RESOLUTION TO APPROVE BACHELOR OF SCIENCE DEGREE IN SYSTEMS BIOLOGY

Documents included:

1. Resolution to Approve Bachelor of Science Degree in Systems Biology
2. Degree Proposal for Bachelor of Science Degree in Systems Biology
3. Degree Proposal Presentation – slides

RESOLUTION TO APPROVE NEW DEGREE IN BACHELOR OF SCIENCE IN SYSTEMS BIOLOGY

WHEREAS, systems biology is a rapidly emerging field that draws on ideas and methods from biological sciences, chemistry, physics, mathematics and statistics, these disciplines lying at the core of science technology engineering and mathematics (STEM) education; and

WHEREAS, systems biology is foundational to our current understanding of the molecular machines and regulatory networks that make life possible at the cellular level, knowledge that is basic to modern industrial developments in biomedicine, biotechnology, pharmaceuticals and agricultural production; and

WHEREAS, Virginia Tech is in an excellent position to initiate a bachelor of science in systems biology, due to its strong base of senior faculty in the College of Science who are actively engaged in research in systems biology, and who are joined in this endeavor by senior faculty in the Department of Computer Science and senior research scientists in the Virginia Bioinformatics Institute, as well as new faculty members across the university who are being hired into this new and rapidly expanding field; and

WHEREAS, the bachelor of science in systems biology will provide students with a knowledge base of theoretical principles and experimental tools and techniques in systems biology; and

WHEREAS, the bachelor of science in systems biology will prepare graduates for interdisciplinary research and education, with employment in the private sector, employment in state and federal government agencies, and for post-baccalaureate training; and

WHEREAS, the undergraduate degree in systems biology is unique in the Commonwealth of Virginia and will establish Virginia Tech and the commonwealth as key leaders in education for one of the most critical technologies of the future;

NOW, THEREFORE BE IT RESOLVED, that the bachelor of science in systems biology be approved effective fall 2015.

RECOMMENDATION:

That the resolution to establish the bachelor of science in systems biology be approved.

November 10, 2014

Virginia Tech Degree Proposal
Bachelor of Science Systems Biology
(CIP: 26.1104)

Type of degree action (circle one): (New) Spinoff Revision Discontinuance

Program description

Virginia Tech seeks approval for a new bachelor of science in systems biology, with the anticipated initiation date of fall, 2015. A systems approach to biology involves the study of the biological, chemical, and physical processes within living organisms interacting in complex ways to produce life-supporting behaviors that are not trivially reducible to the properties of the individual components. Systems-level thinking has a long and distinguished history in biology (for example, organ systems and ecosystems), but it has only recently permeated the field of molecular cell biology, where reductionist approaches have reigned supreme from the discovery in 1953 of the structure of DNA until the complete sequencing of the human genome in 2000.

The proposed B.S. in systems biology at Virginia Tech will focus on molecular systems biology, i.e., on quantitative, computational, systems-level approaches that connect the biochemical and genetic properties of macromolecules (DNA, RNA, protein, lipids, polysaccharides) with the physiological behavior of living cells and tissues. The program is focused at these levels of biological organization because the gap between interacting macromolecules and cell physiology is an active area of current research and a promising area for technological and biomedical innovations. Systems-level thinking at higher levels of biological organization is already covered at Virginia Tech and at other institutions in Virginia by programs in organismal physiology, neuroscience, ecology, and natural resources. The molecular/cell divide is the gap intended to be filled by this program of study designed to train undergraduates from Virginia and other states for employment or graduate education in the burgeoning field of molecular systems biology.

