Program Proposal

Clemson University

M.S. Degree in Biotechnology

Submitted by the Department of Genetics and Biochemistry

November 2006

_____

James F. Barker, President

Classification

Name:	M. S. Degree in Biotechnology—new non-thesis Master's
Proposed by:	Clemson University, Department of Genetics and Biochemistry
Implementation date:	August 2008
CIP code:	26.1201

Justification

Summary: Clemson University proposes a techniques-based, non-thesis M.S. degree designed to fill the needs of the biotechnology industry for qualified research associates. The program will be housed in the Department of Genetics and Biochemistry, and there will be extensive collaboration with the Biosystems Engineering Program. We envision collaboration with other departments and institutions as the program grows. Rather than preparing students to be academic researchers, the program will prepare students in industry-oriented molecular techniques, laboratory skills, bioprocessing, and Good Manufacturing Practices as they relate to biotechnology. The CHE approval of our Program Planning Summary for this degree was on January 20, 2005.

There are two ways in which students may be admitted into the degree program. First, as a graduate of an accredited undergraduate degree, students may apply for admission into the Master's program. However, a second entry is through into the proposed M.S. degree is as part of a B.S.- M.S. program. This entry into the program will allow students in a wide variety of Clemson undergraduate programs to obtain a degree in their undergraduate discipline plus an M.S. in biotechnology in five years plus one summer. A formal admission process is required.

Need for Program. Biotechnology is changing the face of our world. It has been a prolific source of drugs, medical devices, forensic techniques, new crops that are resistant to herbicides and pest insects, etc. The biotechnology industry will also be one of the economic growth engines of the coming decades. Although the biotech industry is barely twenty years old, by 1999 it was already producing revenues of nearly $40 billion, a two-fold increase from 1993. In 2000, 30% of all new pharmaceuticals were developed by the biotechnology industry. There were 4,600 biologically related patents issued in 1996 and 14,000 in 2000. Such a growing industry requires highly trained employees. Biotechnology employment increased by 90% between 1995 and 2005. The national educational system is responding to these needs. The National Center for Educational Statistics reported that the number of Master's degrees in all life sciences increased by 24% between 1995-1996 and 2003-2004. During that same period, the number of Master's degrees awarded in biotechnology increased by 188%. Karl Kelly, CEO of SC BIO (the South Carolina Biotechnology Incubator) pointed out that over the last 15 years, biotechnology in North Carlina has created 15,000 to 17,000 new jobs and generated $100 million new dollars in tax revenue from 72 biotechnology companies. South Carolina now has about 30 companies. Mr. Kelly predicted that the biotechnology industry in South Carolina will have an estimated fiscal impact of $150 million by 2018. The sector could employ 20,000 South Carolinians directly and 60,000 directly and indirectly.

Through its traditional Ph.D. and M.S. programs, the Department of Genetics and Biochemistry is already making strong contributions to the research that drives biotechnology discovery, and

this emphasis area will continue. However, research is only half of the economic growth equation. In order to prosper, the biotechnology industry must have competent technical staff who can profitably manufacture drugs and other biotechnology products. Research associates in the biotech industry are in demand and make good salaries. In June of 2006, the national median salary for a biotechnology Level I Research Associate was $40, 412 and for a Level II Research Associate was $49,190. The traditional degrees are not the best source of these employees, and we believe that our proposal contains the right mix of theory and practical skills to create highly marketable graduates.

Faculty members consulted with the intended "customers" in the development of the proposed program. In 2003, we polled 60 biotechnology, biopharma, and pharmaceutical companies, mostly in the Southeast. We described our proposed degree, including the laboratory skills that the degree would emphasize, and then asked the personnel officer or the chief scientific officer of the company to respond to a series of questions. Fifteen companies responded. While the results varied somewhat with the type of company, several conclusions were clear:

The companies valued a skills-based degree more than a traditional Master's that prepares the student for a career in research. 75% responded that the holders of this degree would be desirable employees in their company; in a separate question, only 25% indicated that they would prefer a graduate from a traditional Master's program. When asked if they would prefer a degree with a less technical emphasis (e.g., more on managerial issues, patent issues, etc.), the responses favored the technical degree by 87% to 13%.

