SUMMARY AGENDA

9:00 a.m.  CHECK-IN & COFFEE  Miller Hall First Floor Atrium

9:15 a.m.  WELCOME AND OVERVIEW OF VISION & CHANGE  Miller Hall 104
Gary Reiness, Lewis & Clark College and Barbara Stebbins-Boaz, Willamette University

9:30 a.m.  KEYNOTE ADDRESS  Miller Hall 104
Beyond Assessing Knowledge—Card Sorting, Superheroes, and Moving Towards Measuring Biological Expertise as Described in Vision & Change
Kimberly Tanner, San Francisco State University

10:30 a.m.  BREAK  Miller Hall Atrium

10:45 a.m.  KEYNOTE RESUMES  Miller Hall 104

11:30 a.m.  INSTITUTIONAL GROUP MEETINGS  TBD

12:00 p.m.  LUNCH AND CONTINUED CONVERSATION  Miller Hall Atrium & Other Spaces

1:00 p.m.  PLENARY PRESENTATION  Miller Hall 104
We Have a Vision, but How Do We Change?
Stasinos Stavrianeas & Jason Duncan, Willamette University
1:45 p.m.  **BREAKOUT SESSION**  
*Applying the Vision and Change Model to Course Design*  
TBD

2:15 p.m.  **BREAK FOR HORS D’OEUVRES AND BEVERAGES**  
*Miller Hall Atrium*

2:30 p.m.  **PLENARY SESSION**  
*Departmental Responses to Vision and Change Curricular Mandates*  
Miller Hall 104  
David Craig, Willamette University & Gary Reiness, Lewis & Clark College

3:15 p.m.  **WORK ON ACTION PLANS IN GROUPS OF SIMILAR INSTITUTIONAL TYPE**  
TBD

3:45 p.m.  **WORKSHOP EVALUATION & CONCLUDING REMARKS**  
*Miller Hall 104*

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*The WVBEN PKAL Regional Network workshop is generously supported in part by grant MCB-1021093 from the National Science Foundation to Gary Tallman.*

*The Network is also appreciative of Lewis & Clark College for hosting the workshop.*
These are exciting times for biologists, with changes occurring in all areas of the life sciences, from breakthroughs in genomics and neuroscience to a deeper understanding of the effects of global climate change on Earth’s ecosystems. And yet, many of these new areas of biology, and the skills needed to understand and engage effectively in them, typically do not appear in science classrooms and textbooks until many years after their inception, leaving undergraduate biology education lagging behind these exciting scientific advances. As a consequence, too many students never learn about the cutting edge discoveries that make biology so exciting to professional scientists, or engage in the kinds of active participation in science that will better prepare them to be informed citizens and — for those choosing to go on — to succeed as modern scientific researchers.

... A key recommendation [of the Vision and Change Report] is that biology courses and curricula must engage students in how scientific inquiry is conducted, including evaluating and interpreting scientific explanations of the natural world. In this volume, you will find the consensus framework that emerged to produce core concepts and competencies that can serve as the distinguishing features of undergraduate biology education.

-- American Association for the Advancement of Science. Vision and Change in Undergraduate Biology Education: A Call to Action. 2011.
KEYNOTE ADDRESS

BEYOND ASSESSING KNOWLEDGE—CARD SORTING, SUPERHEROES, AND MOVING TOWARDS MEASURING BIOLOGICAL EXPERTISE AS DESCRIBED IN VISION & CHANGE

Location: Miller Hall Room 104
Time: Part I - 9:30 - 10:30 a.m.; Part II - 10:45 - 11:30 a.m.
(Break from 10:30 - 10:45 a.m.)

Presenter:
- Kimberly Tanner
  Associate Professor of Biology
  Director of the Science Education Partnership and Assessment Laboratory
  San Francisco State University

How do biology experts structure their thinking about the concepts in their discipline? How is this different from the way those new to the field approach these same ideas? In this interactive keynote address, guest presenter Dr. Kimberly Tanner will engage the audience in thinking about expert and novice thinking in biology by drawing upon her own research that integrates methodologies from science education and cognitive psychology. Approaches to understanding and measuring biological expertise are strongly tied to ideas put forward by the AAAS and the NSF in the recently published, Vision and Change for Undergraduate Biology Education.

VISION AND CHANGE
CORE CONCEPTS

1. EVOLUTION:
The diversity of life evolved over time by processes of mutation, selection, and genetic change.

2. STRUCTURE AND FUNCTION:
Basic units of structure define the function of all living things.

3. INFORMATION FLOW, EXCHANGE, AND STORAGE:
The growth and behavior of organisms are activated through the expression of genetic information in context.

4. PATHWAYS AND TRANSFORMATIONS OF ENERGY AND MATTER:
Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics.

5. SYSTEMS:
Living systems are interconnected and interacting.

KEYNOTE ADDRESS

BEYOND ASSESSING KNOWLEDGE—CARD SORTING, SUPERHEROES, AND MOVING TOWARDS MEASURING BIOLOGICAL EXPERTISE AS DESCRIBED IN VISION & CHANGE

LOCATION: Miller Hall Room 104  TIME: Part I - 9:30 - 10:30 a.m.; Part II - 10:45 - 11:30 a.m.
(Break from 10:30 - 10:45 a.m. in Miller Hall Atrium)

NOTES:

Appreciating the scientific process can be even more important than knowing scientific facts. People often encounter claims that something is scientifically known. If they understand how science generates and assesses evidence bearing on these claims, they possess analytical methods and critical thinking skills that are relevant to a wide variety of facts and concepts and can be used in a wide variety of contexts.

—National Science Foundation, Science and Technology Indicators, 2008.

BEST IDEA:
INSTITUTIONAL GROUP MEETINGS

LOCATION: TBD                      TIME: 11:30 A.M. - 12:00 P.M.

Institutional groups meet to consider how to apply the insights from the keynote address to their home institution.

