CONTRIBUTIONS

Commentary

A History of the Ecological Sciences, Part 10: Botany during the Italian Renaissance and Beginnings of the Scientific Revolution

Modern science consists of more than scientific literature. Besides ephemeral botanic gardens or zoos, there was little more to the natural history sciences of plants and animals in ancient and medieval times than the literature. That situation began to change during the 1500s, when professors of botany, institutional botanic gardens, and herbaria appeared. These developments were essential for the precise identification of species during a century in which Europeans sailed the seven seas and the number of known species jumped from about 500 known to Dioscorides to about 5000. Whether or not ecologists are interested in taxonomy, they need to identify the species they study. Ecologists know about Linnaeus' systematics, but his work was based upon knowledge gained in previous centuries. Along with an increasing precision about species, botanists during the 1500s also gained some understanding of the environmental needs of particular species.

The Italian Renaissance is commonly dated from the early 1300s; it was a cultural expression of the wealth that flowed into Italy with the revival of commerce that began in Venice in the mid-900s and gradually spread throughout Italy (Durant 1953, Zophy 1997). Wealthy merchants wanted to go to heaven and also enjoy the good life their wealth could bring. They were willing to support artists, architects, and scholars who could help them achieve both. These protégés convinced their patrons that the ancient Greeks and Romans knew how to live the good life, and that this could be done safely within a Christian context. Scholars concentrated on the recovery of ancient texts, without emphasizing science. This cultural revival was interrupted when the Black Death ravaged Europe, beginning in 1347, and universities closed when plague struck their town. It took a century for Europe to recover (Cantor 2001), and with the loss of continuity, some knowledge was lost to later scholars (Thorndike 1941, **6**:261–264).

The Turkish conquest of Byzantium in the early-to-mid 1400s coincided with Italy's recovery from the plague, and Greek scholars immigrated to Italy, bringing manuscripts with them. Theodoros Gazes reached Italy about 1435, where he taught Greek and eventually translated the works of Aristotle and Theophrastos from Greek into Latin (Egerton 2002:91). About the same time, Johann Gutenberg (c.1398–1468) was inventing his printing press with moveable type, and he began printing the Bible at Mainz, Germany, in 1454. Although Bibles and other religious works were the most common printed books in 1454–1499, college texts were the second most common books, and science books were foremost among them (Quimby 1958:5–15). The Greek texts of Aristotle and Theophrastos, and also Gazes' Latin translations of them, were published before 1500, and Dioscorides' *Materia medica* was also published in Greek and Latin before 1500 (Sarton 1955:53–70). There was much more interest in Dioscorides' *Materia medica* than in the works of Theophrastos during the 1500s (Wightman 1962, **1**:186), but a century after Gazes' translation of Theophrastos' works was published, Julius Caesar Scaliger severely criticized it in *Commentarii et animadversiones in sex libros de causis plantarum Theophrasti* (1584) (Rose 1975, Reeds 1976:523). By then, precision was very important in botany; how had that happened?

