IO4 – INNOCORE FRAMEWORK

Developing a Multidisciplinary and Transnational Curriculum on Core technologies

This project received funding by the European Commission under the Grant Agreement n° 2019-1-IT02-KA203-063391

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Co-funded by the Erasmus+ Programme of the European Union

Developing a Multidisciplinary and Transnational Curriculum on Core technologies

A "HOW TO" GUIDE

InnoCore

ERASMUS+ project

Project partners:

What is it for and what is inside?

This handbook proposes a framework for the development of innovative curricula targeted at the education and training of current and future Core Facilities' scientists and staff.
The aim of this curriculum is to i) introduce the participants to a career pathway within a research infrastructure, ii) boost their innovation skills by leveraging the cutting-edge technologies present at academic core facilities and iii) bring them at the interface between basic and applied research.
The target audience of this "How to" guide is academic staff working in Higher Education Institutes willing to develop new practices in the educational field, by introducing transnational courses on core technologies and/or education-oriented activities such as traineeships in core facilities, internships in companies, or innovation challenges.
The handbook feeds and merges the practices and the lessons learned within the Erasmus+ InnoCore project during a time frame of three years (2020-2022).

Methodology
▼
Engage
▼
Design
▼
Implement
▼
Assess

1. DEVELOPMENT OF THE MULTINATIONAL COURSES

This chapter describes the guidelines for the development of a course on advanced technologies by merging the competencies and knowledge of teachers and professionals belonging to more than one partner institution.

General considerations

This framework raises the following basic questions to effectively address the instructional design:

Who?	identify the target group of learners
What?	define the instructional goals and the learning objectives
Why?	put objectives into a the context of an overall expected outcome
How?	teaching strategies, learning content, didactic methodology
When?	milestones and duration of individual tasks
Where?	venue of the learning environment?
Was it effective?	assess measurable outcomes providing quantitative evidence

ENGAGE

The development of a new curriculum of studies on advanced technologies requires the cooperation of academic, technological and administrative staff that must be involved in the design of all the different required aspects.
The development of a common curriculum can be based on existing courses that can be combined and modified to create unified courses among the engaged academic institutions.
The key people involved should be:

- governance and academic staff in charge of coordinating teaching activities at each University, in order to agree on the strategies and on the

timing for the introduction of new courses in an existing curriculum.
- professors and instructors teaching similar subjects that may not be aware of possible overlapping contents among the same curriculum.
- core facilities staff, that are experts in advanced technologies. In some institutions these highly specialized technical roles may not be entitled to teach students without the support and supervision of an academic figure.
- students who might be interested in attending the courses and could provide useful suggestions.
- graduated students who can provide important information about their needs and the practical constraints.
- life science companies that can share their vision on their perception of knowledge and skill gaps in their workforce.

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People to involve in course design:

-governance and academic staff

-professors

-core facilities staff

-students

-life science companies

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DESIGN

The design of a curriculum of studies on advanced technologies starts from the identification of one or more technologies that will become the focus of the course. This process of identification should take in consideration skills and competences of all the partners involved, as well as, the availabilityof the specific core facilities within the academic institutions engaged.

The curriculum could be developed within one or more academic institutions. In both cases, through strong collaborative interactions, teachers, researchers and staff scientists invest part of their effort to design courses following the scheme of the ADDIE model, a framework detailing five phases to follow in the design of a training program (Analysis, Design, Development, Implementation, Evaluation).
All teachers involved will define together a common template for the course structure.
The syllabi will be built including theoretical and practical lessons, and an evaluation system will be incorporated into the initial design of the courses..
Each course can be split into different modules that can be taught by different experts at different institutions.

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The ADDIE model to develop a new curriculum

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◇◇◇◇ Factors to consider: accreditation, rules and credits ◇◇◇◇ ◇◇◇◇ Taking advantage of existing courses and experience to develop a new one ◇◇◇◇	Cross-institutional courses can be facilitated by the possibility of offering some of the modules online. The lessons can be offered in presence, as well as online both in a synchronous and asynchronous manner through the development of an online learning environment where contents, resources, activities and tests are organized based on a customised instructional design. One important aspect to consider, while designing new courses, is their accreditation, that will depend on whether the course will be included in MSc or PhD schools at each University, or be proposed as additional learning activities for the students or will be open to external participants . In the first case the partner Universities must agree on the number of European Credit Transfer and Accumulation System (ECTS) associated to the course, whether in the other cases they can exploit Open Digital Badges (see chapter 4 of this guide). Moreover, the technological courses can become a dedicated learning track within the MSc or PhD program, or be considered as individual new courses. IMPLEMENT Implementation of a new course in the Manifesto of a MSc or a PhD program has to take into account the specific requirements and internal institutional deadlines to fulfil the accreditation process at each University premises. The syllabus of each course can be prepared taking into consideration pre-existing courses or developed by combining different courses offered by two or more institutions. Alternatively, a new course is designed from scratch. Different technological aspects are taught in different modules held by multiple experts at partner institutions. Participating students attend one or more modules offered from the different partner institutions, in presence as well as online. The final assessment or evaluation of the students takes in consideration the specific rules and expectations of each partner University in order to consent to the students to receive the proper formative credits.