<table>
<thead>
<tr>
<th>VISION AND CHANGE</th>
<th>CORE COMPETENCIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ABILITY TO APPLY THE PROCESS OF SCIENCE:</td>
<td>Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.</td>
</tr>
<tr>
<td>2. ABILITY TO USE QUANTITATIVE REASONING:</td>
<td>Biology relies on applications of quantitative analysis and mathematical reasoning.</td>
</tr>
<tr>
<td>3. ABILITY TO USE MODELING AND SIMULATION:</td>
<td>Biology focuses on the study of complex systems.</td>
</tr>
<tr>
<td>4. ABILITY TO TAP IN TO THE INTERDISCIPLINARY NATURE OF SCIENCE:</td>
<td>Biology is an interdisciplinary science.</td>
</tr>
</tbody>
</table>
INSTITUTIONAL GROUP MEETINGS

LOCATION: TBD  TIME: 11:30 A.M. - 12:00 P.M.

5. ABILITY TO COMMUNICATE AND COLLABORATE WITH OTHER DISCIPLINES:

Biology is a collaborative scientific discipline.

6. ABILITY TO UNDERSTAND THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY:

Biology is conducted in a societal context.


12:00 P.M. LUNCH IN MILLER HALL ATRIUM & OTHER LOCATIONS

BEST IDEA:
PLENARY SESSION

WE HAVE A VISION, BUT HOW DO WE CHANGE?

Location: Miller Hall Room 104
Time: 1:00 - 1:45 p.m.

Presenters:
- Stasinos Stavrianeas
  Professor of Exercise Science
  Willamette University
- Jason Duncan
  Assistant Professor of Biology
  Willamette University

Interdisciplinary thinking is rapidly becoming an integral feature of the research as a result of four powerful “drivers:” the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems...students, especially undergraduates, are strongly attracted to interdisciplinary courses, especially those of societal relevance.


In this talk Stas Stavrianeas will discuss his iScience framework designed to promote interdisciplinarity and quantitative literacy in science education for all students, and the steps he and colleagues have taken to create opportunities for student and faculty development and science outreach. Jason Duncan will discuss how this framework has facilitated changes in the design of his course in genetics.
PLENARY SESSION

WE HAVE A VISION, BUT HOW DO WE CHANGE?

LOCATION: MILLER HALL ROOM 104  TIME: 1:00 - 1:45 P.M.

NOTES:

... the new science of learning is beginning to provide knowledge to improve significantly people's ability to become active learners who seek to understand complex subject matter and are better prepared to transfer what they have learned to new problems and settings.

Making this happen is a major challenge, but it is not impossible. The emerging science of learning underscores the importance of rethinking what is taught, how it is taught, and how learning is assessed.


BEST IDEA:
Assessing where we are: This relates to collecting information about and making sense of the organization’s competitive environment.

Understanding who we are and where we want to go: This refers to the organization’s aspirations, including its vision, mission, and core values.

Learning how to get there: This is the formulation of strategy, including determination of priorities.

Making the journey: This involves translating the strategy into action by identifying and implementing tactics.

Checking our progress: This is the continuing assessment of the organization’s effectiveness, leading then to a reassessment at the organization’s new level of performance, which it has achieved through the other elements. This starts the learning process all over again.

BREAKOUT SESSION

APPLYING THE VISION AND CHANGE MODEL TO COURSE DESIGN

LOCATION: TBD  TIME: 1:45 - 2:15 P.M.

NOTES:

“Scientific teaching” (as described by Handelsman et al., 2007) recommends that faculty iteratively review and revise a course or curriculum on the basis of evidence that students are learning the ways of science and developing defined concepts and competencies. In this model and that of backward design, student centered courses begin with the articulation of clear, measurable learning goals, followed by the adoption of assessment tools that are appropriate for evaluating the extent to which students have achieved these goals.

The tools assess students’ mastery of facts, conceptual understanding, and acquisition of competencies and skills, as well as their attitudes and motivation (Baldwin et al., 1999; Ebert-May et al., 2003). By following the progress of student learning, faculty can continually select and adjust their teaching strategies to engage the students and help them deepen their understanding of the topics presented in the course. Well-defined learning outcomes explicitly stating what students should know and be able to do at the end of a course can also aid the development of effective instructional materials.

PLENARY SESSION

DEPARTMENTAL RESPONSES TO VISION AND CHANGE CURRICULAR MANDATES

LOCATION: MILLER HALL ROOM 103
TIME: 2:30 - 3:15 P.M.

The necessity for strengthening science education in the United States has been widely acknowledged. Although the most powerful argument for improving the science education of all students may be its role in liberating the human intellect, much of the public discussion has centered on more concrete, utilitarian, and immediate justifications. Ultimately, reform is more about people than it is about policies, institutions, and processes.

And most people—not only educators—tend to change slowly when it comes to attitudes, beliefs, and ways of doing things. Sensible professionals do not replace their strongly held views and behavior patterns in response to fiat or the latest vogue; instead, they respond to developing sentiment among respected colleagues, to incentives that reward serious efforts to explore new possibilities, and to the positive feedback that may come from trying out new ideas from time to time—all of which can take years.


Presenters:

- David P. Craig
  Associate Professor of Biology
  Willamette University
- Gary Reiness
  Professor of Biology & Associate Dean
  Lewis & Clark College

Vision and Change posits a complex array of skills and knowledge that all biology majors should acquire in their undergraduate years. But no single course can be expected to achieve all these learning goals. Given that many elective courses are the “property” of individual faculty members, each of whom has his or her own particular set of learning goals, how can departments ensure that students will meaningfully engage with all the V&C recommendations? We will discuss how our departments have begun to wrestle with this knotty and challenging task.
PLENARY SESSION

DEPARTMENTAL RESPONSES TO VISION AND CHANGE CURRICULAR MANDATES

LOCATION: MILLER HALL ROOM 103       TIME: 2:30 - 3:15 P.M.

NOTES:

. . . collaboration is extremely difficult because not only are our organizations based on principles and structures antithetical to collaboration, so are our larger systems of government, foundations, disciplinary societies, and the like. So, the challenges exist within all parts of the system. Leaders . . . will be more successful encouraging collaboration if they can acknowledge their own challenges in collaborating, learn from these experiences, and try to be role models for higher education—a system that is even more embedded in an ethic that prevents collaboration.