Not only did Byzantine scholars publish Greek science classics in Italy in both Greek and Latin, but they also recruited there a community of humanists committed to Greek learning. One member was Niccolò Leoniceno (1428–1524), the son of a physician, who studied Latin and Greek in his native Vicenza and then studied medicine and philosophy at the University of Padua, receiving his doctorate about 1453. He may have taught there for a while, but in 1464 he joined the faculty at the University of Ferrara, where he taught first mathematics, then philosophy, and finally medicine (Bylebyl 1973). In 1490 he wrote a letter to a colleague in Florence, Angiolo Poliziani (Politianus), criticizing Ibn Sina, and also mentioned that Pliny had in one instance misread the Greek name of rockrose, *cistus*, for the Greek name of ivy, *cissus*. Because he read both Greek and Latin, Leoniceno was able to criticize Pliny, whose enormously popular *Naturalis historia* was first printed at Venice in 1469 (Sarton 1955:78–86). Poliziani accepted the criticisms of Ibn Sina, but not of Pliny. In 1492 Leoniceno, who realized that ancient Greek science was superior to Roman science, responded by publishing *Plinii ac plurium aliorum auctorum qui de simplicibus medicaminibus scripserunt errores notati* ("Errors in Pliny and in several other authors writing on medicinal simples"), in which he explained 22 errors by Pliny due to his mistranslation or misunderstanding and 17 errors by Arabic authors and their Latin commentators. His pamphlet elicited a sharp rebuke from the lawyer-diplomat Pandolfo Collenuccio (1444–1504) entitled *Pliniana defensio…adversus Nicolai Leoniceni acusationem* (c.1493). One historian of botany found much to praise in Leoniceno and little to praise in Collenuccio's response (Greene 1983:Chapters 11–12), but a historian of early science reached the opposite conclusion, that Collenuccio knew more about the actual plants than Leoniceno and that some of Leoniceno's complaints were due to a faulty text of Pliny's N*aturalis historia* (Thorndike 1934: Chapter 66). Meanwhile, Venetian scholar-diplomat Ermolao Barbaro (1454–1493) studied copyists and printers' errors in Pliny's *Naturalis historia* and claimed to find 5000 in two published editions. Previously, Niccolò Perotto had published *Commentariolus in prooemium Plinii* (c.1480) to complain about printer's errors in Giovanni Andrea de' Bussi's edition of Pliny (Nauert 1979:77), and Marc' Antonio Sabellico had also published about a hundred corrections in his *Emendationes in Plinium* (1488) (Branca 1973:223). Barbaro's more ambitious *Castigationes Plinianae* appeared in two parts in 1492–1493. Both Leoniceno and Collenuccio claimed to find support for their case in Barbaro's work, but Barbaro's own sympathy was clearly with Collenuccio, since he criticized Leoniceno without naming him (Greene 1983: Chapter 13, French 1986). Other scholars weighed into this debate on one side or the other, and it might have been considered a draw except that in one sense Leoniceno won, because he continued attacking Pliny in print after both Barbaro and Collenuccio had died (Castiglioni 1953, 274–275). He also was vindicated by being succeeded at Ferrara by one of his pupils, Manardo, an outstanding physician whose botanical expertise is discussed below.

During this time in Italy, professionals began testing classical and medieval authorities against nature. Physicians and artists led the way. Medical schools had been dissecting executed criminals since the late 1300s, and artists began studying animal and human anatomy. Leonardo da Vinci (1452–1519) is the most famous example. He made accurate scientific drawings and took careful notes, but lacked the academic training that might have enabled him to publish his findings (Leonardo da Vinci 1952, Keele et al. 1973). The Italian example influenced others, including Albrecht Dürer (1471–1528), who visited Italy twice to study art. His "The large piece of turf" (1503; reproduced in Brion 1960:92 and Koreny 1985:180–181) was the first ecological drawing, and it inspired other artists to make similar studies (Koreny 1985:180–187). Although Egyptians, Romans, and others had drawn landscapes with appropriate plants and animals for the location, those organisms were part of the scenery. Dürer's drawing explores the relationships between different kinds of plants, but this was only a passing interest. He drew many excellent pictures of animals, but the wild animals were drawn without backgrounds, and the domestic animals were part of human scenes (Eisler 1991). His drawings of landscapes and rock formations show an appreciation of nature (Koschatzky 1973, Leber 1988), but cannot be called ecological drawings. Otherwise, Dürer's scientific interests tended toward the implications of geometry and optics for art (Steck 1971). However, the German artist Hans Hoffmann painted three pictures of hares similar to Dürer's, but in natural settings with vegetation (Koreny 1985:144–149).

Despite such breaths of fresh air, most authors on natural history during the late 1400s and early 1500s were still in the grip of tradition (Wightman 1962, **1**:185–186). They wrote commentaries on classical or medieval texts and compiled encyclopedias that were comparable to those by Albertus Magnus (c.1220–1280) (see Egerton [2003] A History of the Ecological Sciences, Part 9), with the added advantage that theirs were usually published when written. Otto Brunfels (c.1489–1534), a German Protestant

Fig. 1. Otto Brunfels.

Fig. 2. White water lily (*Nymphaea alba* L.). Brunfels, *Herbarum,* **1**:37.

physician–botanist (Fig. 1.; see Stannard 1970*b*, Weigelt 1986), was typical of this tradition when he began compiling his *Herbarum vivae eicones ad naturae imitationem*, "Herbal with living images of plants" (1530–1536; German edition, 1532–1537). Either he or his publisher arranged for an artist, Hans Weiditz, to provide woodcut illustrations, and Weiditz's excellent "living images of plants" did for botany what illustrations in Vesalius' textbook would soon do for anatomy (Fig. 2). Weiditz seems to have had an independent spirit, and he drew 47 plants not represented in the classical pharmacopoeia. Brunfels apologized for including them in his herbal, but nevertheless provided names and descriptions (Arber 1953:321–323, Reeds 1976: 529, Greene 1983: Chapter 5).