◇◇◇◇ Distance learning is a new opportunity to design shared courses ◇◇◇◇	During the COVID19 pandemic new teaching strategies and new tools were developed and the experience gained by teachers and supporting staff to teaching is used to develop new shared courses that can be offered in parallel at different academic institutions within the same country or different ones. Instructional design is central to distance learning promoting higher quality in the teaching-learning process. The instructional design process considers the different aspects of the learning environment, enhancing the relationship between these aspects and the students and teachers. This process is achieved through the collaboration between the teachers and a specialised distance learning team that supports them. Thus, instructional design in distance learning includes: planning; the alignment of the content and activities with the objectives; adaptation of content and activities to online teaching and learning; content analysis; knowledge of the learner's characteristics and profile; privilege asynchronous mode; adequacy of the technology that will be used, considering the pedagogical model; careful time allocation. The structure of the course includes areas of general pedagogical information: Course Overview (learning outcomes, methodology, teachers), Forum, Resources, Satisfaction Assessment. Different teaching enviroments and platform can be used, such as Moodle. To simplify and make it more accessible, the course is organised in modules. For each module include: ● technical and pedagogical guidelines, to guide the students through the course; ● a detailed schedule, which includes information on synchronous sessions; ● a section organised according to the schedule for the videos recorded during the sessions; ● pdf documents with the contents. ● the course model can be replicated and offered in parallel in each partner institution and applied to all courses. ● at the end of each course a satisfaction questionnaire is applied. The questionnaire

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Using online teaching platforms and environments to improve accessibility

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Coordination of parallel courses arizes scheduling and coordination issues

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includes the dimensions considered relevant in this scope:

- platform usability;
- contents and activities;
- instructors;
- interpersonal relationship; expectations;
- strong points and weak points;
- suggestions.

ASSESS

The last step of the process is the evaluation of the results after the first few runs, to ensure a high quality and contribute to a continuous improvement of the program.. In this regard it is crucial to collect data about the number of students choosing the courses (in case of elective ones) and their satisfaction (through evaluation questionnaires that students fill in at the end of the course).

FINAL CONSIDERATIONS

Potential issues arising from the different internal institutional requirements and rules at different academic institutions must be taken into consideration when planning and scheduling the framework of the course.

Different academic institutions could offer courses with a different scheduling time (i.e. different semesters or trimester), thus making it difficult combining the different modules offered at different institutions in one course.

The distribution of the courses over a semester or a trimester, as well as the presence of intensive courses held in a few weeks or days, should be optimised.

Challenges might arise from the organisation of the practical part of the course, typically involving the presence in a laboratory such as a core facility. Notably, COVID-19 pandemics has accelerated the development of efficient online training methodologies

	even for core technologies and instrumentations such as microscopes and flow cytometers.
 **Main themes:** Mobility of students toward: - core facilities - industries ◇◇◇◇ Mobility complements the formal training provided with the courses	**2. IMPLEMENTATION OF MOBILITY ACTIVITIES** ## General considerations This chapter describes good practices for developing short-term project-based mobility periods to implement the teaching program. Mobility can be either in the form of traineeship in a core facility to learn a new technique, a new application or of an internship in a company to work on a translational research project. ## ENGAGE People to involve: - core facilities available to host visiting students and/or students for a small project - companies available to host visiting students and/or students for a small project - students interested in a mobility experience to a core facility or a company - tutors of students thesis projects ## DESIGN <u>Project and mobility based collaboration for innovation.</u> The educational program should be implemented with active project-based collaborations with partner infrastructures and companies to translate education in innovation. Students can combine a study period abroad with a traineeship, further enhancing the learning outcomes and development of transversal skills.

◇◇◇◇	The Erasmus+ higher education mobility action supports this kind of initiative. The mobility experience will expose students to different views, knowledge, teaching and research methods as well as work practices in their study field in the European and international context; students will develop their transversal skills such as communication skills, language skills, critical thinking, problem solving, inter-cultural skills and research skills;
◇◇◇◇ Short-term mobility is not sufficient for project-based activities, but raise awareness on new career opportunities	While long term physical mobility is usually encouraged, it has been recently recognized the need to offer more flexible physical mobility to ensure the Programme is accessible to students from all backgrounds, circumstances and academic specialisations.
◇◇◇◇	Through a mobility experience students will become aware of the role of core facilities and research infrastructure around Europe and will be exposed to a new emerging career pathway that requests highly professional personnel in advanced technologies. Nevertheless, short visits to industries, to know how the R&D, the manufacturing and many other processes are carried on, can have a tremendous impact in the students curriculum. In the long run, the exponential effect of such short-term mobility projects will widen the perception of the students on future job opportunities. IMPLEMENT <u>Traineeships in core facilities</u> Core facilities belonging to the partner universities are required to indicate their availability to host external students. They can provide two different options: - short visits of students for few days: in this case it might be useful to organise the rotation of small groups among the different core facilities

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Already existing networks of academic core facilities facilitate the students exchange

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- project-based traineeships lasting from 1 month to several months with the aim of developing a new technological activity in the context of the student's thesis project.

Internships in industries

Internships in industries have several educational purposes, such as integration in the teams of the companies for developing projects and promotion of applied research.
To obtain the most effective outcomes for both students and companies, internships should last at least 4 months, but even shorter periods can be very useful for the students in exploring career options and for professional socialisation.

Educational perspective:

- learn how core facilities/companies work
- transversal skills (sense of initiative and entrepreneurship, self-empowerment and self-esteem, intercultural skills,)
- communicate with different stakeholders (companies, core facilities, service providers...)

ASSESS

Questionnaires are useful tools to monitor the satisfaction of the students and how the activities met their expectations.
The questionnaire includes a self-assessment part which will make the students reflect on the value of their experience in terms of scientific/technical skills and knowledge of the operative environment of a core facility or a company.

