Course PHYSICS AND CHEMISTRY OF BIOLUMINESCENCE

Basic Information

This is a course, which contributes to MSc award in Biology

Title of the Academic Program	Master's Degree Programs in English "Biological Engineering"
Type of the course	core /mandatory
Course period	From February 1st till June 1st, 1 semester (18 weeks)
Study credits	4 ECTS credits
Duration	144 hours
Language of instruction	English
Academic requirements	- BSc degree in Biology, Physics, Biophysics, Chemistry, Biochemistry, Environmental Sciences or equivalent (transcript of records), - good command of English (certificate or another official document

Course Description

The course "Physics and chemistry of bioluminescence" is a part of International Master Program "Biological Engineering" offered by Siberian Federal University. The course is devoted to studying fundamental and applied aspects of a unique phenomenon of light emission by living organisms, which is called bioluminescence. Bioluminescence is a type of chemiluminescence that is catalyzed by an enzyme. This light emission from an organism should be distinguished from other forms of luminescence that are also biologically meaningful, such as fluorescence, iridescence, diffraction, etc.

Bioluminescence is widespread in nature, but only at levels below that of mammals and plants. Bioluminescent species are randomly distributed among genera, sometimes bioluminescence is found in some species within a genus but not others, without evident reason. Bioluminescence has been found in diverse marine organisms including cephalopods, copepods, ostracods, amphipods, euphausids, and many fish, annelids and jellies. Some bioluminescent organisms,

including fireflies, glow-worms, click beetles and fungi nave been discovered on land. Regarding bioluminescent bacteria, there are many marine species and a few livings on the land.

After successful completion of the course, the participants will have a profound knowledge of the mechanisms underlying bioluminescent reactions. Moreover, they will be able to apply bioluminescent-based assays for toxicity measurements, human stress assessment, etc. Besides this, the participants will have practical knowledge of how to create tangible bioluminescent-based products that can be used in real-world situations.

The course begins with an outline of major trends in biological engineering focusing participants' attention on the following topic: bioluminescent-based biosensors and biochips as a part of the huge and rapidly evolving area of biomolecular and bioanalytical sciences.

The subsequent chapters of the course concentrate on the various aspects of biosensors design: biological and molecular recognition systems, transducers for biosensors and bio-array technologies, miniaturized and micro-engineered systems. Special emphasis will be made on current methods of enzymes immobilization and applications of immobilized enzymes for medical diagnostics, environmental monitoring, pharmaceutical and food industries.

Special Features of the Course

The course is especially designed to introduce students to fundamental physical and chemical principles of bioluminescence phenomenon, to provide participants with comprehensive information about light-emitting organisms and their bioluminescent enzymatic systems, cloning process of bacterial lux gene cassette and the main principles of bioluminescent assays.

Course Aim

The course is aimed at extending and deepening students' knowledge and professional skills in the field of bioluminescent biosensors, molecular biology of bioluminescent organisms and designing of new technology based on bioluminescent assays.

Course Objectives

The objectives of the course are:
- to enable students to build up their knowledge and skills pertaining to the use of living organisms for solving real-world problems related to the life sciences;
- to give students an introduction of recent trends in the area of bioluminescent research;
- to make students familiar with various luciferase-based assays and their applications in different research areas;
- to provide students with practical skills of designing biosensing agents, which contain functional nanomaterials and can be used in various medical research areas and environmental monitoring;
- to make students familiar with fundamental principles of creation and design of bioluminescent reagents and biosensors using immobilization procedure or crowding agents.

Learning Outcomes of the Course

By the end of the course students will be able:

to describe fundamental mechanisms underlying bioluminescence reactions of various luminous organisms;

to present the basic methods of bioluminescent analysis and describe the ways of their application in biology, ecology, medicine etc;

to demonstrate basic methods of constructing bioluminescent reagents;

to manipulate various microbiological techniques;

to interpret obtained data after bioluminescent testing;

to understand the importance of multidisciplinary disciplines within the scope of modern science;

to solve problems in new environment including a broader, multidisciplinary context;

to arrange an independent search of information in professional publications;

to apply successful laboratory practice principles in experiment planning, conducting and control.

Course Outline

Week	Lectures	Practice sessions / Seminars	Hours[1]
1-2	**Lecture 1.** **Overview of bioluminescence: bioluminescence in nature, luciferases and luciferins, photo proteins, biochemistry and biophysics of bioluminescence**	**Seminar 1.** **Determination of the main kinetic parameters of NAD(P)H:FMN-oxidoreductase + luciferase bioluminescent system**	**4**
3-4	**Lecture 2.** **«The diversity of luciferases. Luciferins. Photoproteins» (Firefly/bacterial/Cypridina/Fungi/ Renilla/ Gonyaulax/ Gaussia/ Metridia/ Vargula/ Cypridinalucifera se).**	**Seminar 2.** **Determination of the kinetics features of enzyme reactions (Km, Vmax) using NAD(P)H:FMN-oxidoreductase + luciferase bioluminescent system**	**4**
5-6	**Lecture 3.** **Cloning of different bacterial lux gene cassette and their various applications in healthcare, basic research and bio-diagnostics**	**Seminar 3.** **Determination of pH and temperature optimums of NAD(P)H:FMN-oxidoreductase + luciferase bioluminescent system**	**4**
7-9	**Lecture 4.** **Terrestrial bioluminescence: firefly and insects, bacteria, fungi, mollusks, arthropods and earthworms**	**Seminar 4.** **Determination of marine water contamination** **Seminar 5.** **Are plates and dishes contained any washing-up liquids after washing-**	**6**