Leoniceno was criticized for being a bookish botanist. Be that as it may, he trained two or more students who followed Collenuccio's admonition to study nature and also to learn from those who had direct experience with plants, regardless of their formal education. One of these students was a native of Ferrara, Giovanni Manardo (1462–1536), whose very popular *Epistolae Medicinales* contains three long epistles matching ancient plant names with living plants (1521; Book 8 on botany was added to the second edition, 1532). Manardo traveled widely in central Europe and "drew upon observations made in the course of his travels to distinguish among the properties of the variants that occur within a single species growing in differing locations" (Cotton 1974:75). The other student was a German scholar, Euricius Cordus (1486–1535), who received his doctorate under Leoniceno in 1522, when the latter was 94 years old; it seems likely that Manardo was already de facto professor by then. Perhaps Cordus learned, or at least polished, his Greek under Leoniceno, for in 1532 he published a Latin translation of two ancient Greek pharmaceutical poems. However, Cordus is remembered for his colloquy, *Botanologicon* (1534), which attempted to correct the mismatch between the names of plants used by Dioscorides and Galen and the actual plants of Germany. Brunfels, for example, while rendering valuable service by publishing his illustrated herbal, had nevertheless mismatched some classical names with his illustrations, one being a picture of *Corydalis* to illustrate a classical account of *Aristolochia* (Cordus 1534:96). Because Cordus had studied plants in both Italy and Germany, he knew that *Aristolochia* grew in the former country but not in the latter (Greene 1983:247–248, 364–365). Although Cordus died in the year after publishing *Botanologicon*, he had already begun the education of his son, Valerius, who was able to make a more substantial contribution to botany than had his father (Schmitz 1971*a*, *b*, Greene 1983: Chapter 9).

Still another of Leoniceno and Manardo's students was Antonio Musa Brasavola (1500–1555), a native of Ferrara who also mastered both Greek and Latin and who taught there at various times logic, natural philosophy, and medical theory (Thorndike 1941, **5**:446). He wrote *Examen omnium simplicium medicamentorum quorum in officinis usus est* ("Examination of all medical simples used in apothecary shops") (1536), which has the same purpose and dialog format as Cordus' *Botanologicon,* but is twice as long. Brasavola stated (1536:502) that he only came across *Botanologicon* as he was finishing his own book. His methodology was also similar to that of Cordus—when doubtful about identifications, study the plants and compare them with the ancient descriptions in question. Once the correct plant was determined, however, the efficacy of the medical prescription never seems to have been questioned. Like Brunfels, Brasavola only provided detailed descriptions of plants that seemed unknown to ancient authorities (Greene 1983:676–678), but he realized that the ancients had only known "a hundredth part of the herbs existing in the whole world" (translated by Morton 1981:118).

Other authors wrote works similar to these by Cordus and Brasavola (Thorndike 1941, **5**:449–470), but there were diminishing returns for later emulators. A new synthesis of botanical knowledge was needed, and it was provided by Parisian physician Jean Ruel (or Ruelle, 1474–1537), who translated Dioscorides' *Materia medica* from Greek into Latin (1516) and became dean of the medical school. Ruel's *De natura stirpium libri tres* (1536) is a comprehensive treatise somewhat comparable to Albertus Magnus' *De vegetabilibus*, except that Ruel had the advantage of consulting the botanical treatises by Theophrastos

Fig. 3. Title page, Ruel 1536.

(and also works by some 50 other ancient authors listed by Greene 1983:993, note 25). He did not, however, cite the work of Brunfels, which was then being published, nor did he provide illustrations for his plant descriptions. Yet this was a virtue of sorts, because Ruel had a very precise command of Latin (Fig. 3), and his verbal descriptions are models of clarity (Greene 1983:611–641). In order to distinguish the different species, Ruel realized the need for a technical vocabulary with definitions, which he provided, largely collected from earlier sources. This was an important step; on the other hand, Morton (1981:122) discounted Ruel as a theoretical botanist. For example, Ruel perpetuated a long-lasting notion that plants lack sex and that wind breathes life into seeds (1536, Book I, Chapter 10; partly translated in Greene 1983:649).