Faculty initially expected that certain laboratory techniques would be most in demand by the companies. However, the most desired skills were more general--data analysis, experimental design, project management, communication skills, problem-solving, and Good Laboratory Practice or GLP (e.g., accepted procedures for maintaining records, specimen storage, keeping research animals, etc.). For an introduction to GLP, see http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=58. Ability to adapt to new techniques were repeatedly mentioned. Bioprocessing knowledge (industrial-scale production of bulk product and then separation, purification and sterilization of the product) were seen as more important than classical laboratory techniques.

Manufacturing (rather than research) is the main job of many of these companies, and familiarity with current Good Manufacturing Practices (GMP) was frequently suggested as an important part of the degree. For example, the Medical University of South Carolina established a Pharmaceutical Development Center (PDC) in 1979, and one of the PDC's important assets is a state-of-the-art GMP-compliant facility. For an introduction to GMP (in the drug industry, in this case) see http://www.cgmp.com/drug.htm. As the respondent from Goodwin Biotech (Florida) concluded, "As a manufacturer we find a lack of graduates with practical experience and training at the university level. I realize your aim is to prepare researchers. However, there is a growing need for manufacturing personnel in the GMP production of these products. If a product cannot be manufactured, it cannot be sold."

The design of the proposed degree program directly addresses the industry identified needs.

Consistency with Clemson's Mission. The proposal is entirely consistent with Clemson's mission and recent direction. "Biotechnology and Biomedicine" is one of Clemson's eight Emphasis Areas, and recent history shows that Clemson has acted vigorously on this priority. Clemson hired its first molecular genetics researcher around 1990. Today it has 50-60 molecular genetics researchers. In the 1990's the Clemson University Genomics Institute was established. In 2002, Clemson was a founding partner in the South Carolina Biotechnology Incubator. Since 2004, Clemson has begun an undergraduate degree in Genetics, built the Biosystems Research Complex, and established the South Carolina DNA Learning Center. In the future, Clemson plans to complete a Biomanufacturing Facility that will allow Clemson students to learn the industrial-scale processes that will be especially important to our biotechnology students. This facility would act as a pilot-scale biorefinery capable of producing biopharmaceuticals, biomaterials, and bioenergy, and act as a teaching lab as well. When it is completed, this facility will be an excellent resource for our proposed program.

Relationship to Other Programs at Clemson. One of the strengths of this program is its collaborative nature. Although this degree will be housed in the Department of Genetics, Biochemistry, and Life Sciences Studies even at this early stage, it is a collaborative project between that department and Biosystems Engineering, a program in the Department of Agricultural and Biological Engineering. Both these departments are in the College of Agriculture, Forestry, and Life Sciences. Genetics and Biochemistry faculty will teach the more laboratory-based and "academic" techniques, and the Biosystems Engineering faculty will focus on training in bioprocess engineering for the design and scale-up of processes to include bioproduction, primary isolation and purification of gene products, plus GLP and GMP. Biosystems Engineering faculty (led by Dr. Terry Walker) will teach the new core course called Industrial Biotechnology Techniques.

Collaboration will not stop there. Participation in the BS-MS program is meant to be expanded. As the section on Curriculum explains, the program is being proposed with two options– Molecular Biology (for those with more purely biological interests) and Bioprocessing (for those with more of an engineering/manufacturing orientation). At present, the two main sources for these students will be the Department of Genetics and Biochemistry and the Biosystems Engineering Program, respectively. We anticipate that other departments will elect to participate in the future. The key condition for participating in a B.S. - M.S. program is that the B.S. degree faculty must agree to substitute the program's graduate courses for some of its undergraduate courses. Any department that can come to such a curriculum agreement with Genetics and Biochemistry is welcome to participate and perhaps to propose new options.

Relationship to Programs Outside Clemson. The South Carolina degrees that resemble the proposed program most closely are a Professional Master's in Biotechnology at USC-Columbia and a Master's in Biotechnology at Claflin University. The USC program (http://www.cosm.sc.edu/professional/cosm1.html) seems to have a managerial and business emphasis. Its three core courses are "Business and Legal Issues for Science Managers," "Scientific and Technological Problems in Business and Industry," and an internship that might be done in an industry, but might also be done in a government agency. It has few required laboratory courses and focuses on plant biotechnology. This program seems to be aimed at

aspiring biotechnology managers and entrepreneurs who need technical knowledge but not laboratory skills; ours is aimed at biotechnology research associates.