BEST IDEA:
WORK ON ACTION PLANS

LOCATION: TBD  TIME: 3:15 - 3:45 p.m.

Breakout groups of faculty from the same or similar institutions will discuss an action plan—bringing *Vision and Change* back to campus to motivate curricular reform.
WORK ON ACTION PLANS

LOCATION: TBD        TIME: 3:15 - 3:45 p.m.

NOTES:

FROM BOEING AIRCRAFT GROUP
TEAM MEMBER TRAINING
MANUAL (EXCERTPTS):

• EVERY member is responsible for the team’s progress and success

• Listen to and show respect for the contributions of other members; be an active listener.

• CONSTRUCTIVELY criticize ideas, not persons.

• Only one person speaks at a time.

• Everyone participates; no one dominates.

• Be succinct—avoid long anecdotes and examples.

• No rank in the room.

• Ask questions when you do not understand.

• Attend to your personal comfort needs at any time, but minimize team disruption.

• HAVE FUN!!

BEST IDEA:
WORKSHOP EVALUATION & CLOSING REMARKS

LOCATION: MILLER HALL ROOM 104  
TIME: 3:45 - 4:00 P.M.

We [scientists] . . . address key problems by knowing what the components are, what they do well, and understand that unless those component parts are interacting with one another, they are worth nothing . . . How do the pieces fit? Asking such a question is one of the primary reasons to keep connected to the people you meet along the way.

— Jim Gentile, President, Research Corporation for Science Advancement.
# RESOURCES

## INCLUDED MEETING RESOURCES

Vision and Change in Undergraduate Biology Education: A Call to Action. Pages 11 - 19.

http://www.visionandchange.org

Vision and Change Core Competencies

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## OTHER RESOURCES

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CHAPTER 2

BIOLOGICAL LITERACY

Because of the extraordinary pace of changes in the science of biology, keeping the undergraduate biology classroom current and dynamic without overwhelming students is a constant challenge. And yet, the cutting-edge discoveries that make biology so exciting to professional scientists can also excite undergraduates. All of us who teach undergraduates, therefore, need to find a balance between providing the depth of coverage required to promote appropriate student conceptual understanding while still providing needed factual knowledge. To meet this challenge, we can no longer rely solely on trying to cover a syllabus packed with topics to be covered in lecture and guided laboratory sessions—an approach that can be counterproductive and can often leave students with a misguided and, possibly, negative impression of biology. Rather, we all need to rethink what we teach—what has been historically significant in biology, what key research is being carried out today, and what implications that research may have in the future—while meeting the needs of an ever more diverse student population.

The intent of the Vision and Change conversations and national conference was to move toward a consensus framework in the biology community that would be broadly adaptable, given the unique structures, capacities, and constraints of individual life science programs. Building on the recent work of others (e.g., Association of American Medical Colleges and Howard Hughes Medical Institute, 2009; Wood, 2009a), participants proposed the core concepts and competencies described in this chapter as the distinguishing features of undergraduate biology education, providing a strong foundation to guide the development of curricular frameworks. Clearly, the utility of any proposed framework depends on its potential to be adapted to meet the local needs and resources of diverse colleges and universities. So, rather than offer a “one-size-fits-all” directive, we pose these core concepts and competencies as a resource and starting point based on the collective experience and wisdom of a broad national community of biological scientists and educators. The core concepts and competencies, outlined below, closely mirror those recently posed by others.

In our discussions, we came to a consensus that five organizing themes describe lines of inquiry in modern biology and, thereby, help define core concepts for the discipline. These concepts provide an organizational model for improving undergraduate biology education generally and designing curricula to meet the needs of the “New Biology” (NRC, 2008, 2009) in particular. The concepts also help provide a set of overarching principles that are important throughout the living world, and their use in teaching biology lends meaning to the multitude of facts that the student encounters in any undergraduate biology course. However, we agreed that the practice of biology requires more than just understanding core concepts. To understand, generate, and communicate knowledge about the living world, students need to develop and apply relevant skills. Therefore, in addition to understanding concepts, undergraduates must have opportunities to develop core competencies to better prepare them to practice biology, as well as to address the complex biology-related issues that our society faces. The core concepts and competencies, derived from general features of the discipline, together offer a framework informed by modern themes in biology that reflect disciplinary practice and are flexible enough to be useful in informing course design in diverse academic contexts.

Meeting participants also noted that, even though life sciences curricula typically serve biology majors, introductory courses help prepare all students to understand the natural world and many significant challenges of the 21st century. Although instructors teaching an introductory course cannot be expected to present the same material that will be developed in a full curriculum for majors, an introductory course should still use the core concepts and competencies to provide a solid foundation for all students.
five core biological concepts and six core competencies proposed here can serve as the basis for any undergraduate biology course, whether it is for those students who take only one or two introductory biology courses to satisfy core requirements or for biological science majors who pursue advanced studies.

FOUNDATIONS OF UNDERGRADUATE BIOLOGY

The practice of identifying key concepts and competencies for student learning is well established in science education. As early as 1985, The American Association for the Advancement of Science (AAAS) proposed a conceptual framework in its *Benchmarks for Science Literacy*. This proposal was followed by the National Research Council (NRC) report, *National Science Education Standards*, in 1996. Also, the identification of biology-specific concepts has been described in *BIO 2010* (NRC, 2003); the Association of American Medical Colleges, (2009); and the College Board Advanced Placement Study Program (2009). In concert with these efforts, the core concepts and competencies identified next form the backbone of a relevant, exciting 21st century biology education for undergraduates.

