. (1998). Snowflake Bentley. Boston: Houghton Mifflin.


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One of the greatest frustrations with studying conservation biology at the undergraduate level is that, while it often leads to an understanding of the environmental issues, it rarely offers the opportunity to personally confront them. The dichotomy between an active involvement in learning and a passive understanding is not a problem limited to the field of conservation biology; it extends to most large, memory-intensive science courses at Dartmouth. Biology 52, a course on the behavioral ecology of invasive species, stands out as an example of how to avoid these common pitfalls. Two features in particular distinguished it from other similar classes. First, as a seminar-style course with small enrollment, it allowed for a considerable amount of student interaction. Second, the ultimate goal of the course—a class paper submitted to a scientific journal—allowed students to make a real world contribution. Thus, this case study, which outlines the invasion of the Red Fire Ants, is one among sixteen papers, each of which contributed background research to a class-wide project coalesced and condensed into a single essay by the professor, Professor Jason Jones. It represents a piece of a larger picture of a science class that provided students with an opportunity to take an active approach to their education and make a direct contribution to their field of study.

The first invasive species biology class at Dartmouth arose not out of long years of research, but indirectly out of Jones’ experience in the field combating invasives. For example, as a bird-watcher on Vancouver Island, one problem familiar to Jones was the difficulty in preventing the ubiquitous and exotic European Starling from taking over nest sites of the threatened western Purple Martin. European House Sparrows are but one example of how invasive species are destroying habitats and altering the ecology of the world as they cross previously insurmountable boundaries. Jones took advantage of the relative liberty provided by his status as a Crossdale Fellow to design the course around an issue of such current importance that had plagued his own research. He incorporated the often under-developed framework of animal behavior into the study of invasive species, thus setting the stage for original thought.

Though Jones set-up the framework of study, he expected the students to contribute much of the research. Each student gave a presentation and wrote a term paper detailing the behavioral characteristics of invaders, which ranged from the euosociality of the dreaded Africanized Bees to the many modes of dispersal of the rapidly multiplying zebra mussel. In this way, students played a principal role in the selection of themes presented and in the education of their classmates. Jones describes the structure of the class as a way for students “to learn to think and not to memorize.” Accordingly, the culminating class-wide term paper was “an important paper, which needed to be written” and also “a trick to get students to own their education and not just their mark,” says Jones. Rarely does there exist such an opportunity for symbiosis between professors’ and students’ work within the classroom.

Why does Dartmouth not offer more biology classes in a seminar-like style? The idea of small discussion style classes is by no means novel, yet it does not occur with great frequency at Dartmouth. Mark McPeek, the chair of the biology department, explains that the original intention of the culminating experience was to offer a seminar class. However, the department has never had enough staff to implement such a structural change. To do so, McPeek says, would require each professor to hold twelve additional classes a year. Perhaps this lack of funding is just one more dreary fact to ponder as one sits down to begin the vast quantities of memorization required for an upcoming biology test. Or, perhaps it is possible for students to initiate change by taking an active approach on this front as well.

The Discovery of the Interleukin-2 Molecule at Dartmouth Medical School

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Interleukin-2 (IL-2), originally called T-cell Growth Factor (TCGF), is a naturally occurring substance produced by the body that stimulates the reproduction of cells within the immune system. This molecule is important in the study of cancers and HIV and has opened the door to a new field of medical research known as molecular immunology. The process of discovery began in 1960 with Peter Nowell, a pathologist at the University of Pennsylvania, and was carried out through the collaborative efforts of many different laboratories over the course of forty years. However, several investigators here at Dartmouth Medical School,
including Ross McIntyre, Kendall Smith, Steven Gillis, Paul Baker, Richard Robb, and Margaret Favata, all played instrumental roles in the identification, isolation, purification, and characterization of the IL-2 molecule.