The Claflin Master's program (http://www.claflin.edu/academic/BioTech/Index.htm) says that it "aims to successfully prepare all of its students for quality leadership in government, private sector, and university, specifically those related to Biotechnology industries." Claflin also has a Bachelor's in Biotechnology. It is "designed to prepare world-class scientists to participate in the shaping of our future. These students will be leaders in the biotechnology industry, in academia and in government." The content of both these degrees appears to be biologically oriented, but more like Clemson's traditional Master's degrees than this proposed program.

We do not regard these existing degrees as being duplicated with our proposal. On the contrary, we anticipate that Claflin may be a natural source of students who wish to come to Clemson for an additional year plus a summer and graduate build on the Claflin undergraduate degree with a masters from Clemson.

Outside South Carolina, the program that seems most similar to ours (including its status as part of a 5-year B.S. - M.S. program) is at the University of Nevada at Reno <http://www.ag.unr.edu/biot/Programs.htm>. This degree gives its graduates both a B.S. and an M.S. in Biotechnology. The emphasis appears to be academic rather than industrial. The participating departments are Biology, Animal Biotechnology, Biochemistry, Microbiology, and Pharmacology. Note that there is no participation by any engineering discipline. However, an industry internship is part of the degree. The stated aim of the program is help Nevada develop a biotechnology industry. Another 5-year B.S. - M.S. program is offered by the University of Maryland at Baltimore County: http://www.umbc.edu/biosci/Graduate/amb/fiveyear.html. This program is clearly practical and job-oriented, but there does not appear to be any explicit industrial content. Aside from these programs, there are many biotechnology degrees that range from the extremely biological and academic (e.g., Johns Hopkins at http://advanced.jhu.edu/biotechnology/biotech.cfm) to the much more engineering-oriented program at Northwestern http://www.mbp.northwestern.edu/, which has separate tracks for biologists, chemists, and engineers. However, we did not find any program exactly like ours.

Enrollment

Admissions Criteria for the M.S. in Biotechnology. The entrance requirements for the M.S. in Biotechnology will be:

- A Bachelor of Science degree in some life science, chemistry, or bioengineering field
- Satisfactory scores on the GRE
- Basic courses in biochemistry, genetics, and microbiology
- A mathematics course on modeling with differential equations is recommended for the Molecular Biology Option but required for the Bioprocessing Option.

Admission criteria for the combined B.S./M.S. plan are:

- A minimum of 94 credit hours of the bachelor's curriculum completed
- Minimum GPA of 3.40 on the 94 credit hours
- Endorsement by the program coordinator or department chair of both programs
- Conditional admission is provided until the undergraduate degree is completed
- GRE scores required

- Maximum of 12 graduate credits can be applied toward the bachelor's degree

Total Enrollment. The total enrollment reflects both new graduate students and seniors who elect to participate in the combined B.S. – M.S. degree program track. Seniors may enroll in 12 graduate credits and these students are included in the total projection enrollment shown below. The total program enrollment predicted is to start with 10-15 students and grow to about 40 after five years. Assuming startup in Fall of 2008, total enrollment would grow as follows:

Table 1. **Projected student headcount and credit hours in the M.S. in Biotechnology.**

PROJECTED TOTAL ENROLLMENT						
YEAR	**FALL**		**SPRING**		**SUMMER**	
	Hdct	Cred Hrs	Hdct	Cred Hrs	Hdct	Cred Hrs
2008-09	10	50	10	40	10	0
2009-10	25	130	25	150	25	40
2010-11	35	220	35	215	35	60
2011-12	40	260	40	260	40	80
2012-13	40	260	40	260	40	80

The assumption behind these numbers is that the number of students entering in each Fall from 2008-2010 will rise from 10 to 15 to 20, and then remain at that number. The program takes two years. Therefore, the long-term enrollment is expected to be 40 (20 in the first year and 20 in the second year). This compares with a total Spring 2006 enrollment of 291 undergraduate majors and 53 graduate students in Genetics, Biochemistry, and Biosystems Engineering. The credits are computed from the curriculum. This would vary with the option selected, but the credit load tends to be higher in the Fall than in the Spring. Biosystems Engineering 835 is the only course planned for the summer, and that is taken only by second-year students.