Core Concepts for Biological Literacy

After much discussion and debate, Vision and Change participants agreed that all undergraduates should develop a basic understanding of the following core concepts:

1. **EVOLUTION:**

   *The diversity of life evolved over time by processes of mutation, selection, and genetic change.*

   Darwin’s theory of evolution by natural selection was transformational in scientists’ understanding of the patterns, processes, and relationships that characterize the diversity of life. Because the theory is the fundamental organizing principle over the entire range of biological phenomena, it is difficult to imagine teaching biology of any kind without introducing Darwin’s profound ideas. Inheritance, change, and adaptation are recurring themes supported by evidence drawn from molecular genetics, developmental biology, biochemistry, zoology, agronomy, botany, systematics, ecology, and paleontology. A strong preparation in the theory of evolution remains essential to understanding biological systems at all levels.

   Themes of adaptation and genetic variation provide rich opportunities for students to work with relevant data and practice quantitative analysis and dynamic modeling. Principles of evolution help promote an understanding of natural selection and genetic drift and their contribution to the diversity and history of life on Earth. These principles enable students to understand such processes as a microbial population’s ability to develop drug resistance and the relevance of artificial selection in generating the diversity of domesticated animals and food plants.

2. **STRUCTURE AND FUNCTION:**

   *Basic units of structure define the function of all living things.*

   Structural complexity, together with the information it provides, is built upon combinations of subunits that drive increasingly diverse and dynamic physiological responses in living organisms. Fundamental structural units and molecular and cellular processes are conserved through evolution and yield the extraordinary diversity of biological systems seen today.

   Understanding of biological regulatory systems and communication networks has become increasingly sophisticated, yielding knowledge about the functional responses of the components of those systems and networks at differing scales, from the molecular to the ecosystem level of organization. Knowledge of relationships between biological structure and function is informed by design approaches from engineering and from models based on the quantitative analysis of data. The application of tools from the physical sciences often facilitates our understanding of biological structure–function relationships. For example, anatomical analysis of body morphology and function by means of a biomechanics approach and robotics...
(e.g., Spenko et al., 2008) provides a venue for discussing the interface between applied physics and biology in an undergraduate biology course. Rational drug design strategies offer useful case studies emphasizing the importance of the basic structure–function concept. For instance, elucidating the molecular structure of a target protein such as HIV protease has provided the basis for novel approaches to the discovery of drugs, leading to important antiretroviral therapies to treat AIDS.

3. INFORMATION FLOW, EXCHANGE, AND STORAGE:

The growth and behavior of organisms are activated through the expression of genetic information in context. The convergence of systems approaches and powerful bioinformatics tools has dramatically expanded our understanding of the dynamics of information flow in living systems. From gene expression networks to endocrine mechanisms for physiological regulation, and from signal transduction and cellular homeostasis to biogeochemical cycling, all may be understood in terms of the storage, transmission, and utilization of biological information. Moreover, the collection, archiving, and analysis of information about living organisms and their components has created an extraordinary breadth and diversity of data that facilitate analyses of how information flows through systems. Real-time analytical approaches facilitate the study of cellular dynamics in response to environmental changes. Studies of the dynamics of information flow raise questions about topics such as the storage of genetic information and the transmission of that information across generations.

All students should understand that all levels of biological organization depend on specific interactions and information transfer. Information exchange forms the basis of cell recognition and differentiation, the organization of communities from microbial assemblages to tropical forests, and the mating behavior of animals. The introduction of the topic of information exchange offers undergraduates many opportunities to learn how scientists apply quantitative skills and tools in the management and analysis of large data sets.

4. PATHWAYS AND TRANSFORMATIONS OF ENERGY AND MATTER:

Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics. The principles of thermodynamics govern the dynamic functions of living systems from the smallest to the largest scale, beginning at the molecular level and progressing to the level of the cell, the organism, and the ecosystem. An understanding of kinetics and the energy requirements of maintaining a dynamic steady state is needed to understand how living systems operate, how they maintain orderly structure and function, and how the laws of physics and chemistry underlie such processes as metabolic pathways, membrane dynamics, homeostasis, and nutrient cycling in ecosystems. Moreover, modeling processes such as regulation or signal transduction requires an understanding of mathematical principles.

For example, knowledge of chemical principles can help inform the production of microorganisms that can synthesize useful products or remediate chemical spills, as well as the bioengineering of plants that produce industrially important compounds in an ecologically benign manner. These are topics of intense current interest.

5. SYSTEMS:

Living systems are interconnected and interacting. As defined in A New Biology for the 21st Century (NRC, 2009), systems biology seeks a deep quantitative understanding of complex biological processes through an elucidation of the dynamic interactions among components of a system at multiple functional scales. A systems approach to biological phenomena focuses on emergent properties at all levels of organization, from molecules to ecosystems to social systems. Mathematical and computational tools and theories grounded in the physical sciences enable biologists to discover patterns and construct predictive models that inform our understanding of biological processes. Through these models, researchers seek to relate the dynamic interactions of components at one level of biological organization to the functional properties that emerge at higher organizational levels.
Systems biology provides rich opportunities for all students to learn about scientific inquiry and, because of the complex nature of the research involved, to practice in a multidisciplinary context. For example, early applications of systems biology to ecosystem processes resulted in useful simulation models.

**Core Competencies and Disciplinary Practice**

Knowledge of concepts and the development of competencies form the bases for the practice of any discipline, but particularly in the sciences. All students need to develop the following competencies:

1. **ABILITY TO APPLY THE PROCESS OF SCIENCE:**

   *Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.*

   All students need to understand the process of science and how biologists construct new knowledge by formulating hypotheses and then testing them against experimental and observational data about the living world. Studying biology means practicing the skills of posing problems, generating hypotheses, designing experiments, observing nature, testing hypotheses, interpreting and evaluating data, and determining how to follow up on the findings. In effect, learning science means learning to do science. For example, authentic research experiences in undergraduate biology through course-based projects, independent or summer research, community-based student research, or other mechanisms can be a powerful means of providing students with opportunities to learn science by doing it (Mulnix, 2003; Sadler and McKinney, 2010).