A successful undergraduate program in molecular systems biology must cover two distinct and complementary areas: bioinformatics and mathematical modeling. The genomics revolution has created many new and exciting ways to collect data on the scale of the entire genome. These new technologies create vast quantities of data that can only be handled, analyzed, and interpreted with the help of concepts, algorithms, and software tools from the field of biological informatics. The next step is to use this curated information about molecules and biochemical interactions to understand how cells move around, feed, grow, divide, differentiate and eventually die, which is the domain of mathematical modeling. At Virginia Tech we have world-renowned research scientists in the areas of bioinformatics and network modeling. Building on this faculty expertise, the undergraduate degree program will train students in all aspects of molecular system biology, preparing them to unravel the molecular basis of cell and tissue physiology. In addition to novel integration of concepts and skill sets from biology, chemistry, physics, mathematics, statistics, and computer science, the degree in systems biology will rely

heavily on new methods of pedagogy (active learning) and will be capped off by a significant research experience in the senior year.

Curriculum summary

Students may enter the degree via two routes. One route is the "traditional" route, inw which students must pass a series of introductory science courses equivalent to: principles of biology (8 cr), general chemistry (8 cr), general physics (8 cr), elementary calculus and linear algebra (8 cr), statistics (3 cr) and computer science (3 cr). The second, or alternative, route is to enter the degree through the Integrated Science Course (ISC), a new series of four 8-credit courses taken during the first and second years of residency. Conducive to the goals of the systems biology degree, the ISC will provide students with basic knowledge and skills in the physical, life and mathematical sciences in an integrative, multi-disciplinary environment.

Regardless of their route of entry, all students in the systems biology degree must take the 8-credit Introduction to Systems Biology course in year two. This course will expose students to systems-level thinking, fill in gaps in their preparation, and get them excited about a career in systems biology. Building on this foundation, the core courses of year three (Systems Biology of Genes and Proteins, and Network Dynamics and Cell Physiology) will focus on functional genomics, proteomics, bioinformatics, metabolic control, signal transduction networks, dynamic modeling, experimental verification, human diseases and drug development. These courses will prepare students for a research experience in year four.

Every student will be involved in the laboratory of an affiliated faculty member by enrolling in The Research Experience in Systems Biology (8 cr). In parallel, every major will take a course in Professionalism in Systems Biology (4 cr), which will include instruction in research practice and ethics, in writing and presentation skills, in grantsmanship, and in the critical give-and-take of team science. The climax of these courses will be a capstone thesis to be submitted one month before graduation.

The curriculum will be presented in creative ways that emphasize active learning, mastery of diverse ideas and skills, integration of ideas, problem solving, and teamwork. Each of the new courses in this curriculum will be integrative in terms of scientific disciplines and methods, lectures and lab experiences, formal instruction and active problem solving, individual effort and collaborative teamwork. This integrative style will be modeled by all instructors and expected of all students in all core courses required for the major.

In summary (see below), the B.S. in systems biology comprises 120 credits, distributed among the following categories of courses: (1) Curriculum for a Liberal Education (38 cr), (2) systems biology required core (36 cr), (3) additional mathematics and science courses (27 cr), (4) restricted electives (12 cr), and (5) free electives (7-13[§] cr).

Curriculum for a Liberal Education (38 credits; required of all students)

Area 1: Writing and Discourse (6 cr)
Area 2: Ideas, Cultural Traditions, and Values (6 cr)
Area 3: Society and Human Behavior (6 cr)
[§]Area 4: Scientific Reasoning and Discovery (BIOL 1105-6, Principles of Biology, 8 cr)

§Area 5: Quantitative and Symbolic reasoning (MATH 1025-6, Elementary Calculus, 6 cr)
Area 6: Creativity and Aesthetic Experience (3 cr)
Area 7: Critical Issues in a Global Context (3 cr)

Systems Biology Required Core (36 credits; required of all students)
*SYSB 2025: Intro to Systems Biology (4 cr)
*SYSB 2026: Intro to Systems Biology (4 cr)
*SYSB 3035: Systems Biology of Genes and Proteins (4 cr)
*SYSB 3036: Systems Biology of Genes and Proteins (4 cr)
*SYSB 3115: Network Dynamics & Cell Physiology (4 cr)
*SYSB 3116: Network Dynamics & Cell Physiology (4 cr)
*SYSB 4065: Research Experience in Systems Biology (4 cr)
*SYSB 4066: Research Experience in Systems Biology (4 cr)
*SYSB 4135: Professionalism in Systems Biology (2 cr)
*SYSB 4136: Professionalism in Systems Biology (2 cr)