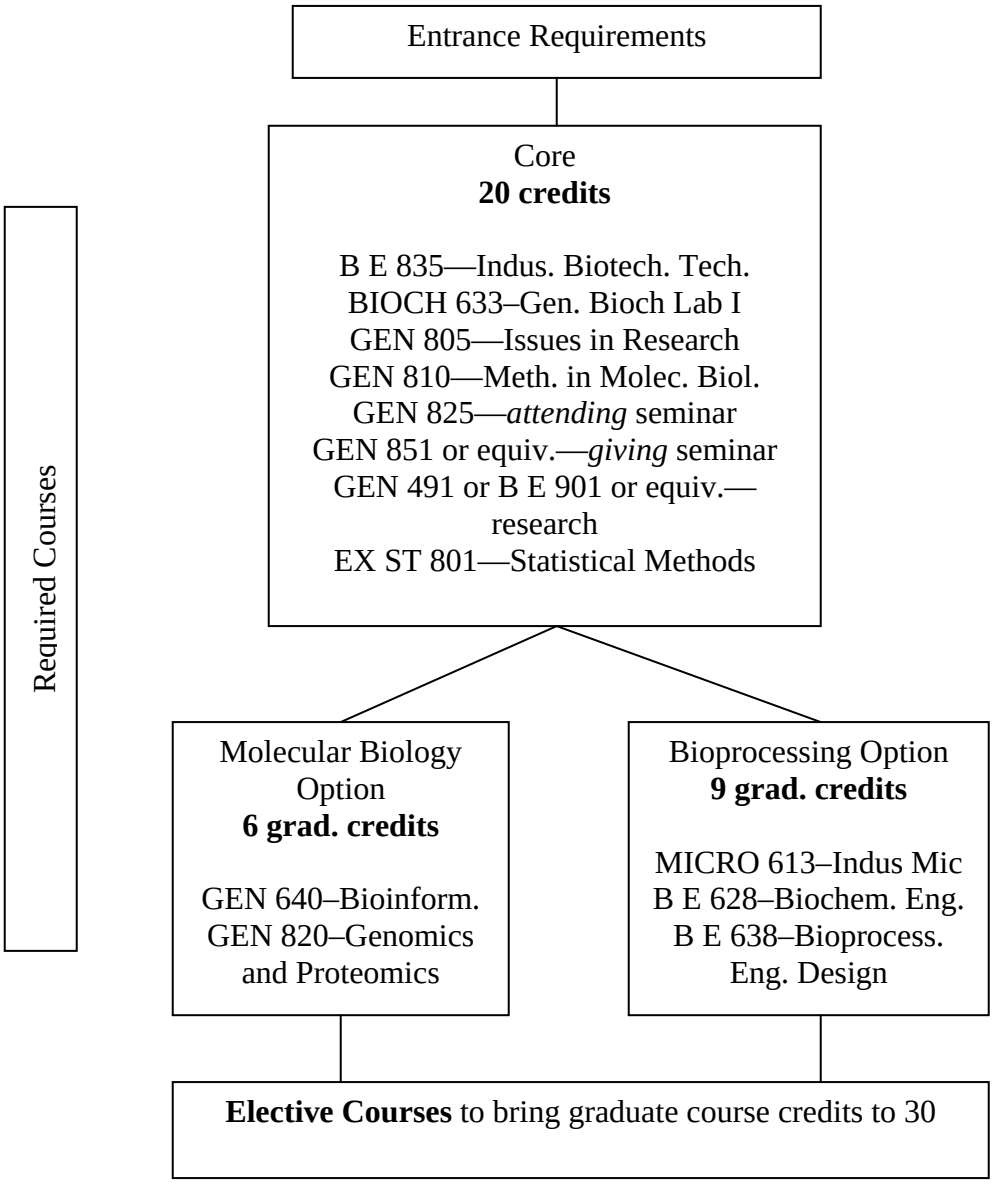
New Enrollment. The CHE uses this term to refer to students from outside Clemson that are not students in any existing Clemson program. The proposed degree was envisioned as an alternative to the traditional research degree. It will mainly attract Clemson students who work in the biotechnology industry, but find they have no interest in independent research. It will also be attractive to students from life science departments at Clemson and other universities.

Table 2. Projected new enrollment in the M.S. in Biotechnology.

ESTIMATED NEW ENROLLMENT						
YEAR	**FALL**		**SPRING**		**SUMMER**	
	Hdct	Cred Hrs	Hdct	Cred Hrs	Hdct	Cred Hrs
2008-09	1	5	1	4	1	0
2009-10	5	38	5	25	5	4
2010-11	8	52	8	51	8	16
2011-12	10	62	10	60	10	24
2012-13	12	78	12	78	12	24

Curriculum

All Biotechnology students will take a series of required courses (the "core"), a further list of courses required by their option, and then a series of courses chosen from a list of possible electives. This is put in flowchart form below. No new courses will be needed. All the listed courses except one (B E 835) are already being taught, and B E 835 was approved in 2005. An explanation of the courses follows the flowchart.