Jerome Bock (1498–1554) was in charge of the botanic garden of Count Palatine Ludwig in Zweibrücken by 1523 (Fig. 4). In 1539, he published a herbal written in German, which also lacked illustrations and therefore required precise verbal descriptions (Stannard 1970*a*, Greene 1983: Chapter 7). He deliberately sought out new plants to describe and provided rather detailed descriptions, including localities, for about 800 native and cultivated species (Hoppe 1969). A second edition of his herbal (1546) was illustrated with 465 woodcuts, many copied from herbals by Brunfels and Fuchs (Figs. 5 and 6).

The most lavish German herbal was written by Leonhart Fuchs (1501–1566), professor of medicine at Tübingen (Greene 1983: Chapter 6, Meyer et al. 1999: Chapter 2). His Latin text (1542) was mainly derived from other authors whom he named, but he did not always make clear what he borrowed from them. For example, he praised Ruel's botany book (1542, unnumbered page vii; translated by Meyer et al. 1999:206–207), but did not explain that his own technical vocabulary (1542, unnumbered pages xvi–xix; translated by Meyer et al. 1999:227–259) was mainly pulled together from Ruel (Egerton 1978, Greene 1983:626). His excellent illustrations, however, were originals done under his supervision. He aspired to publish further volumes for which he accumulated much information and illustrations, but never found a publisher (Meyer et al. 1999: Chapter 5). For each species, Fuchs gave an indication of its habitat. For example, for the common periwinkle (*Vinca minor* L.): "It grows in rich, shady, fertile uncultivated soil, on the borders of fields and vineyards." However, for species only known as domesticates, the habitat usually was indicated in a perfunctory way, like that given for the Madonna lily (*Lilium candidum* L.): "It occurs everywhere in Germany in gardens." (Meyer et al. 1999:409–410).

The conventional date given for the start of the Scientific Revolution is 1543, because in that year two revolutionary books were published: Nicholas Copernicus' *De*

Fig. 4. Jerome Bock.

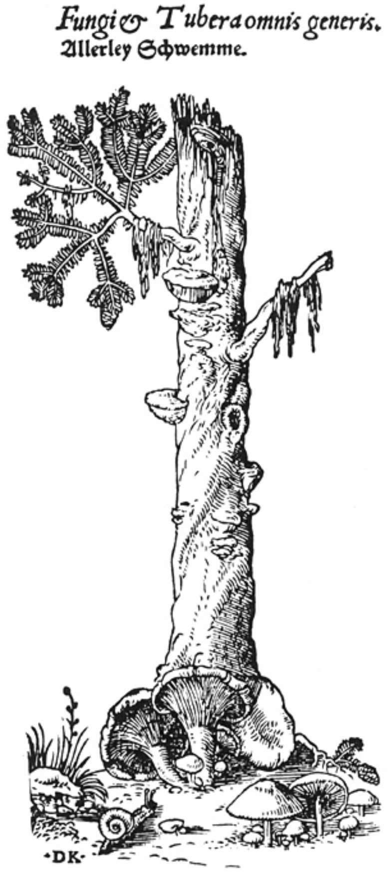

Fig. 5. Mushrooms. Bock, *Stirpium* (1552), 940.

revolutionibus orbium coelestium ("On the Revolutions of the Celestial Orbs") and Andreas Vesalius' *De humani corporis fabrica* ("On the Fabric of the Human Body") (Hall 1983: Chapter 2). Copernicus' book made Ptolemy's treatise on astronomy obsolete, and even astronomers who did not accept his theory of the earth circling the sun still used his book, because Copernican calculations were easier. Vesalius learned and taught anatomy with human cadavers, and soon realized that Galen had only had access to monkeys and other mammals. Vesalius wrote a textbook of human anatomy, for which he obtained excellent anatomical drawings done under his supervision in Italy. His book made Galen's anatomical treatises obsolete where humans were concerned. No such revolution occurred in natural history, but incremental progress was made continuously in botany.