FINAL CONSIDERATIONS

Potential issues to be aware of:

- Budget issues: Universities tend to prefer Erasmus+ long-term mobility to the short-term ones

	- Transnational mobility issues - Given the initial bureaucratic issues, companies tend to prefer long internship periods (at least 6 months-1 year) - IP issues when involving companies in project-based activities - ensure that activities that are based on a company-hosted project are integrated into an academic research project/thesis that satisfies the needs for obtaining a research degree
 ◇◇◇◇ In challenge-based learning approach students face real-world problems in their complexity and multidisciplinarity ◇◇◇◇	**3. IMPLEMENTATION OF INNOVATION ACTIVITIES: INNOCORE CHALLENGE** ## General considerations Bringing training closer to the business world is a complex issue that has sought various solutions over time. Pedagogically, there have been approaches and methodologies in which students were brought into contact with business cases or company presentations; recently, a new approach has emerged in which the student comes into contact with the business world by learning about the problems of companies and, by trying to solve them, getting to know the relational dynamics and corporate culture. Challenge-based learning (CBL) is a pedagogical approach inscribed in constructivism and in the self-directed learning (SDL) approach through which students are actively involved in identifying, analysing, and designing a sustainable solution that solves a challenge on current, real-world problems. Due to the fact that students approach real and complex problems, the learning experience is multidisciplinary, includes stakeholder perspectives, and aims to collaboratively find a sustainable solution. Moreover in a CBL activity university's teachers are more than academic experts in one subject: they are facilitators of the process of building questions, gathering information, analysing data, proposing solutions, and implementing the result.

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Actors to engage in the challenge preparation:

- companies
- students
- expert mentors from the core facilities and/or the academic staff

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ENGAGE

In a challenge there are three main actors to be involved: the problem provider, the experts supporting the students and the students who will solve the problem(s).

All three of these categories can be engaged through a public call and/or in the case of the experts among the organisers.

In the case of INNOCORE, the companies, problem providers and students were engaged through a public call, while the experts were identified among the project partners.
In the case of both companies and students, the networks of the project and project participants were crucial.

DESIGN and IMPLEMENT

Every challenge activity requires training and design by the organiser and co-operation with the companies involved. Crucial is also the relationship with those who know the skills the students can bring to the table.
In a dynamic process, the stages of activity development can then be constructed.

The INNOCORE challenge was organised in three phases: in the first phase, HIT provided training on the organisation of a challenge-based event to the other project partners. Following the training, a challenge format and a plan for the activities to be implemented was co-designed between the project partners. In the second phase, the partners implemented the activities, which ended with the delivery of the solutions to the companies, and in the third phase, a follow up with the companies was started.

ASSESS Education Impact

◇◇◇◇ Challenge-based learning approach is disruptive from what the students were used to ◇◇◇◇	It is therefore crucial to design the educational aspects and the assessment system particularly on the development of students' skills. In particular, a set of the tools used for the evaluation are related to the self directed learning (SDL) approach. In SDL, learners control their experiences and are co-responsible for their learning processes and outcomes. In this context, participants are responsible for their learning processes and they are invited to co-design and evaluate their experience by filling a set of documents that help them to think about and be engaged in their activities. This approach is disruptive from what students were used to because it denied top-down teaching and learning and proposed a proactive involvement from them. This new model of learning requires new assessment tools that monitor the soft skills acquisition process. Specifically, reflective learning tools can support this assessment through the process of remembering acts and events and then exploring why things went a certain way, and finally, taking possible actions for further experiences. In the INNOCORE challenge pilot, different tools were used: the learning agreement, learning diaries, the final solution presentation, the final report, the reflection report, and the EPIC tool. 1. The learning agreement is an individual document negotiated between the organisers of The Challenge and the learners in which both parties make a respective commitment to achieve and have participants achieve a set of learning objectives. 2. Learning diaries are one-pager reports delivered for each phase of the challenge and were introduced to evaluate the team's quality of work and understanding of the undergoing process. In the learning diaries, teams evaluated how they were working by evaluating the teamwork. 3. Each team presents its final project in a pitch in front of a jury composed of the challenge provider (company mentors) and supervisors (mentors from universities and knowledge transfer institutions). The teams are evaluated on the proposed overall solution, its correspondence with the challenge's objective and the challenge provider's

requirements, as well as the quality of the presentation and question-and-answer session.

4. Before presenting the solution to the problem provider, the teams separately present the solution accompanied by a document/software/prototype in which an answer to the challenge proposed by the company is given. The result is submitted to the challenge provider.
5. After the challenge, the students have to fill out a reflection report that guides them through the learning experience, giving them the opportunity to put things in order, identify what went well and what did not go well, and plan their next actions. This individual report corresponded to the student's learning contract.
6. The Entrepreneurial Potential and Innovation Competences (EPIC) assessment tool is designed by HEI Innovate with the aim to help educators to measure the effectiveness of their entrepreneurship courses. In the INNOCORE challenge it was used to assess the skill and competence development of participants. Thus, it was provided to students at the beginning and at the end of the challenge. INFO: https://www.heinnovate.eu/en

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Challenges help the development of problem solving skills, learning to work in a team and dealing with different languages and groups of people

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FINAL CONSIDERATIONS

Challenges can have different impacts on individuals, but all experiences have certain similarities.
Challenges help the development of problem solving skills, learning to work in a team and dealing with different languages and groups of people.

4. DIGITAL RECOGNITION AND CERTIFICATION

This chapter describes the practices deployed by the InnoCore project to recognize and certify the competences acquired and the attendance to the curriculum, combining formal and non-formal education