Core Required Courses (20 credits)

- Industrial Biotechnology Techniques B E 835 4(3,3). An introduction to industrial techniques, project management, GLP, and GMP. When the Biomanufacturing Facility comes online, this 4(3,3) course will be expanded to form a required 5(3,6) course. This is the only course on this list that is not already being taught. B E 835 was approved as a new course by Clemson in November, 2005.
- General Biochemistry Laboratory I BIOCH 633 2(0,4) An exploration of current techniques in biomedical research.
- Issues in Research BIOCH 805/GEN 805 2(2,0) Covers scientific writing, oral presentation, evaluation of scientific communication, plus legal and ethical issues.
- Methods in Molecular Biology GEN 810 3(3, 0) Prokaryotic and eukaryotic gene structure, regulation of transcription initiation and protein synthesis, and analysis of protein function.
- Seminar BIOCH 825/GEN 825 1(1,0) This course will function both as a seminar experience and as exposure to molecular biology topics for students from outside Genetics and Biochemistry. Will be taken once.
- Seminar (presentation for grade) BIOCH 851/GEN 851 1 (1,0) or presentation of a seminar on a biotechnology topic in a similar course in the student's major. We hope that allowing seminar courses in other majors to substitute for this course will facilitate expansion of the degree in future years.
- Statistical Methods I EX ST 801 4(3,3)
- Research GEN 491 (3 credits) Again, a research experience on a biotechnology topic in a similar course in the student's major can be substituted if approved. In the Bioprocessing option, B E 901 substitutes for this course.

Required Courses for "Molecular Biology" Option (6 credits)

- Bioinformatics GEN 640 3(3,0) Application of computational technology to biotechnology problems.
- Genomics and Proteomics BIOCH 820/ GEN 820 3(3,0) Study of genomes, transcriptomes, and proteomes, along with the technology used to obtain the information.

Required Courses for "Bioprocessing" Option (9 credits)

- Industrial Microbiology MICRO 613 3(2,3) Microbial aspects of large-scale processes for the production of foods, antibiotics, enzymes, fine chemical and beverages. Topics include strain selection, culture maintenance, biosynthetic pathways, continuous cultivation, production of single-cell protein.
- Biochemical Engineering BE/CHE 628 3(3,0) Use of microorganisms and enzymes for the production of chemical feedstocks, single-cell proteins, antibiotics, and other fermentation products. Topics include kinetics and energetics of microbial metabolism, design and analysis of reactors for microbial growth and enzyme-catalyzed reactions, and considerations of scale-up, mass transfer, and sterilization.
- Bioprocess Engineering Design BE 638 3(2,2) Design and analysis of systems for processing biological materials; topics include biotechnology, thermodynamics, transport processes and biological properties related to bioprocess design and computational simulation; unit

operations include basic bioreactor operation, bioseparations, and preservation techniques. Laboratory content applies basic bioprocessing theory, tours bioprocessing facilities and gain hands-on experience with bioprocessing equipment. Introduction of bioprocess design simulation software.

Elective Courses
Student will choose courses to bring course graduate credits to 30.

- Physical Approach to Biochemistry BIOCH 631 3(3,0)
- Biochemistry of Metabolism BIOCH 632 3(3,0)
- General Biochemistry Laboratory II BIOCH 634 2(0,4).
- Biochemical Basis of Disease BIOCH 643 3(3,0)
- Advanced Biochemistry BIOCH 814 3(3,0)
- Signal Transduction BIOCH 816 3(3,0)
- Cellular Metabolism BIOCH 818 3(3,0) Preq. GEN 810 and 820.
- Proteins BIOCH 821 3(3,0) Preq. BIOCH 623 or 631.
- Enzymes BIOCH 822 3(3,0) Preq. BIOCH 623 or 631.
- Structure and Function of Nucleic Acids BIOCH 832 3(3,0)
- Special Topics in Biochemistry BIOCH 890 variable credit.
- Bioinformatics GEN 640 3(3,0) Preq. Required for Molecular Biology Option.
- Advanced Genetics GEN 814 3(3,0)
- Genomics and Proteomics BIOCH 820/ GEN 820 3(3,0) Required for Molecular Biology Option.
- Special Topics in Genetics GEN 890
- Industrial Microbiology MICRO 613 3(2,3) Required for Bioprocessing Option.
- Design and Analysis of Experiments EX ST 805 3(3,0)
- Biochemical Engineering B E 628 3(3,0) Required for Bioprocessing Option.
- Applications in Biotechnology Engineering B E 635 3(2,3).
- Bioprocess Engineering Design B E 638 3(2,2) Required for Bioprocessing Option.
- Advanced Bioprocess Engineering B E 838 3(3,0).
- Transport Phenomena CH E 601 3(3,0)
- Chemical Engineering Thermodynamics CH E 804 3(3,0).
- Applied Numerical Methods in Process Simulation CH E 814 3(3,0)
- Tissue Engineering BIO E 849 3(3,0)