} Capstone Thesis

*Indicates new course

Additional Mathematics and Science Courses (27 credits; see note below)
§CHEM 1035-6: General Chemistry (6 cr)
§CHEM 1045-6: General Chemistry Lab (2 cr)
§CHEM 2514: Survey of Organic Chemistry (3 cr)
§PHYS 2205-6: General Physics (6 cr)
§PHYS 2215-6: General Physics Lab (2 cr)
§MATH 1114: Elementary Linear Algebra (2 cr)
§STAT 3615: Biological Statistics (3 cr)
CS 1044: Introduction to Programming in C (3 cr)

Restricted Electives (12 credits from the following):
BIOL 4104 Developmental Biology
BIOL 4734 Inflammation Biology
BIOL 4844 Proteomics & Biol Mass Spec
STAT 3104 Probability & Distributions
STAT 4444 Applied Bayesian Statistics
PHYS 4714 Intro to Biophysics
MATH 4254 Chaos & Dynamical Syst
MATH 4454 Applied Mathematical Modeling
MATH 4445 Intro to Numerical Analysis
MATH 4446 Intro to Numerical Analysis
CHEM 4615 Phys Chem for Life Sci
CHEM 4616 Phys Chem for Life Sci
CS 2114 Softw Des & Data Structures
CS 3414 Numerical Methods
ECE 3704 Cont & Discrete System

Free Electives (7-13§ credits)
§**NOTE**: An alternative to the set of entry-level science and math courses is available for students who seek a more integrated approach to the life sciences as their core experience in this degree program. Upon acceptance of their application, selected students will be admitted into the following Integrated Science Curriculum program:

Integrated Science Course (32 credits)
ISC 1105, 1115: Integrated Science (8 cr)
ISC 1106, 1116: Integrated Science (8 cr)
ISC 2105, 2115: Integrated Science (8 cr)
ISC 2106, 2116: Integrated Science (8 cr)

Successful completion of the full sequence of the Integrated Science Curriculum (32 cr) will satisfy Areas 4 and 5 of the CLE requirements (14 cr) and most of the additional mathematics and science courses (24 cr) listed above. The six credit hours saved by taking the ISC will be added to the free electives for the degree:

Free Electives (13 credits instead of 7 credits for the option listed above)

Relevance to university mission and strategic planning

A B.S. in systems biology advances the mission of the university and the College of Science (http://www.science.vt.edu/about/about-mission.html) which aims to prepare future professionals in disciplines that enhance "the well-being and development of the university, the local community, the Commonwealth, the nation, and the world." It enriches the academic experience of undergraduate students by emphasizing interdisciplinary learning and a capstone research-thesis project. It fosters scholarship and professional development in the key areas of health, food and nutrition and innovative technologies and complex systems. It focuses students' intellectual assets on societal issues that will engage the best scientific minds of the future. Moreover, the B.S. in systems biology will help to fulfill the mission of the university by contributing to the "discovery and dissemination of new knowledge" in the life sciences (http://www.president.vt.edu/mission_vision/mission.html).

By bringing to bear the concepts and tools from the physical, chemical and mathematical sciences on current problems in health, agriculture, and biotechnology, the new and growing field of systems biology promises to create, convey and apply knowledge across disciplinary boundaries to improve the quality of human life and to foster the economic competitiveness of the Commonwealth and the nation. The new degree is fully consistent with the university's vision: to train productive citizens and future professionals, to blur the distinctions between basic and applied research and the boundaries between disciplines, and to foster an atmosphere of intellectual discovery and excitement (http://www.president.vt.edu/strategic-plan/2012-plan/2012-strategic-plan.pdf).