◇◇◇◇ ODBs are portable digital certifications used to valorize specific achievements ◇◇◇◇ ODBs offer the advantage of a higher flexibility compared to ECTS ◇◇◇◇	and related certification. Overall, the practice proposes a modular delivery of the certification that can be combined by the students and designed in relation to the single target participant's needs. ## General considerations Since the courses of the curriculum are developed as modules, this feature allows the programme to be adaptable to the use of digital certifications that may be aligned with academic certifications within MSc and PhD courses. The modules are thus developed to release recognition of skills through ECTS and Open Digital Badges (ODBs) certifications. ODB are digital credentials, adhering to a new logic of tracking and acknowledgement of educational development in highly flexible contexts, both formal and informal. In a system of recognized validation, Open Digital Badges address the development of certifications for lifelong learning and lifewide learning. In the proposed framework, each single module releases a number of ECTS consistent with the contents of the courses and with the number of ECTS released for MSc modules/courses within the HEIs MSc programmes; thus the ODB release is consistent with the number of ECTS recognized. ODBs are portable digital certifications used to valorize the skills of the participants to different education and training activities delivered through formal and non-formal learning. ODBs released for the modules are equivalent to ECTS recognized for the modules. These features make the ODBs to be highly adaptable and attractive even to non-academic learners, such as research and technical staff from private organisations and companies who may need to access advanced training in specific technologies and to be certified and recognized for the skills acquired. On the other hand they represent a complementary means of certification for academic students and staff who may need recognition of qualifying non-formal learning performed within their academic studies and/or work. The flexibility of this certificate makes it highly suitable for the recognition of entrepreneurial skills acquired through hands-on training as well as soft skills, even in integration of certification of

specific technical and scientific training through formal education (i.e. class, lectures even online).
In conclusion, considering the multinational environment, successful completion of the learning opportunity (course, mobility or challenge), from any of the partner universities and documented with an agreed credential, should be recognised by any of the other partner universities and may be assigned ECTS credits or ODBs by the providing institution or the learner's home institution.

ENGAGE

People to involve

- online/distance learning experts or persons in charge for the mutual recognition of the learning activities;
- instructional designers for the organisation of metadata and design of the badges;
- teaching coordinators for the alignment of the digital credits with ECTS;
- learners/target groups;
- a platform for publication and release of ODBs.

DESIGN and IMPLEMENT

The ODB are digital badges composed of two parts: graphics and a part containing metadata, that specify the acquired skill, the method used to validate it, issuer information and the identity of the person who obtained it. They are easily exportable on social platforms (LinkedIn, Twitter, Facebook, etc) and on websites, enabling badge holders to make their skills more visible. Examples of the InnoCore OBDs are available at the following links:

- BestR platform: https://bestr.it/project/show/137?ln=en
- My Open Badge platform: https://app.myopenbadge.com/progetti/show/ufnasNqX-9718dc64f54f1b98c3440b0fcfcc8787-KTlpJDMcNiG-3

4..1 Design of the ODBs

When designing the ODBs, each certificate must be related to a set of metadata that are consistent with the contents of the courses and modules programmes. These data include: i) the learning outcomes, ii) the syllabus and, even more generally, the description of the content of the courses, iii) the description of the specific knowledge, iv) the technical skills and of the soft skills acquired once attended the course, v) if applicable, the number of ECTS related to the course/module.
The ODBs may be designed as a multiple level digital certification, recognizing specific skills and knowledge gained within i) a single course, ii) multiple courses along a curriculum, iii) a combination of course(s) related to a specific path and/or complementary topics with non formal education/training activities. Accordingly, three-fold certification may be designed:

1) basic ODB: recognition of the attendance and positive evaluation achieved within a specific course/module, that may have been delivered online or in class. This ODB may recognize even non-formal and qualifying learning activities (es. InnoCore Challenge, InnoCore Mobility);
2) silver ODB: recognition of the attendance and positive evaluation achieved within a combination of courses/modules that are qualifiable as a clear path assigning specific knowledge and skills (es. InnoCore Specialist ODB, InnoCore Innovator ODB), and that may have been delivered online or in class;
3) gold ODB: may recognize a full curriculum composed by formal and non-formal education and training, combining attendance to courses, positive evaluation to these courses and hands-on activities such as mobility programmes, project-based mobility, intensive training.

4.2 Aspects on delivery and platform
Open Digital Badges can be issued through different platforms (es. MyOB, Bestr) promoting skills acquired outside formal education, in formal and informal environments.
When planning and designing certification through ODBs within an international network/consortium, one of the first aspects to define which organisation will be the issuer, and how the issuer organisation will collect the

	information and data needed to correctly issue the digital certificate. Developing an international curriculum, as discussed above, aims to align objectives and contents of a list of courses and activities. This element facilitates the definition of the ODB related data that are propedeutically agreed by the participating HEIs and/or training institutes. The design of the ODB implies a previous agreement of parties even on graphical aspects i.e. including in the visual badge the credits to all the involved education/training institutes such as the logo of each one. ODBs can be released: - automatically: this is the case of a full self-learning online course when, after having attended lectures and performed self assessment online procedures the ODBs is assigned. This feature requires a larger technical intervention and preparation of the online contents, and fit particularly courses completely online and in a auto-learning mode; - manually: this feature applies for ODBs that are recognized under attendance to classrooms and/or synchronous or asynchronous online lessons in combination with non-automated evaluation procedures (i.e. project presentations and discussion) that require action by teachers and operators. 4.3 Delivery of Open Digital Badges - collect the necessary information about the completed activities from the teachers or the teaching offices of the Universities the students belong to. - prepare a list of students that are eligible for the ODBs. Such a list could be manually or automatically updated every semester (the period can be decided according to the frequency of the evaluations) - for the students that are external to the issuer institution, an authentication procedure might be necessary - the issuer notifies the students the procedure to obtain the ODB, according to the privacy and data protection regulations.

ASSESS

The quality and the level of satisfaction in the assignment of ODBs could be assessed through questionnaires submitted to the participants to verify the perception of aspects such as platform usability, instructional design.

FINAL CONSIDERATIONS

The case where the learner, to complete the online course and related evaluation, implies the interaction with the teacher(s) (i.e. for final presentation), would privilege ODB manual release. That would result in a higher effort to be invested by teachers and operators involved in the courses and credits recognition. On the other hand, this effort and resources invested would certainly favour the motivation of the participants. These investments could be possible in academic environment where teachers are open to integrate their formal teaching activities with non formal education, hands on training and adoption of online practices.