2. **ABILITY TO USE QUANTITATIVE REASONING:**

   *Biology relies on applications of quantitative analysis and mathematical reasoning.*

   The application of quantitative approaches (statistics, quantitative analysis of dynamic systems, and mathematical modeling) is an increasingly important basic skill utilized in describing biological systems (Jungck, 1997; Brewer and Gross, 2003). Advances in several fields of the biological sciences provide opportunities for students to appreciate the impact of mathematical approaches in biology and the importance of using them. For example, the dynamic modeling of neural networks helps biologists understand emergent properties in neural systems. Systems approaches to examining population dynamics in ecology also require sophisticated modeling. Advances in understanding the nonlinear dynamics of immune system development have aided scientists’ understanding of the transmission of communicable diseases.

   All students should understand that biology is often analyzed through quantitative approaches. Developing the ability to apply basic quantitative skills to biological problems should be required of all undergraduates, as they will be called on throughout their lives to interpret and act on quantitative data from a variety of sources.

3. **ABILITY TO USE MODELING AND SIMULATION:**

   *Biology focuses on the study of complex systems.*

   All students should understand how mathematical and computational tools describe living systems. Whether at the molecular, cellular, organismal, or ecosystem level, biological systems are dynamic, interactive, and complex. As new computational approaches improve our ability to study the dynamics of complex systems, mathematical modeling and statistical approaches are becoming an important part of the biologist's tool kit. Biologists must understand both the advantages and the limitations of reductionist and systems approaches to studying living systems. Also important is the advantage of qualitative analyses, including steady-state behaviors (e.g., homeostasis) and associated stability analyses (e.g., responses to perturbations). A combination of these approaches is essential to teasing apart the complexities of biological systems.
A variety of computational educational tools is readily available to examine complexity as it arises in biological systems. These tools can simulate many interacting components and illustrate emergent properties that allow students to generate and test their own ideas about the spatiotemporal complexity in biology. Today, modeling is a standard tool for biologists, so basic skills in implementing computational algorithms for models are increasingly being incorporated into the undergraduate curriculum (Rowland-Godsmith, 2009; NetLogo, n.d.).

4. ABILITY TO TAP INTO THE INTERDISCIPLINARY NATURE OF SCIENCE: 
*Biological science is an interdisciplinary science.*

Integration among subfields in biology, as well as integration between biology and other disciplines, has advanced our fundamental understanding of living systems and raised a number of new questions. As exciting new areas of study emerge from the interstices, solid grounding in the sciences, including computer science and social science, can advance the practice and comprehension of biology. Accordingly, all students should have experience applying concepts and subdisciplinary knowledge from within and outside of biology in order to interpret biological phenomena.

Interdisciplinary science practice may be achieved in several ways. For future biologists, one way is through developing expertise not just in an area of biology, but also in a related discipline. That way, students will develop the vocabulary of both disciplines and an ability to think independently and creatively in each as well. A second, less intensive approach is to develop deep expertise in one area and fluency in related disciplines. A third option is to serve as a biologist on a multidisciplinary team. All of these routes develop a student's facility to apply concepts and knowledge across traditional boundaries. For those not majoring in biology, the inherent interdisciplinary nature of biology practice lends itself to forming connections between biology and other sciences and, in so doing, can help all students understand the way science disciplines inform and reinforce each other.

5. ABILITY TO COMMUNICATE AND COLLABORATE WITH OTHER DISCIPLINES: 
*Biological science is a collaborative scientific discipline.*

Biological research increasingly involves teams of scientists who contribute diverse skills to tackling large and complex biological problems; therefore, all students should have experience communicating biological concepts and interpretations. As the science of biology becomes more interdisciplinary in practice and global in scope, biologists and other scientists need to develop skills to participate in diverse working communities, as well as the ability to take full advantage of their collaborators’ multiple perspectives and skills.

Effective communication is a basic skill required for participating in inclusive and diverse scientific communities. Communicating scientific concepts through peer mentoring helps students solidify their comprehension and develop the ability to communicate ideas not only to other biology students, but also to students in other disciplines. Practicing the communication of science through a variety of formal and informal written, visual, and oral methods should be a standard part of undergraduate biology education.

6. ABILITY TO UNDERSTAND THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY: 
*Biological science is conducted in a societal context.*

Biologists have an increasing opportunity to address critical issues affecting human society by advocating for the growing value of science in society, by educating all students about the need for biology to address pressing global problems, and by preparing the future workforce. Biologists need to evaluate the impact of scientific discoveries on society, as well as the ethical implications of biological research. Cross-disciplinary opportunities for students to explore science in a social context may be generated through real-life case studies embedded in biology courses, or in social science courses designed specifically to explore the effect of science and technology on human beings (e.g., Fluck, 2001; Pai, 2008).
Table 2.1 describes the core competencies as sets of skills linked to disciplinary practice. The development of these skills will enable students to better understand the core concepts presented earlier and, consequently, will advance their ability to practice biology. Biology majors achieve an increasing understanding of the core concepts and greater proficiency in doing biology as they proceed down their chosen academic path, but all students should have opportunities to develop these basic competencies.
CHAPTER 2: CULTIVATING BIOLOGICAL LITERACY

Table 2.1: Core Competencies and Disciplinary Practices. A competency-based approach to undergraduate biology education focuses on demonstrating analytical, experimental, and technical skills as measurable outcomes of student learning. Biology literacy is defined primarily in terms of acquired competencies, demonstrated within the context of fundamental biology concepts.