Degree Completion Process for M.S. Students

Table 3 provides an outline of the typical course of study for a student entering the M.S. in biotechnology with an undergraduate degree in a life science or engineering field.

Table 3. Degree completion process for graduate students who enter the program with a B.S. degree.

	Molecular Biology	**Bioprocessing**
Undergraduate course work	*Suggested* modeling course MICRO 305	*Required* Modeling Course MICRO 305 GEN 302
Fall, Year 1	GEN 491 GEN 805 BIOCH 633	BE 628 GEN 805 GEN 810
Spring, Year 1	GEN 491 GEN 810 GEN 640	B E 638 BIOCH 633 Elective
Fall, Year 2	GEN 825 EX ST 801 Elective	GEN 825 EX ST 801 MICRO 613
Spring, Year 2	GEN 820 GEN 851 Elective	B E 901 GEN 851 Elective
Summer, Year 2	B E 835	B E 835

Degree Completion Process for B.S./M.S. Students

B.S. - M.S. students can complete the program in their Senior year, a graduate year, and a summer. Table 4 shows how undergraduate students in Genetics, Biochemistry, and Biosystems Engineering would probably complete the 5-year degree. It is assumed that the Genetics and Biochemistry students would complete the Molecular Biology option and the Biosystems Engineering students would complete the Bioprocessing option.

Table 4. Degree completion process for Genetics, Biochemistry, and Biosystem Engineering students entering the proposed program at the end of their Junior year.

	Genetics	**Biochemistry**	**Biosys. Eng.**
Previous Semesters	*Modeling Course (recommended)* *MICRO 305* *GEN 640*	*Modeling Course (recommended)* *MICRO 305* *BIOCH 633*	*Modeling Course (required)* *MICRO 305* *GEN 302*
Senior Fall	*GEN 491* GEN 805 BIOCH 633	*BIOCH 491* BIOCH 805 GEN 810	B E 628 GEN 805 GEN 810
Senior Spring	*GEN 491* GEN 810	*BIOCH 491* GEN 640	B E 638 BIOCH 633 Elective
Graduate Fall	GEN 825 EX ST 801 Elective	GEN 825 EX ST 801 Elective	GEN 825 EX ST 801 MICRO 613
Graduate Spring	GEN 820 GEN 851 Elective	GEN 820 GEN 851 Elective	B E 901 GEN 851 Elective
Graduate Summer	B E 835	B E 835	B E 835

Courses in italics will not be counted in the 30-credit course total for graduation because they are either undergraduate courses or they are 400/600-level courses taken at the 400-level before the student is admitted to the B.S./M.S. program.

Credit Totals

A non-thesis M.S. must contain 30 graduate credits, half of which are at the 800 level or higher. Students starting from Genetics, Biochemistry, or Biosystems Engineering will easily meet these requirements. They will take from 21-23 graduate credits in required courses alone, and at least 15 of these required courses will be 800-level. They will have from 7-10 elective credits when their required courses are completed.

Faculty

The proposed degree uses only courses that are already being taught. The one exception is B E 835, which will be taught by Dr. Terry Walker of Biosystems Engineering, and perhaps by other Biosystems faculty. Therefore, the faculty who will be teaching in the program are highly qualified and will all be teaching in their fields. Genetics and Biochemistry does anticipate hiring a lecturer to both teach in the program and take over its administration. The Table 5 lists these faculty by rank.

Table 5. Qualifications of faculty who will teach in the proposed program.