ANNEX 1

List of the courses on Core Technologies held at the premises of the partner Universities during the academic years 2020/21 and 2021/22:

- *Genomics technologies* for MSc in Cellular and molecular biotechnology (University of Trento)

- *Macromolecular Imaging* for MSc in Cellular and molecular biotechnology (University of Trento)
- *Advanced Imaging* for MSc and PhD students (CNC-University of Coimbra)
- *Light microscopy methods in biology - theoretical & practical courses* (CEITEC-Masaryk University)

- *Proteomics and protein characterization* for MSc in Cellular and molecular biotechnology (University of Trento)
- *Methods for protein characterization* (CEITEC-Masaryk University)
- *Proteomics Approaches in Life Sciences* for MSc and PhD students (CNC-University of Coimbra)

- *High Throughput Screening* for MSc in Cellular and molecular biotechnology (University of Trento)
- *High Throughput Screening for target and drug discovery* for the Doctoral Program in Experimental Biology and Biomedicine (PDBEB) (CNC-University of Coimbra)

- *Biotechnology Management and Regulations* for MSc in Cellular and molecular biotechnology and in Quantitative Computational Biology (University of Trento) (*this course is described on the IO1 Guide for Cooperation as practice for A-I collaboration*)

List of the online courses developed:
(https://didatticaonline.unitn.it/ricerca/course/index.php?categoryid=20&lang=en):

- Genomics technologies
- Advanced imaging
- Proteomics and protein characterization
- High Throughput Screening
- Regulations and Innovation Management in Life Sciences

Advanced Imaging Online Course

Genomics Technologies Online Course

Learning goals:
After completing the course, the student is expected to be able to:
Understand the principles underlying the Next Generation Sequencing technologies
Discuss the importance of using NGS approaches in the study complex biological questions, explaining their potential and limitations.
Critically choose the NGS approach for the qualitative and quantitative analysis that is best suited to answer the scientific question of interest.
Evaluate the appropriate method for sample preparation considering compatibility with NGS platforms, as well as the purpose of the experiment.
Understand the principle of operation of the main phases of the NGS and NNGS analysis,
Consult online databases and interpret, process and present experimental results.
Understand the principles behind Single Cell Analysis and Spatial Transcriptomics for the structural analysis of proteins and protein complexes.
Read and understand scientific articles in the field of NGS applications, Single Cell Analysis and Spatial Transcriptomics.

Syllabus of the course:
The course aims at explaining the opportunities that high-throughput technologies give in the analysis of genomes and of transcriptomes, being introduced to the concepts and tools of Precision Medicine. The course will focus on Next Generation Sequencing technologies and Next-Next Generation Sequencing technologies, their problems, and perspectives. The goal is to provide the students with the ability to apply the presented methods and strategies to their own research.
The course is divided into three modules, each module including multiple lessons. To access the content of each lesson, the students are supposed to watch the videos and download the relative slides.

Module 1: Introduction to NGS
Teacher: M. A. Denti and V. De Sanctis
Lesson 1 Denti: Sanger Sequencing vs NGS
Description: Sanger Sequencing description, sequencing principles, first human genome draft, the three phases of NGS.
Lesson2 Denti: General description of applications and Illumina Sequencing (first part)

Description: Exome enrichment, introduction to Illumina Sequencing (second part)
Lesson 3 Denti: General description of applications and Illumina Sequencing
Description: Description of Illumina chemistry, samples multiplexing, single reads and paired end sequencing
Lesson 4 Denti: Pacific BioScience sequencing
Description: description of PacBio technology and chemistry; NNGS advantages and disadvantages.
Lesson 5 Denti: Oxford Nanopore sequencing
Description: description of ONT technology and chemistry; NNGS advantages and disadvantages.
Lesson 6A-B-C-D De Sanctis: MGI sequencing platforms
Description: description of MGI istruments and DNBSEQ Technology; ssCirDNA library; DNA nanoball; DNB platform and CoolMP Technology advantages and disadvantages. Applications.

Module 2: NGS and NNGS applications
Teachers: M.A. Denti, B. Tichy, C. Egas
Lesson 7 Denti: General introduction to NGS and NNGS applications
Description: DNA and RNA sequencing, location-based techniques, clinical applications
Lesson 8 Tichy: Clinical NGS application.
Description: Germline WGS, WES and Gene Panels; Somatic genome analysis; Prenatal/Preimplantation diagnostics; Microbiology
Lesson 9 Tichy: Quality Controls in NGS
Description: Sample Quality Control; Spectrophotometry/Fluorimetry/Electrophoresis/qPCR; Problematic samples
Lesson 10 Egas: Metagenomics
Description: Batcterial Metabarcoding/16S; Fungal Metabarcoding/ITS; Metabarcoding amplicon sequencing; Metabarcoding analysis/OUT table; Metagenomics sequencing; Environmental microbial interactome/ Deep Sea environments: MAR (Mid-Atlantic Ridge).

Module 3: Single cells analysis and Spatial Transcriptomics
Teacher: V. De Sanctis, T. Tebaldi
Lesson 11 De Sanctis: Single Cell NGS technologies
Description: Sample Prep key factors to uncover single cells; isolation/enrichment methods; Quality Controls; low and high throughput SC approaches; 10x Genomics; Biorad/Illumina ddSEQ; Takara ICELL8 cx; MGI DNBelab C4 Pocket lab.
Lesson 12 De Sanctis: Spatial Transcriptomics and Innovative NGS technologies
Description: From a Start-UP AT Karolinska Institute to 10X GENOMICS VISIUM; FFPE Spatial Transcriptomics; VISIUM HD; Innovative NGS technologies: Stratos/Genapsys/Omniome
Lesson 13 Tebaldi: Analysis and interpretation of single cell and spatially resolved sequencing data

Description: Single- cell vs bulk RNA sequencing; Main applications for scRNA-sequencing; Comparison of platforms for scRNA-seq; scRNA sequencing: data processing; Experimental Evaluation of doublets using species-mixing; Key analysis steps; Dimensionality reduction techniques; RNA velocity.