The herbals by Brunfels, Bock, and Fuchs appeared in both German and Latin editions, and many herbals written by other authors also appeared during the 1500s (Sarton 1955:98–104, Quimby 1958:77–189), most notably by the German Valerius Cordus (1515–1544), who added further to the terminology of plant descriptions (Greene 1983: Chapter 9, Schmitz 1971*b*), and the Italian Pietro Andrea Mattioli (1501–1577), whose later editions had some 1200 illustrations (Zanobio 1974, Greene 1983: Chapter 21). Meanwhile, other developments were leading toward a more precise botany. Italian universities established the earliest lectureships in botany, at Padua in 1533 and at Bologna in 1534. The latter position was filled by the Italian professor of medical botany Luca Ghini (1490–1556), whose prominent students included Ulysses Aldrovandi, Andrea Cesalpino, and William Turner. Ghini invented the plant press and compiled the first herbarium, now lost, but one compiled by one of his students survives (Mazzini 1949, Battiato 1972, Keller 1972). Ghini also initiated the botanical gardens (see Fig. 7) at Pisa and Florence (Morton 1981: 120–121, Greene 1983:706–707, Reeds 1991:35–36, Cooper 2000).

Conrad Gessner (Latinized as Gesnerus, 1516–1565) of Zurich was more similar to Albertus Magnus than Ruel, in that he wrote encyclopedias on both animals and plants and added his own observations (Wellisch 1984). His father was too poor to raise all of his children, and Conrad was raised by a great-uncle who had a herbal garden that he used as a source of medicines for his family and friends (Fischer 1966*a*). Gessner became a proficient scholar in Latin and Greek, then studied medicine at several universities before returning to Zurich to practice and teach. To supplement his income, he began publishing books in 1537 and continued to do so regularly for the rest of his life (Fischer et al. 1967). In 1545 he became the father of bibliography by publishing his large *Bibliotheca Universalis* (1264 folio pages; Sarton 1955:108–110, Fischer

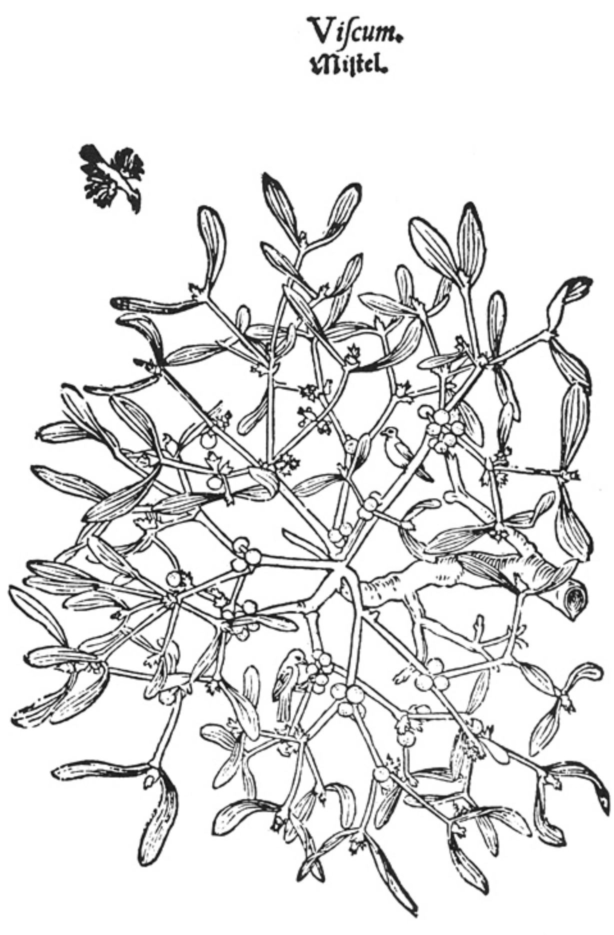

Fig. 6. Mistletoe (*Viscum album* L.). Bock, *Stirpium* (1552), 949.

Fig. 7. Padua Botanical Garden, founded 1545.

1967*b*). However, it was surpassed in size by his *Historia animalium* (four volumes, 1551–1558). He collected information and illustrations on plants for several decades, and managed to publish small portions of it (Greene 1983: Chapter 20). He also delayed publishing his own botanical work in order to edit important botanical writings by the deceased Valerius Cordus (1515–1544), which Gessner published in two parts (1561–1563; an example in English can be found in Bodenheimer 1958:224–225). Then Gessner's own untimely death during an epidemic prevented him from publishing his great *Historia plantarum*. Two parts of it appeared in 1751–1771, but it was not fully published until 1972–1991.