Justification for the proposed program

At present, molecular systems biology is one of the most active areas of life science research in the world, as evidenced by the growing number of graduate programs in systems biology at major universities, the growing number of new research institutes in systems biology being established worldwide, the new funding opportunities at the National Institutes of Health, National Science Foundation, and Department of Energy, at private foundations, and the growth of employment opportunities for systems biologists at biotech startup companies and well established pharmaceutical firms. However, few undergraduate degree programs in systems biology exist anywhere in the world.

This gap will soon be filled by colleges and universities that aspire to lead the nation in educating the next generation of systems-thinking life scientists. Virginia Tech can become a national leader in this area of undergraduate education because it is the only public university in Virginia with the depth and breadth of faculty expertise to be a strong national contender in this arena. Our proposed undergraduate degree in systems biology

is perfectly aligned with the report of a distinguished committee of the National Research Council[2] ("BIO2010: Transforming Undergraduate Education for Future Research Biologists"; http://www.nap.edu/openbook.php?record_id=10497&page=27). The committee's number one recommendation was:

> Given the profound changes in the nature of biology and how biological research is performed and communicated, each institution of higher education should reexamine its current courses and teaching approaches to see if they meet the needs of today's undergraduate biology students. Those selecting the new approaches should consider the importance of building a strong foundation in mathematics and the physical and information sciences to prepare students for research that is increasingly interdisciplinary in character.

The potential benefits of systems biology extend beyond basic biology to practical issues in agriculture, forestry, veterinary and human medicine, and biomimetic engineering. A solid program in systems biology at the undergraduate level will prepare the future work force of Virginia in these essential areas serving our society.

Student Demand

The ultimate target enrollment for the systems biology degree is a total of 65 majors. The Department of Biological Sciences, with more than 1,600 majors, provides a large pool of prospective candidates for a degree in systems biology. In a poll of freshmen (spring 2011) enrolled in Principles of Biology, students were informed that the College of Science is considering adding new courses and a possible new major in systems biology. When asked whether they would be interested in taking systems biology courses, 35% (102 of 291 respondents) said yes; and when asked whether they would be interested in majoring in systems biology, 12% replied affirmatively (33 of 278 respondents). Consequently, a systems biology degree could meet its enrollment goal if only half of these entry-level life science students who expressed an interest in the major were to sign up. In addition, because of the broad interdisciplinary character of the degree, it should attract students from the physical sciences and from engineering at Virginia Tech, at the very least as a unique opportunity for a double major. Moreover, because this systems biology degree would be the first such program in Virginia and one of a very few in the world, it is expected that additional students from out-of-state and internationally will apply to Virginia Tech to take advantage of this opportunity.

Existing courses illustrate the great potential for populating systems biology courses. Table 1 shows total enrollment for relevant courses in biology, statistics, physics, electrical and computer engineering, mathematics, computer science, and chemistry from 2009 to fall 2013. Listed are the restricted electives for the systems biology curriculum, these being good indicators of student interest in the systems biology areas. Note particularly that the enrollment in almost all of these courses has grown over the five-year period.

Table 1. Total enrollment for restrictive elective courses in the systems biology curriculum from 2009 to 2013 (data retrieved from Banner on 11/26/2013, ¥data retrieved from Banner on 03/17/2014, £data retrieved from Banner on 04/23/2014).

Existing Courses	2009	2010	2011	2012	2013
BIOL 4104	NA	40	40	43	49
BIOL 4734	NA	NA	NA	35	50
BIOL 4844	NA	NA	2	NA	2
CHEM 4615	172	186	230	248	236
CHEM 4616	131	151	165	162	192
CS 2114£	138	209	251	293	350
CS 3414£	45	45	54	49	50
ECE 3704¥	101	162	124	133	141
MATH 4254	10	9	8	6	13
MATH 4445¥	38	40	52	61	67
MATH 4446¥	49	36	40	51	42
MATH 4454	23	19	29	NA	29
PHYS 4714	3	11	17	15	NA
STAT 3104	NA	NA	11	28	21
STAT 4444	5	6	17	8	12

Market Demand

From recent degree-related employment projections of the U.S. Bureau of Labor Statistics and the Virginia Employment Commission, it is evident that the demand for life scientists will see robust growth over the next 5-10 years. Popular job search websites currently list thousands of public and private sector job advertisements under the search terms “systems biology”, “computational biology”, “genomics”, and “bioinformatics”, with many being open to applicants with bachelor degrees.