TEACHERS

Michela Alessandra Denti
Since 2008 she is Principal Investigator of the Laboratory of RNA Biology and Biotechnology at the Centre for Integrative Biology of the University of Trento, Italy, first as Assistant Professor of Molecular Biology (2008 – 2014) and then as Associate Professor of Applied Biology (2014 – present). Her laboratory has two main research interests: modulation of RNA splicing as a cure for inherited diseases and microRNAs as biomarkers of cancer, cardiac and neurodegenerative diseases. Research in her laboratory was/is funded by grants from Telethon Italia, the Italian Ministry of Health, the Italian Ministry of Education, University and Research, and the Autonomous Province of Trento.

Veronica De Sanctis
NGS Facility Staff Scientist at CIBIO, University of Trento, since 2011, when she set up the facility with his colleague Roberto Bertorelli. Now she manages the NGS Core facility in the University of Trento dealing with all common and custom NGS sequencing applications and developing novel methods. Her main interest is the implementation of emerging technologies in her Facility and Department.

Boris Tichy
Since 2010 he is Head of Genomics Core Facility – CEITEC, Brno (CZ), and since 2018 also Assistant Professor. In CEITEC, Boris is leader of molecular oncology and bioinformatics team, focusing on cancer genome studies and development of novel bioinformatics tools for cancer research and diagnostics.

Conceicao Egas
Researcher at the Centre for Neuroscience and Cell Biology, University of Coimbra in Portugal and Head of the NGS facility.

Toma Tebaldi
Researcher at DeCIBIO since 2021 his research aims at understanding the RNA molecular mechanisms underlying dysregulation in human diseases, by combining experimental and computational approaches and with focus on alternative splicing events, binding of non-coding RNAs and mutant RNA binding proteins, RNA modifications (the epitranscriptome), translation dynamics and single cell expression data.

MODULE Learning Outcomes

Module 1
Upon successful completion of this module, students should be able to :

Distinguish between Sanger sequencing, Next Generation Sequencing (NGS) and Next-Next Generation Sequencing (NNGS).
Describe the basic principles for the most common NGS platforms such as Illumina, Pacific biosciences, and Oxford Nanopore.
Explain the different steps of Illumina sequencing (DNA library synthesis, DNA sequencing and data analysis).
Explain the advantages and disadvantages with the different NGS platforms.

Module 2
Upon successful completion of this module, students should be able to :

Comprehend how to synthesize and quality control DNA libraries for Illumina sequencing – synthesis, purification, and multiplexing.
Describe different methods applied to enrich different parts of the genome and transcriptome before sequencing.
Understand and apply different types of quality control methods before, during and after Illumina DNA library synthesis.
Illustrate NGS applications in Medical Genomics.
Illustrate NGS applications in Metagenomics.

Module 3
Upon successful completion of this module, students should be able to:

Describe different methods for Single Cell analysis and understand Spatial Transcriptomics techniques.
Understand the output data files from Illumina sequencing and the most basic SC NGS analysis.

METHODOLOGY
The course is a self-learning course and includes:
About 15 hours of videos
individual study and preparation of the final project.
You can attend it in complete autonomy.
For the final assessment you will be asked to design a project based on the technologies you have learned and submit it as a 10 minutes-video recording and one-page summary
Each module includes some videos and the print version of the course, if needed.
If you have doubts, take a moment to go over the contents once more.
Any doubts or questions about the contents of the course can be addressed directly to the coordinator of the course.

Proteomics and Protein characterization Online Course

Learning goals:
After completing the course the student is expected to be able to:
1. Understand the principles underlying the expression, purification and characterization of proteins.
2. Discuss the importance of using mass spectrometry in the study of proteins in complex biological samples, explaining their potential and limitations.
3. Critically choose the proteomic approach for the qualitative and quantitative analysis that is best suited to answer the scientific question of interest.
4. Evaluate the appropriate method for sample preparation considering compatibility with mass spectrometry analyses, as well as the purpose of the experiment.
5. Understand the principle of operation of the main components of the mass spectrometer, optimising the parameters that determine its performance.
6. Read mass spectra (e.g., de novo sequencing) and understand the logic of complex dataset analyses via software.
7. Consult online databases and use the most common software for processing experimental data.
8. Interpret, process and present experimental results.
9. Understand the principles behind Nuclear Magnetic Resonance (NMR) spectroscopy, X-ray crystallography, and cryoelectron microscopy (CryoEM) for the structural analysis of proteins and protein complexes.
10. Read and understand scientific articles in the field of protein analysis.

Syllabus of the course:
The aim of the course is to provide a broad knowledge of methods and applications within Proteomics, exploring advanced methods for protein characterization and functional proteomics. Emphasis will be placed on purification and separation methods, on MS-based strategies and on high-end proteomics workflows and technologies, including NMR, Crystallography and Cryo-EM. Moreover, specific examples of practical applications and case studies will be provided. The goal is to provide the students with the ability to apply the presented methods and strategies to their own research.
The course is divided into three modules, each module including multiple lessons. To access the content of each lesson, the students are supposed to watch the videos and download the relative slides.

Module 1: Purification and characterization of proteins
Teacher: E. Biasini, C. Del Bianco
Lesson 1: Introduction to Analytical Biochemistry
Description: basic principles of biochemistry; begin understanding the different strategies to study macromolecules;start being familiar with the concept of analytic biochemistry.