<table>
<thead>
<tr>
<th>Core Competency</th>
<th>Ability to apply the process of science</th>
<th>Ability to use quantitative reasoning</th>
<th>Ability to use modeling and simulation</th>
<th>Ability to tap into the interdisciplinary nature of science</th>
<th>Ability to communicate and collaborate with other disciplines</th>
<th>Ability to understand the relationship between science and society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantiation of Ability in Disciplinary Practice</td>
<td>Biology is an evidence-based discipline</td>
<td>Biology relies on applications of quantitative analysis and mathematical reasoning</td>
<td>Biology focuses on the study of complex systems</td>
<td>Biology is an interdisciplinary science</td>
<td>Biology is a collaborative scientific discipline</td>
<td>Biology is conducted in a societal context</td>
</tr>
<tr>
<td>Demonstration of Competency in Practice</td>
<td>Design scientific process to understand living systems</td>
<td>Apply quantitative analysis to interpret biological data</td>
<td>Use mathematical modeling and simulation tools to describe living systems</td>
<td>Apply concepts from other sciences to interpret biological phenomena</td>
<td>Communicate biological concepts and interpretations to scientists in other disciplines</td>
<td>Identify social and historical dimensions of biology practice</td>
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<td>Examples of Core Competencies Applied to Biology Practice</td>
<td>Observational strategies</td>
<td>Developing and interpreting graphs</td>
<td>Computational modeling of dynamic systems</td>
<td>Applying physical laws to biological dynamics</td>
<td>Scientific writing</td>
<td>Evaluating the relevance of social contexts to biological problems</td>
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<tr>
<td></td>
<td>Hypothesis testing</td>
<td>Applying statistical methods to diverse data</td>
<td>Applying informatics tools</td>
<td>Chemistry of molecules and biological systems</td>
<td>Explaining scientific concepts to different audiences</td>
<td>Developing biological applications to solve societal problems</td>
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<td></td>
<td>Experimental design</td>
<td>Mathematical modeling</td>
<td>Managing and analyzing large data sets</td>
<td>Applying imaging technologies</td>
<td>Team participation</td>
<td>Evaluating ethical implications of biological research</td>
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<td></td>
<td>Evaluation of experimental evidence</td>
<td>Developing problem-solving strategies</td>
<td>Incorporating stochasticity into biological models</td>
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<td>Collaborating across disciplines</td>
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<td>Cross-cultural awareness</td>
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</table>

NEXT STEPS

The core concepts and competencies described in this chapter serve as a framework for initiating conversations about curricular evaluation and revision within biology departments and for catalyzing cross-departmental discussions about interdisciplinary programming. As a first step, this framework provides departments with a structure for using biology curricula to identify learning outcomes appropriate for the students they serve and for their institutions’ academic objectives. Such a framework can reveal a strategy for designing and applying learning assessments appropriate to varied types of programs. In turn, standards for student learning can inform discussions focused on revising existing curricula or creating new ones.

For instance, curricular discussions may focus on questions concerning (1) the types of linkages that exist or that should exist between concepts and competencies, (2) the best time to introduce specific competencies, (3) ways of increasing the depth and sophistication of the competencies, and/or (4) ways of supporting...
the integrated development of student competencies throughout the academic curriculum. Departments and programs may incorporate core concepts into theme-based curricula that enable students to develop comprehension by discovery or application in hands-on courses. Curriculum committees might focus on strategies for utilizing core concepts to organize new programs that integrate various disciplines or, particularly for those not majoring in biology, that address an interdisciplinary problem (e.g., the study of biodiversity, global climate change, or local or regional access to safe water).

Shifting the framework for biology education and learning also entails changing the ways in which student learning is evaluated and progress is measured. Scientific literacy includes the acquisition of skills that enable the productive use of experimentally generated data sets and scientific information. These competencies and others cannot be adequately measured solely by correct answers on multiple-choice tests, but must be assessed through demonstrations of students' thinking and scientific problem-solving abilities. Curriculum revision must involve giving students regular opportunities to demonstrate their skills in controlled contexts—a challenging task for any program, especially an undergraduate program with a large and diverse student enrollment. The challenge of developing effective strategies for assessing scientific competencies will undoubtedly occupy the creative efforts of biology educators for some time to come.

**ACTION ITEMS**

- Introduce the scientific process to students early, and integrate it into all undergraduate biology courses.
- Define learning goals so that they focus on teaching students the core concepts, and align assessments so that they assess the students' understanding of these concepts.
- Relate abstract concepts in biology to real-world examples on a regular basis, and make biology content relevant by presenting problems in a real-life context.
- Develop lifelong science learning competencies.
- Introduce fewer concepts, but present them in greater depth.
- Stimulate the curiosity students have for learning about the natural world.
- Demonstrate both the passion scientists have for their discipline and their delight in sharing their understanding of the world with students.
UNDERGRADUATE STUDENT VOICES

DISCUSSION QUESTION

In what ways can biology education be improved?

STUDENT RESPONSES

Introductory courses are too broad

• Give entering Bio 101 students a diagnostic test, and split them into three groups: the ones who really need more basics to supplement what they didn’t get in high school, the ones ready for 101, and the ones ready for something more advanced. Stop the “one-size-fits-all” Bio 101.
• Reduce the amount of information in classes; teach students how to learn so they can gain depth on their own.
• Have more topic-based or concept-oriented courses, especially for nonmajors.

Less emphasis on memorization

• More emphasis on application and problem solving—if science changes so much, why are we trying to memorize everything?
• More emphasis on the “how” of science: what is the evidence and how did we obtain it?
• Have projects where knowledge needs to be applied instead of exams where facts are regurgitated.
• More essay questions on exams. Even in classes where we discuss broader concepts, we are still tested on the fine details.
• Use case studies where the professor facilitates a discussion about them.

More connections across the curriculum

• Professors should be more explicit about what they want students to get out of the course and why it’s necessary to know those things.
• More connections between lecture and lab components within an individual course.
• More connections across the disciplines (e.g., between chemistry and biology and between physics and biology).
• There should be greater discussion of the curriculum as a whole with the students: why you need this course, that technique, etc., and how it all fits together; have a short seminar course before or with introductory biology for those who know they want to be biology majors.
• More interdisciplinary courses.