The bioscience field as a whole, encompassing both the public and private sectors and extending beyond obvious biomedical applications to innovations in agriculture, energy, and the environment, is one of the fastest growing sectors of the economy. According to a report (http://www3.bio.org/local/battelle2010/Battelle_Report_2010.pdf) of the Battelle Institute for Private Industry, the bioscience industry added 193,748 jobs from 2001 to 2008, a hefty growth rate of 15.8 percent. This rapid rate of job growth was 4.5 times the overall growth rate for the national private sector (3.5 percent). According to the report, even with the economic recession in 2008, the national annual “employment in the bio-science industry grew at 1.4% while total private sector employment declined by 0.7%.” As listed below, a healthy number of job prospects await our graduates who seek employment with their undergraduate degree.

Job listings on http://www.simplyhired.com

Job Title	All Job Listings	Open to B.S.
Systems Biology	9216	521
Computational Biology	1402	62
Genomics	3362	148
Bioinformatics	2395	92

In addition to employment opportunities in Virginia, there are several graduate programs in bioinformatics, computational biology and systems biology at Virginia universities for which our graduates would be eminently qualified:

Virginia Tech, Graduate School
Ph.D. Genetics, Bioinformatics and Computational Biology

George Mason University, School of Systems Biology
M.S. Bioinformatics and Computational Biology
M.S. Bioinformatics
M.S. Biomedical Sciences (Systems Biomedicine)
Ph.D. Bioinformatics and Computational Biology

Virginia Commonwealth University, Center for the Study of Biological Complexity
M.S. Bioinformatics
Ph.D. Integrative Life Sciences

Resource Needs/Savings

The newly created systems biology courses will be primarily delivered by the faculty in the departments of biological sciences, of chemistry, of physics, and of mathematics. It is anticipated that two new hires at the assistant professor rank in the field of molecular systems biology will be assigned to the systems biology program. These faculty members will be housed jointly within the Academy of Integrated Science and departments within the College of Science. These hires are associated with re-distribution of faculty positions within the College of Science.

The College of Science initiated cluster hiring in 2004 as a means of strategically re-aligning resources to better meet the needs of the university, of positioning the college to address interdisciplinary grand challenges in science, and of educating our students in a more comprehensive manner. Hiring in clusters, rather than specific disciplines, is a strategy for the college to seek and acquire the best faculty to promote our research and educational agenda and thereby achieve a stronger institution. Reallocation and/or realignment of resources to make faculty hires in systems biology is a continuation of the college's on-going strategic initiatives.

Four graduate teaching assistants (GTAs) will adequately cover the laboratory courses as well as the recitation sections throughout the curriculum.

No additional library or telecommunication resources will be required for the program beyond those that already exist.

In terms of space and equipment, the program will use a synergistic combination of existing resources, which includes faculty research laboratories and existing teaching laboratory spaces:

- The college has recently constructed three dynamic, interdisciplinary lab spaces that will be shared in the initial stages of the program. This space is uniquely positioned within the Biological Sciences and adjacent to the Physics department.
- The laboratory space that is available to systems biology students comprises chemical hoods, instrumentation, team bench spaces, cell culture facilities, and team data discussion spaces.
- The university has instituted a mechanism by which lab fees can be collected to help maintain equipment and supplies.
- As the program matures, the expectation is that the planned science research lab building will house these laboratory courses.

RESOURCE	ESTIMATED COSTS (NA: not applicable)
Faculty	$199,120 (salary and benefits for 2 positions)
Administrative Staff	NA
Graduate Teaching/ Graduate Research Assistants	$113,564 (stipend, benefits and tuition for 4 graduate teaching assistants)
Space	NA
Library	NA
Equipment	$800,000 (as part of startup for 2 positions)
Other	$4000/y for software licenses; laboratory costs will be recouped from student lab fees