Lesson2: Production of recombinant proteins
Description: Methods and tips on protein expression; cellular host, design of expression vectors, solubility of proteins.
Lesson 3: Proteins purification
Description: extraction methods, principles of chromatography with specific examples, precipitation and dialysis techniques.
Lesson 4: Purification of insoluble proteins.
Description: extraction and purification of proteins from inclusion bodies with specific examples.

Module 2: Mass spectrometry and proteomics
Teachers: E. Biasini, R.Belli and D.Peroni
Lesson 5: Introduction to Proteomics.
Description: Proteomics definition, principles and applications.
Lesson 6: Mass Spectrometry-Based Proteomics: from sample preparation strategies to high-performance liquid chromatography.
Description: Top-Down versus Bottom-Up Approaches in Proteomics; protein extraction, fractionation/enrichment and digestion; rules and methods to eliminate or reduce contaminants that interfere with MS analysis; general principles and specific applications of nano ultra high-performance liquid chromatography (nanoUHPLC).
Lesson 7: MS - The instrument.
Description: Main components of the instrument (ion source, mass analyzer, fragmentation cell) and operating principles (e.g., full-scan and MS/MS).
Lesson 8: Mass spectrum.
Description: Analysis and manual interpretation of mass spectrum.
Lesson 9: Protein Identification
Description: Automatic identification of peptides from MS2 data, From peptides level to proteins level, Protein interference problem, and strategies of database search.
Lesson 10: Quantitative proteomics. Label-free and label-based relative quantification.
Description: Label-free quantification (LFQ) and label-based relative quantification (SILAC, iTRAQ/TMT); strengths and weaknesses of the different approaches. DDA and DIA acquisition mode.

Lesson 11: Targeted Proteomics
Description: Different techniques for targeted proteomics, Peptide selection and transitions, Spectral libraries, and Data-independent analysis.
Lesson 12: Analysis of Post-translational modifications (PTMs) of proteins by MS.
Description: enrichment strategies for specific PTMs (e.g., phosphorylation, ubiquitination, methylation and acetylation); PTMs identification and quantification by LC-MS/MS.

Module 3: Structural analyses of proteins and protein complexes.
Teacher:
Lesson 13: NMR L. Graziano, R. Fiala, K. Kubicek, P. Kaderavek, J. Novacek
Description: NMR principles; what NMR can tell about proteins; study of interactions and protein structure determination by NMR.
Lesson 14: XRay Crystallography
Description: Introduction to protein crystallography; protein engineering for crystallography; crystallization: thermodynamics, kinetics, experimental setup and practical tips; evaluation of crystals quality; soaking and cryoprotection; crystallographic symmetry; X-ray diffraction and resolution; structure solution, validation and deposition.
Lesson 15: Cryo-electron microscopy
Description: Application of the electron microscopy in life-science research; transmission electron microscopy, cryo-electron microscopy, principles of image formation; data alignment in 2D, techniques for 3D model determination in cryo-EM.

To assess the meeting of the learning objectives, the students are required to present one key paper from the fields of mass spectrometry and proteomics. The aim of the presentation is to illustrate the methodology, the techniques and experimental controls used, discussing virtues and limits of the study, highlighting critical aspects and/or missing experiments and controls.

TEACHERS

Emiliano Biasini
Associate professor of Biochemistry in the Department CIBIO at University of Trento, member of the Dulbecco Telethon Institute, co-founder and scientific advisor at Sibylla Biotech. His group integrates computational, chemical, biophysical, biochemical and cellular technologies with the ultimate objective of defining novel therapeutic approaches for neurodegenerative diseases.

Lolli Graziano
Assistant professor of Biochemistry in the Department CIBIO at University of Trento, co-founder and scientific advisor at Sibylla Biotech. His group works on the determination of protein structures and in the development of inhibitors either as tool compounds (chemical probes) for the elucidation of the proteins physiological roles or as hit and lead compounds for further pharmacological evaluation.

Cristina del Bianco
Manager of the Protein Technology Facility at DeCIBIO since 2015. She has experience in protein chemistry and structural biology. She specializes in the

study of macromolecular complexes of proteins and nucleic acids. She likes working with students and sharing her knowledge on proteins.

Romina Belli
Manager of the MS and Proteomics Facility at DeCIBIO since 2013, when she set up the facility. She specializes in liquid chromatography (LC) coupled to mass spectrometry (MS)-based analysis. Her main fields of interest include developing LCMS-based methods, their applications in life science, and data analysis.

Daniele Peroni
Mass Spectrometry (MS) and Proteomics Facility manager in the Department CIBIO, University of Trento. He has a strong expertise in Molecular Biology and Biochemistry. His main interest is in establishing and implementing advanced experimental proteomic and MS-based workflows for analysis of deep proteomes.

Radovan Fiala CEITEC (Central European Institute of Technology) Brno (Czech Republic)
Associate Professor of Biomolecular Chemistry at Masaryk University, Brno, Czech Republic, and head, Josef Dadok National NMR Centre, CEITEC Masaryk University. Specializes in the development of methods of NMR spectroscopy and their application to studies of structure and dynamics of biomolecules, especially nucleic acids.

Karel Kubicek CEITEC (Central European Institute of Technology) Brno (Czech Republic)
Associate professor of Biophysics in the Department of Condensed Matter Physics at the Faculty of Science of the Masaryk University (MU), Brno, Czechia. Also appointed as a senior scientist in the research group of prof. Richard Štefl at CEITEC MU. Main interest and expertise is in elucidation of biomolecular structures with nuclear magnetic resonance and electron microscopy; and studying interactions of biomolecules with various binding partners.