Gessner may have been the first naturalist to climb mountains to study their natural history. In the process, he became enamored of the scenery and the experience (Sarton 1955:107–108). He first expressed these feelings in a published letter to Jacob Vogel (Latinized as Avienus) in 1541 (in *Libellus de lacte*, quoted in English in Bodenheimer 1958:232–233). Another of Gessner's smaller works, *De raris et admirandis herbis* (1555), on luminescent plants of the Swiss Alps, returned to this theme in terms that Wellisch (1984:12) thinks are

> *remarkable for the glowing description of the beauty and majesty of the Alps, and in particular of Mount Pilatus near Lucerne which he ascended together with some friends. This is thought to be not only the first scientific description of the Alps but marks also the beginning of Alpinism and the appreciation of nature for its own sake.*

Another of Gessner's minor botanical works contributed to ecology and phenology. He published part of it as an appendix to another scholar's botanical dictionary in 1553, and an expanded version appeared posthumously as *De stirpium collectione* in 1587 (Wellisch 1984:78, 107). The latter edition is noteworthy for being "the first to present much ecological matter succinctly, and in an admirably tabulated form," which Greene (1983:792) quotes in translation. The same book contains the first substantial phenology of plants: in 180 pages, Gesner indicated for the Zurich region the times of unfolding of leaves, flowering, maturing of fruits, and shedding of seeds for 1250 trees, shrubs, and herbaceous plants (Greene 1983:793–794).

The herbal tradition continued for another century (Arber 1938, Quimby 1958:190–420, Anderson 1977), by which time scientific botany was a strong rival of medical botany. Botanists had become more interested in studying plants in nature than in books, yet books, herbaria, and botanic gardens all remained important for ensuring the correct identity of species. Although revolutionary developments did not occur in botany during this period, progress was substantial and included notable ecological observations.

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Frank N. Egerton
Department of History
University of Wisconsin-Parkside
Kenosha WI 53141
E-mail: frank.egerton@uwp.edu

How To Write A Successful Doctoral Dissertation Improvement Grant Proposal

The Doctoral Dissertation Improvement Grant (DDIG) Program of the National Science Foundation <http://www.nsf.gov/bio/progdes/bioddig.htm> provides funding in several biological disciplines including ecology, animal behavior, evolutionary biology, and systematics. To be eligible, a doctoral student must have achieved candidacy and be enrolled in a U.S. institution of higher learning. DDIGs are available to students of all nationalities. Grants range in size and duration, but are generally a few thousand to $12,000; grant duration can extend up to 24 months. Additional funding is available for those proposing collaborative research with foreign institutions. Although they are not comparable in scale to regular NSF grants, these funds can represent a significant resource for a doctoral student. In addition, the Program represents an outstanding opportunity for graduate students to gain skills in proposal writing and to establish a track record with an important funding agency. Finally, getting a DDIG looks great on a CV.

Between 25% and 30% of all DDIG proposals are funded. In the world of Federal grant funding, these are excellent odds. You can be successful if you follow some straightforward guidelines.

Read the directions

During the latest round of funding, nearly 10% of all applications were returned without being reviewed. Follow, to the letter, all instructions regarding font size, margins, statement length, etc. After you upload your proposal on Fastlane it is possible to print it out. Do this so that you can check to make sure that your proposal will look as you intend it to when it reaches your reviewers. There is no excuse for mistakes in formatting your proposal. Similarly, there is no excuse for submitting past the deadline. Proposals are not considered submitted until done so by your sponsored research office. Be aware of your own institution's requirements and lead times for submission.

Be organized

Your proposal will be reviewed by three people, each of whom will have about 25 proposals to judge during a short period. Imagine that you are dealing with a weary, time-challenged reader and you have the correct idea. Break your proposal into sections whose titles are logical and reveal the flow of your proposal. A reader should be able to skip from section to section easily to find what they want to see. Finally, typos are annoying to your reviewers; eliminate them.

Show that you understand the larger context for your research

Many proposals are taxon-centric or, in other ways, are focused on a small subspecialty. Your proposal will be read and judged by people whose interests are not the same as yours. You need to connect what you do to a larger field of interest in the proposal abstract, in the introduction, and in the closing significance section. This should be done in a meaningful way; throwaway statements are easily detected.

Connect specific hypotheses to testable predictions

Many proposals contain objectives or goals, but no specific hypotheses. Other proposals contain irrefutable predictions, or predictions that will not really be tested by the research activities proposed. Vagueness and lack of careful thought is the kiss of death.

Then connect results from completed and proposed experiments and analyses back to the larger context

It is a proposal for an "improvement"

Proposals written by first- and second-year students have lower odds of success. However, submitting a proposal early in a student's program does allow fine-tuning