1 Hours designed for Classroom sessions, Web-sessions, Home Assignments etc.

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10-11	**Lecture 5. Bioluminescent analysis**	**Seminar 6. Determination of soil contamination**	**4**
12	**-**	**Seminar 7. Analysis of activity of proteases and antiprotease in medicine**	**4**
13	**-**	**Seminar 7. Analysis of activity of NADH-dependent dehydrogenases (lactate dehydrogenase, glucose-6-phosphate dehydrogenase, alcohol dehydrogenase)**	**4**
14	**-**	**Seminar 8. Determination of human's stress conditions in sport medicine.**	**2**
15-18	**Final research project (including preparation)**		**36**

Assessment

The course assessment assignments will include:

- Short-response questionnaire
- Seminars
- Final research project

Student's grades will be based on the following scheme:

20 % Short-response questionnaire (Appendix 2) and class participation

30 % Seminars

50 % Final research project

Attendance Policy

Students are expected to attend classes regularly. The final research project is **obligatorily** for performance.
Each studying period has its own points:
One lecture costs 3 points;
One seminar costs 4 points;
Final research project costs 53 points.
To receive certification that a student has completed the course, a student must score more than 85 points.

Web page of the course

The webpage of the course «Physics and chemistry of bioluminescence» is available through E-learning SibFU web site: www.e.sfu-kras.ru. You must be logged in to access this course. Course Guide and all accompanying materials are also available at the course web-page.

Core reading

Books:

- *Osamu Shimomura Bioluminescence: Chemical Principles and Methods, 2006. ISBN 978-9812568014;*
- *John Lee BIOLUMINESCENCE, the NATURE of the LIGHT;*
- *Therese Wilson, J. Woodland Hastings Bioluminescence: Living Lights, Lights for Living, 2013. ISBN 978-0674067165;*
- *Vincent Pieribone, David F. Gruber, Sylvia Nasar Aglow in the Dark: The Revolutionary Science of Biofluorescence, 2006. ISBN 978-0674019218;*
- *Marc Zimmer Bioluminescence: Nature and Science at Work (Nonfiction - Young Adult), 2015. ISBN 978-1467757843;*
- *Anita Sitarski Cold Light: Creatures, Discoveries, and Inventions That Glow. 2007. ISBN 978-1590784686;*
- *Kratasyuk, V.A., Gitelson, J.I. Application of luminous bacteria in bioluminescent analysis. Uspekhi microbiologii, 1987.*

Journal articles:

- *Frank Mc Capra Chemical mechanisms in bioluminescence, Acc. Chem. Res., 1976, 9 (6), pp 201–208;*
- *Esimbekova, E., Kratasyuk, V., Shimomura, O. Application of enzyme bioluminescence in ecology, AdvBiochemEngBiotechnol, 2014, 144, pp 67-109;*
- *Chang-ik Song, Young Min Rhee Dynamics on the Electronically Excited State Surface of the Bioluminescent Firefly Luciferase–Oxyluciferin System, J. Am. Chem. Soc., 2011, 133 (31), pp 12040–12049;*
- *Panče Naumov, Yutaka Ozawa, Kei Ohkubo and Shunichi Fukuzumi Structure and Spectroscopy of Oxyluciferin, the Light Emitter of the Firefly Bioluminescence, J. Am. Chem. Soc., 2009, 131 (32), pp 11590–11605;*
- *Bo-Wen Ding, PančeNaumov, and Ya-Jun Liu Mechanistic Insight into Marine Bioluminescence: Photochemistry of the Chemiexcited Cypridina (Sea Firefly) Lumophore, J. Chem. Theory Comput., 2015, 11 (2), pp 591–599;*
- *Avisek Ghose, Mateusz Rebarz, Oleg V. Maltsev, Lukas Hintermann, Cyril Ruckebusch, Eduard Fron, Johan Hofkens, Yves Mély, PančeNaumov, Michel Sliwa, Pascal Didier Emission Properties of Oxyluciferin and Its Derivatives in Water: Revealing the Nature of the Emissive Species in Firefly Bioluminescence, J. Phys. Chem. B, 2015, 119 (6), pp 2638–2649;*
- *Esimbekova, E.N., Kondik, A.M., Kratasyuk, V.A. Bioluminescent enzymatic rapid assay of water integral toxicity. Environ Monit Assess.2013. 185, pp 5909–5916.*

Web pages:

a) Photobiological sciences online

b) The Bioluminescence Web Page

c) National Geographic Society: Encyclopedic entry

d) Scripps Institution of Oceanography

Recommended web pages for searching paper for preparing the final project:

a) Scopus data base

b) Web of Science data base

Course Instructor and Tutor and Contact information

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