For more information, visit http://media.collegeboard.com/digitalservices/pdf/ap/10b_2727_AP_Biology_CF_WEB_110128.pdf
## A Willamette Valley Biological Education Network (WVBEN) Workshop in Partnership with Project Kaleidoscope

### Responding to the Mandate of "Vision and Change in Undergraduate Biology Education"

<table>
<thead>
<tr>
<th>Course Titles</th>
<th>Ability to apply the process of science</th>
<th>Ability to use quantitative reasoning</th>
<th>Ability to use modeling and simulation</th>
<th>Ability to tap into interdisciplinary nature of science</th>
<th>Ability to communicate and collaborate within and across disciplines</th>
<th>Ability to understand the relationship between science and other disciplines</th>
<th>Ability to communicate and collaborate within and across disciplines</th>
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<td>Instructors</td>
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<td>VISION &amp; CHANGE CORE COMPETENCIES</td>
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* 29*
PRESENTER BIOGRAPHIES

David P. Craig, Associate Professor and Chair of the Department of Biology at Willamette University was on the leadership team of the RCN-UBE incubator grant to WVBEN. He is an experienced teacher-scholar with a record of growing achievement as a science educator and undergraduate research mentor with a focus on general biology, animal behavior, ecology, and evolution. He has maintained an externally funded research program for 10+ years and has multiple publications with student co-authors. His engagement in the PKAL includes Faculty for the 21st Century (2006), Summer Leadership Institute (2008), and being an organizer in the recent WVBEN workshops. A 2010 PBS Nature program featuring his crow research and his use of crowdsourcing wildlife data has made him a popular science speaker to community audiences of the National Audubon Society, Guild of Natural Science Illustrators, Cornell Lab of Ornithology, and the OMSI 'science pub' series.

Jason Duncan is an Assistant Professor in the Department of Biology at Willamette University. A native of Canada, Jason earned a BSc in Zoology and an MSc in Physiology from the University of Manitoba in Winnipeg, Manitoba. Years of sub-zero temperatures took their toll and he headed south to the University of Southern California in Los Angeles where he completed a PhD in Molecular Biology, followed by a post-doctoral position in the Department of Cellular and Molecular Medicine at the University of California, San Diego. Jason has been at Willamette University since 2008 where he teaches courses in Cell Biology and Genetics, Gene Structure and Function, and Molecular Genetics. In addition, Jason serves as co-director of Willamette University's Core Imaging Facility.

Gary Reiness, Professor of Biology and Associate Dean of Lewis and Clark College’s College of Arts and Sciences, was co-PI of the RCN-UBE incubator grant to WVBEN. He is an experienced administrator with a record of accomplishments in biology education at the national level. He has served in numerous capacities within Project Kaleidoscope, most recently as a member of the National Steering Committee (2002-6) and Project Advisory Board (2006-9), and as Scientist in Residence (2008-9), and he has been a biology councilor of the Council for Undergraduate Research and an Associate Editor of CBE- Life Science Education.

Stasinos Stavrianeas, Professor of Exercise Science at Willamette University is a dedicated teacher with several external grants to his credit. He participated in the Keck-funded Project Kaleidoscope FIDL project, contributed to the work of the Portland PKAL, and maintains an active scholarship agenda on science education. In addition to his research work on the physiological adaptation to training, he serves as President-Elect of the American College of Sports Medicine Northwest Chapter and is a regular reviewer in several research journals.

Barbara Stebbins-Boaz, Associate Professor of Biology, Willamette University, was co-PI and project coordinator of the RCN-UBE incubator grant that supported WVBEN in 2010-11. She has directed Willamette’s Science Outreach Program to support female college science majors and engage them to prepare and implement investigative activities in the fifth grade of a high diversity elementary school. She was PI on a grant to enhance inquiry-based learning and guided research in introductory biology labs.

Kimberly Tanner is a faculty member in Biology at San Francisco State University. She directs SEPAL – the Science Education Partnership and Assessment Laboratory, which is focused on understanding how people learn science, especially biology. Her research in biology education holds the promise of revealing insights into preconceptions and misconceptions in biology that can guide strategies for curriculum improvement and teaching reform. Trained as a research neurobiologist, Dr. Tanner has been nationally recognized for both her research and her teaching in biology. Her most recent awards include being named the 2011-12 Outstanding Undergraduate Science Teacher Award by the Society for College Science Teachers and being elected this past fall as a Fellow to the California Academy of Sciences.
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A Willamette Valley Biological Education Network (WVBEN) Workshop
in Partnership with Project Kaleidoscope

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Upcoming PKAL & AAC&U STEM Events

2012 PKAL Summer Leadership Institutes for STEM Faculty
Crestone, CO: July 17 - 22, 2012 and July 31 - August 5, 2012
https://www.aacu.org/pkal/events/sli/index.cfm

Network for Academic Renewal Conference
Student Success: Pushing Boundaries, Raising Bars
March 22-24, 2012—Seattle, WA
http://www.aacu.org/meetings/studentsuccess12/index.cfm

Network for Academic Renewal Conference
Next Generation STEM Learning: Investigative, Integrative, Innovative, and Inspiring
November 8-10, 2012—Kansas City, Missouri
Event webpage coming soon.
Project Kaleidoscope’s Current Initiatives

- On the Cutting Edge of STEM Education
  Funded by the W.M. Keck Foundation, PKAL has engaged thirty campus teams around the country in establishing goals, strategies, and recommendations for fostering more effective and widespread interdisciplinary undergraduate STEM learning. For more information, see: www.aacu.org/pkal/interdisciplinarylearning/index.cfm.

- Leadership for 21st Century STEM
  For the past 15 years, PKAL has offered summer leadership institutes as well as regional workshops for early- and mid-career faculty to develop leadership skills and the capacity required to improve STEM education. Supported by the National Science Foundation. For more information, see: www.aacu.org/pkal/interdisciplinarylearning/index.cfm.

- Partnership with Disciplinary Societies
  Funded by the Fund for the Improvement of Postsecondary Education (FIPSE), PKAL, Mobilizing STEM Education for a Sustainable Future, and the Disciplinary Associations Network for Sustainability (DANS) join with selected disciplinary societies on programs that will increase student learning and better prepare them for the 21st century “Big Questions” related to issues such as energy, air and water quality, and climate change. For more information, see: www.aacu.org/pkal/mobilizing/index.cfm.

- A National Community Focused on STEM Reform
  Cultivated by a grant from the National Science Foundation, PKAL has regional networks and collaborating partners in California, Connecticut, Georgia, Minnesota, Oregon and the Appalachian region. For more information, see: For more information, see: www.aacu.org/pkal/regionalnetworks/index.cfm.