Rank	Highest Degree Earned	Field of Study	Teaching in Field (Yes/No)
Professor #1	Ph.D.	Genetics	Yes
Professor #2	Ph.D.	Biochemistry	Yes
Associate Professor #1	Ph.D.	Biochemistry	Yes
Associate Professor #2	Ph.D.	Biochemistry	Yes
Associate Professor #3	Ph.D.	Genetics	Yes
Associate Professor #4	Ph.D.	Genetics	Yes
Associate Professor #5	Ph.D.	Biosystems Engineering	Yes
Associate Professor #6	Ph.D.	Biosystems Engineering	Yes
Associate Professor #7	Ph.D.	Bioengineering	Yes
Associate Professor #8	Ph.D.	Chemical Engineering	Yes
Assistant Professor #1	Ph.D.	Genetics and Bioinformatics	Yes
Assistant Professor #2	Ph.D.	Genetics	Yes
Assistant Professor #3	Ph.D.	Microbiology	Yes
Assistant Professor #4	Ph.D.	Microbiology	Yes
Assistant Professor #5	Ph.D.	Genetics	Yes
Assistant Professor #6	Ph.D.	Genetics	Yes
Assistant Professor #7	Ph.D.	Genetics	Yes
Assistant Professor #8	Ph.D.	Biochemistry	Yes
Assistant Professor #9	Ph.D.	Biochemistry	Yes
Assistant Professor #10	Ph.D.	Biochemistry	Yes
Assistant Professor #11	Ph.D.	Genomics	Yes
Assistant Professor #12	Ph.D.	Chemical Engineering	Yes
Lecturer #1	Ph.D.	Biosystems Engineering	Yes
Lecturer #2	Ph.D.	Genetics and Biochemistry	Yes

The numbers of FTE administrators, faculty and staff who will be associated with the program are shown in Table 6 below. We assume that the courses will contain 1/3 Biochemistry, 1/3 Genetics, and 1/3 Biosystems Engineering students (student population influences the mix of courses that must be offered), and that the faculty will teach on average two graduate courses (enrollment 20) per year. Starting in the second year (the year in which B E 835 will be taught for the first time), we plan to hire two adjuncts from the biotechnology industry to help with the Good Manufacturing Practices part of that course. These two individuals will amount to 0.1 FTE each. Their costs will be primarily due to travel, lodging, and meals. With regard to administration, we assume that in the first year, we will hire a program administrator who will be 30% administration and 70% teaching in the program. The program administrator will be a

lecturer with experience in the biotechnology industry. The Genetics and Biochemistry Chair will also have to devote 10% of his or her time to the program. Once the program reaches its mature size, 1.0 FTE staff person will be taking care of its needs. The personnel requirements of the degree will be as follows:

Table 6. Program needs for administration, faculty, and staff support, 2008-2013.

UNIT ADMINISTRATION/FACULTY/STAFF SUPPORT						
YEAR	**NEW**		**EXISTING**		**TOTAL**	
	Hdcount	FTE	Hdcount	FTE	Hdcount	FTE
Administration						
2008-09	1	0.3	1	0.1	2	0.4
2009-10	0	0	2	0.4	2	0.4
2010-11	0	0	2	0.4	2	0.4
2011-12	0	0	2	0.4	2	0.4
2012-13	0	0	2	0.4	2	0.4
Faculty						
2008-09	1	0.7	5	1.3	6	2.0
2009-10	2	0.2	12	4.0	14	4.2
2010-11	0	0	14	5.8	14	5.8
2011-12	0	0	14	6.7	14	6.7
2012-13	0	0	14	6.7	14	6.7
Staff						
2008-09	0	0	4	0.5	4	0.5
2009-10	0	0	5	1.0	5	1.0
2010-11	0	0	5	1.0	5	1.0
2011-12	0	0	5	1.0	5	1.0
2012-13	0	0	5	1.0	5	1.0

Physical Plant and Equipment

The degree as presented here will be taught in existing teaching facilities. Before the Biomanufacturing Facility becomes available, we have space in McAdams Hall for up to 20 students per class. McAdams has a new biotechnology lab with autoclave, hoods, some bioprocessing equipment such as a 7 L bioreactor, pilot liquid chromatography and ultrafiltration, and large-scale supercritical fluid extraction for purifying of pharma products. Wonderware pharmaceutical plant software controls the processing equipment with a programmable logic controller. We can handle some student projects in the Biosystems Research Complex. There we have access to high-performance liquid chromatography, plate readers, and 15 L bioreactors. We might be able to use some extra space in Jordan Hall as well. Recall that the degree presently has two options—Molecular Biology and Bioprocessing. It would be convenient to teach the Molecular Biology subjects in Jordan Hall and the Bioprocessing aspects

in McAdams for now. The Biosystems Research Complex can function for higher end research equipment demonstration.