In 1960, Nowell made the serendipitous discovery that kidney bean extract containing a compound called phytohemagglutinin (PHA) induced the division of lymphocytes, which were previously thought to be end-stage cells that lacked the ability to proliferate. Soon thereafter in 1965, two seminal papers appeared in the journal Nature describing the discovery of a blastogenic activity found in the culture media of stimulated lymphocytes that promoted their proliferation. However, the response to this agent in "conditioned media" was yet to be characterized as a single molecule.

In 1972, Smith, who had previously been at the National Cancer Institute (NCI), joined McIntyre's hematology research laboratory at Dartmouth as a postdoctoral fellow. The primary research interest of the laboratory at that time had been antiviral factors called interferons. Following a loss of funding in 1973, Smith traveled to France where he continued his immunological training with Georges Mathe, who was using immunotherapy to treat leukemia. By 1974, Smith had returned to Dartmouth as an Assistant Professor of Medicine in the Division of Hematology and Oncology.

As head of his own laboratory, Smith recruited Gillis to join his lab as a postdoctoral fellow, and Paul Baker joined the lab in 1976 as a postdoctoral fellow. In 1976, a report from the NCI showed that the "lymphocyte conditioned media" could support the long-term growth of T lymphocytes in culture. This activity was most likely caused by the same ingredient that had already been identified as the blastogenic factor a decade earlier in the Nature papers.

With his small team at Dartmouth, Smith set out to find the active ingredient in the lymphocyte conditioned medium that was responsible for the long-term T cell growth. Several critical discoveries by Smith's team over the next decade eventually led to the isolation and characterization of the molecule now known as IL-2. The understanding of IL-2 and its functions has already aided researchers in developing new treatments for immunological diseases. Most immunosuppressive therapies used today, such as glucocorticoids and cyclosporin-A, in fact by blocking the production and activities of IL-2. In addition, applications of interleukins include new experimental immune-based therapies, now being pioneered by Smith and others, for the treatment of cancer and chronic viral infections, as well as for the treatment of kidney failure and hepatitis. Smith and his collaborators have also developed monoclonal antibodies reactive with interleukins and cytokines as new treatments for rheumatoid arthritis and inflammatory bowel disease. These applications provide hope for future treatments of immunological diseases, as well as for both cancer and HIV, through continuing research in the rapidly evolving field of molecular immunology.

The authors would like to sincerely thank both Dr. McIntyre and Dr. Smith for their illuminating interviews as well as Dr. Smith for his kind help with editing.

Generated monoclonal antibodies reactive with the IL-2 molecule, enabling the purification of milligram quantities of IL-2 to be purified through a one-step affinity process. Through these steps and years, Smith and his laboratory isolated and characterized the IL-2 molecule in addition to identifying the IL-2 receptor. By 1983, they were able to publish in The Journal of Immunology on the development of monoclonal antibodies and their discovery of the IL-2 molecule.

The IL-2 molecule is now known to be a 15.5 kDa globular glycoprotein of 133 amino acids. Its discovery and characterization of its structure and function have been instrumental in the development of an entirely new class of "immunological molecules." IL-2 serves as a prototype for the group, which currently includes 29 members. These are considered to be the "hormones of the immune system," the immunological equivalent to those in the endocrine system. They serve to "communicate" between the varying cells of the immune system and lead to their development, reproduction, and responses to invading foreign microbes.

The influential discovery of IL-2 brought research within the medical community to a new level, furthering the understandings of the complicated human immune system. The understanding of IL-2 and its functions has already aided researchers in developing new treatments for immunological diseases. Most immunosuppressive therapies used today, such as glucocorticoids and cyclosporin-A, in fact by blocking the production and activities of IL-2. In addition, applications of interleukins include new experimental immune-based therapies, now being pioneered by Smith and others, for the treatment of cancer and chronic viral infections, as well as for the treatment of kidney failure and hepatitis. Smith and his collaborators have also developed monoclonal antibodies reactive with interleukins and cytokines as new treatments for rheumatoid arthritis and inflammatory bowel disease. These applications provide hope for future treatments of immunological diseases, as well as for both cancer and HIV, through continuing research in the rapidly evolving field of molecular immunology.

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