- STEM Transfer Student Success
  Creating more holistic pathways that ensure the effective transition of students into STEM programs from community college is the focus of this project funded by the Bill & Melinda Gates Foundation. For more information, see: www.aacu.org/pkal/rampingupstem/index.cfm.

How to Connect with Project Kaleidoscope

- Attend a meeting, conference or summer institute organized by PKAL: www.aacu.org/pkal/events.cfm.
- Join the ALL-PKAL mailing list and receive occasional e-mails regarding events, activities, and other relevant information. For more information: www.surveymonkey.com/s/pkalemaillist.
- Read our blog: pkal.aacu.org/blog.
- Become a fan of our Facebook page: www.facebook.com/pages/Washington-DC/Project-Kaleidoscope/297578778115.
- Follow PKAL on Twitter at: www.twitter.com/projectkaleido.

Project Kaleidoscope Resources

Through the collective work of the PKAL community, an extensive online library of resources is available that can be adapted by campus leaders and faculty across the country working to ensure robust STEM learning environments for all their students. These resources span a range of topics: academic program planning, pedagogy and assessment, facilities design, leadership, supporting faculty careers, the national STEM education context, and outreach and collaboration. For more information, see: www.pkal.org/documents.
ABOUT AAC&U

Founded in 1915, AAC&U is the only national U.S. higher education organization that is solely focused on strengthening the quality of undergraduate education, both in general education and in departmental programs. The common thread throughout AAC&U’s work remains a steadfast commitment to extending the advantages of a liberal education to all students regardless of background, enrollment path, academic specialization, or intended career.

AAC&U resources cut across office, department, and discipline lines in strategic areas that include:
- General education
- Diversity and making excellence inclusive
- Integrative learning
- Civic engagement
- Global interdependence
- Faculty development

The PKAL and AAC&U Partnership

In 2008, AAC&U and PKAL announced a partnership to align and advance the work of both organizations in fostering meaningful twenty-first-century liberal education experiences for all undergraduate students, across all disciplines.

For nearly a century, AAC&U has been a leader, a catalyst, and a facilitator in building and sustaining the collective commitment to liberal education at both the national and local levels. In this same spirit, PKAL has engaged the STEM community in building and sustaining strong undergraduate programs in the STEM disciplines.

This new partnership represents a natural progression, as nearly 75 percent of campuses with PKAL community members are also AAC&U member institutions. Together, AAC&U and PKAL will apply their collective expertise in undergraduate learning, assessment, leadership, and institutional change to accelerate the pace and reach of STEM transformation.

Partnership Benefits for AAC&U Members and the PKAL Community

The partnership provides collective leverage of AAC&U and PKAL communities, expertise and resources through current and future projects to advance what works in STEM education:
- STEM-focused sessions, workshops, and events embedded in AAC&U’s annual meeting, network conferences and summer institutes.
- Annual Engaged STEM Learning Network for Academic Renewal conference.
- STEM “threads” strategically woven into AAC&U projects, such as Liberal Education and America’s Promise (LEAP), Valid Assessment of Learning in Undergraduate Education (VALUE), The Educated Citizen and Public Health, and Shared Futures
- National projects on connecting what works in undergraduate STEM education to institutional leadership and change.
- Spotlight articles on STEM-related topics in AAC&U’s periodicals Peer Review and Liberal Education, plus STEM news and events in AAC&U’s monthly e-newsletter

Project Kaleidoscope Executive Director
Susan Elrod, PhD (elrod@aacu.org)

Susan Elrod began as the executive director of Project Kaleidoscope at AAC&U on January 1, 2010. She holds a PhD in genetics and has taught extensively and conducted scientific and educational research. Elrod came to PKAL from California Polytechnic State University – San Luis Obispo, where she has been a professor of biological sciences since 1997, and most recently served as associate dean for strategic initiatives in the College of Science and Mathematics and as the director of Cal Poly’s Center for Excellence in Science and Mathematics Education (CESaME). Elrod has experience in curricular reform, learning assessment and program evaluation, faculty development, and departmental and institutional governance, and has led a wide array of STEM education initiatives, including the Keck/PKAL initiative on interdisciplinary STEM learning. For more, see: www.aacu.org/press_room/experts/elrod.cfm.

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Please provide any comments on your overall evaluation of the meeting. We will draw on these comments when planning future WVBEN/PKAL Network events.

1. Rate the keynote presentation by Kimberly Tanner: “Beyond Assessing Knowledge – Card Sorting, Superheroes, and Moving Towards Measuring Biological Expertise as Described in Vision & Change”
   - Outstanding
   - Very Useful
   - Useful
   - Not useful
   
   Comments:

2. Rate the plenary session by Stasinos Stavrianeas and Jason Duncan: “We have a Vision, but how do we Change?”
   - Outstanding
   - Very Useful
   - Useful
   - Not useful
   
   Comments:

3. Rate the subsequent breakout session:
   - Outstanding
   - Very Useful
   - Useful
   - Not useful
   
   Comments:

4. Rate the plenary session by Dave Craig and Gary Reiness: “Departmental responses to Vision and Change Curricular Mandates”
   - Outstanding
   - Very Useful
   - Useful
   - Not useful
   
   Comments:

5. Rate the subsequent breakout/planning session:
   - Outstanding
   - Very Useful
   - Useful
   - Not useful
   
   Comments:

CONTINUED ON REVERSE
**Overall Comments:**

1. Please provide any comments on your overall evaluation of the meeting:

2. What was the most valuable component for you? Why?

3. What would you suggest as a way to improve future WVBEN/PKAL network meetings?

4. What will you do in the next 60 days as a result of this meeting?

5. Are you interested in attending more WVBEN/PKAL Network meetings organized around topical themes on undergraduate biology education, broadly defined? If so, what theme would encourage your participation?

6. General final comments:

PLEASE RETURN TO EVENT ORGANIZERS. THANK YOU!