While it is not necessary to get our degree program started, ultimately, the department hopes that the Clemson Biomanufacturing Facility will be completed and can be used to teach our students industrial-scale bioprocessing as well as cGMP standards. This will be the principal home of B E 835, our capstone Industrial Biotechnology Techniques course. This facility is planned to have a pilot-scale biorefinery capable of producing biopharmacenticals, biomaterials, and bioenergy, and act as a teaching lab as well. It will contain a GLP/GMP facility, including clean rooms, bioreactors ranging up to 1000 L, and several kinds of separation technologies used in the biotechnology industry, such as simulated moving bed chromatography, continuous centrifuges, micro and ultrafiltration units, distillation, crystallizers, and lyophilizers. North Carolina State has constructed a similar complex for $30 million, and other states have similar plans.

The equipment requests are modest. In order to outfit the capstone B E 835, we would like to purchase a 20-30 liter steam-in-place, fully controlled teaching bioreactor (approximately $30,000), a biosafety cabinet ($7,000), a refrigerated centrifuge, and supplies such as ultrafiltration cartridges and chromatography columns and media. The total first-year cost will be approximately $50,000. After that, we anticipate continuing costs of about $10,000 per year for the next four years.

Library Resources

Clemson has been a power in biotechnology research for years, so library resources are more than sufficient to support this degree program. The *ALA Standards for College Libraries* does not provide specific standards for biotechnology. However, the general operations of the Clemson University Libraries are accredited by the Southern Association for Colleges and Schools plus thirteen other bodies (none of which specifically address biotechnology). A search of the Libraries' holdings discloses 705 book titles under the general heading of "Biotechnology"; 218 of these titles were published in the last five years. The Libraries also subscribe to 15,000 journals, and has a growing list of "e-journals" and an effective Interlibrary Loan program to acquire books and journals not on its list.

E**stimated Cost**

New costs of the M.S. in Biotechnology are principally due to the hiring of the program administrator (70% teaching and 30% administration), 1.5 months of summer salary for the faculty member who will teach B E 835, and the purchase of new teaching equipment. This equipment will be necessary to support the increased number of students in courses already being taught and to outfit the new capstone course, B E 835.

Table 7. Anticipated new costs and revenues of the M.S. in Biotechnology.

NEW ESTIMATED COSTS BY YEAR						
CATEGORY	**1st**	**2nd**	**3rd**	**4th**	**5th**	**TOTALS**
Program Administration	$15,000	$15,000	$15,000	$15,000	$15,000	$75,000
Faculty Salaries	$45,000	$45,000	$45,000	$45,000	$45,000	$225,000
Graduate Assistants	$40,000	$40,000	$40,000	$40,000	$40,000	$200,000
Clerical/Support Personnel						
Supplies and Materials	$10,000	$10,000	$10,000	$10,000	$10,000	$50,000
Library Resources						
Equipment	$50,000	$10,000	$10,000	$10,000	$10,000	$90,000
Facilities						
Other (Identify)						
TOTALS	$160,000	$120,000	$120,000	$120,000	$120,000	$640,000
NEW SOURCES OF FINANCING BY YEAR						
Estimated FTE Revenue Generated from the State	$11,130	$55,650	$89,040	$111,300	$133,560	$400,680
Tuition Funding (New students only)	$7990	$39,950	$63,920	$79,900	$95,880	$287,640
Other State Funding (Legislative Approp.)						
Reallocation	$140,880	$24,400				$165,280
Federal Funding						
Other Funding (Endowment, Auxiliary etc.)						
TOTALS	$160,000	$120,000	$152,960	$191,200	$229,440	$853,600

Approval History

Clemson University Board of Trustees	October 22, 2004
Degree program approved by departmental Curriculum Committee	September 14, 2005
Degree program approved by departmental faculty	September 29, 2005
Degree program approved by college Curriculum Committee	April 28, 2006
Degree program approved by Dean	April 28, 2006
Degree program approved by University Graduate Curriculum Committee	September 8, 2006
Degree program approved by Provost	November 7, 2006
Degree program approved by President	November 7, 2006