Pavel Kaderavek CEITEC (Central European Institute of Technology) Brno (Czech Republic)
Staff scientist in the Core facility Josef Dadok National NMR Centre and researcher in the research group at CEITEC. His main field of interest include NMR techniques for characterization of biomolecules, especially investigation of dynamics of proteins and nucleic acids by NMR.

Jiri Novacek CEITEC (Central European Institute of Technology) Brno (Czech Republic)
Manager of the Cryo-electron microscopy and tomography core facility at CEITEC Masaryk University. The main interest is application of (cryo-)electron microscopy for research in Structural and Cellular Biology. He also focuses on implementation

of the emerging technologies and automation in the life-science electron microscopy.

MODULE Learning Outcomes

Module 1
Upon successful completion of this module, students should be able to :

- Lecture 2

Know the main steps of recombinant protein expression
Analyze protein biochemical and physical properties to design a purification strategy.
Plan for the best cellular host, expression vector, construct design.
Focus will be given to expression of protein in bacteria.

- Lecture 3

Analyze and discuss the different steps of a protein purification scheme.
Know the main techniques and tips for protein extraction.
Learn about the different chromatography techniques.
Understand the biochemical and physical properties underlying dialysis and salt precipitation for protein purification.

- Lecture 4

Become familiar with the setup and main technical aspects of a Fast Liquid Protein Chromatographic instrumentation.
Learn the different approaches for the purification of insoluble proteins from inclusion bodies.
Discuss and analyze different protein purification examples from the literature.

Module 2
Upon successful completion of this module, students should be able to :

- Lecture 5

Define and apply common proteomics terminology and applications.
Understand of the concepts of proteomics as an integrated part of an -omics approach to biological/biochemical analysis.

- Lecture 6

Describe and critically discuss the design of proteomic strategies in terms of a simple or a more complex sample addressing several biological questions.
Discuss and evaluate the use of different sample preparation methods for MS-based proteomics, including protein isolation, enrichment, digestion and clean-up methods.

Known best practices and MS-compatible reagents which can guide researchers to obtain high quality data from MS analysis.

- Lecture 7-9

Discuss why the mass spectrometer is a powerful instrument for studying proteins.
Describe the architecture of a mass spectrometer.
Explain the origin of a mass spectrum and interpret its peaks.
Extract with confidence mass and charge information of precursor ions.
Known whether two ions with similar mass are distinctly observable.
Discuss a list of proteins.
Check if the identification of a protein in a dataset is reliable

- Lecture 10

Understand how MS-based proteomics can be quantitative.
Known the most common label-free and label based- quantitative approaches (Label free quantification, SILAC and iTRAQ/TMT methods) for the analysis of proteomes, secretomes and interactomes.
Understand advantages and disadvantages of these different quantitative methods.
Develop the ability to critically choose the best quantitative strategy considering your experimental model and goals.
Familiarize with the main differences between Data Dependent Acquisition (DDA) and Data Independent Acquisition (DIA) modes in bottom-up proteomics.

- Lecture 11

Pick and target the best candidate from a pool of candidates to confirm your hypothesis.
Absolute quantify selected proteins.

- Lecture 12

Characterize the diversity of post-translational modifications (PTMs) understanding their impact on proteome complexity.
Learn the principles behind enrichment methods of specific PTMs (e.g. phosphorylation, acetylation and methylation).
Familiarize with MS acquisition methods and tools for the global profiling of PTMs.

Module 3

Upon successful completion of this module, students should be able to :

- Lecture 13

Know and discuss NMR principles.
Understand what NMR can tell about proteins.

Learn the main applications of NMR in the proteomics field to determine protein structure and interactions.

- Lecture 14

Design protein constructs for crystallization.
Define a crystallization strategy, set crystallization trials and evaluate results.
Know principles of X-ray diffraction and of the corresponding data analysis towards structure solution and refinement.

- Lecture 15 CryoEM

Understand the principles of electron microscopy and cryo-electron microscopy.
Know how to use cryo-EM in life-science research.

METHODOLOGY

The course is a self-learning course and includes:

- 14 hours of videos
- individual study and preparation of the final project.

You can attend it in complete autonomy.
For the final assessment you will be asked to design a project based on the technologies you have learned and submit it via e-mail as a 10 minutes-video recording and one-page summary.
Each module includes some videos and the print version of the course, if needed.
If you have doubts, take a moment to go over the contents once more.
Any doubts or questions about the contents of the course can be addressed directly to the coordinator of the course.

High Throughput Screening Online Course

Syllabus of the course:

The course is divided in four modules, each module including multiple lessons. To access the content of each lesson, the students are supposed to watch the videos and download the relative slides.
To assess the meeting of the learning objectives, the students are required to present a screening project selected from a list provided by the teacher. The aim of the presentation is to illustrate pros and cons of the strategy proposed, to describe the methodology and the techniques used, with reference to the content of the course.

The course is divided in four modules:

Module 1 - Introduction to Drug Discovery and HTS

Lesson 1: The Drug Discovery process
Description: The starting point: target, phenotype, existing ligands, Approaches: serendipity, screening, rational, Timing/costs and criticisms

Lesson 2: Academic Drug Discovery: why?
Description: Example of the discovery of Gleevec, Failure of Drug Discovery, Paradigm shift in innovation: from closed innovation to open innovation

Lesson 3: High Throughput Screening: general concepts
Description: High Throughput experimentation, Multidisciplinarity in HTS, From the bench to the HTS, Academic screening

Module 2 - HTS: the players

Lesson 4: The Compounds, The Automation
Description: Libraries, Chemical space, Microplates and miniaturization, Liquid handling, DNA Encoded Libraries

Lesson 5: The Assay
Description: Requirements of a Bioassay for HTS, Assay classification, Detection methods

Lesson 6: The Analysis
Description: Assay performance methods, Z' factor, Normalization methods, Z score and POC, Hit selection, Multidimensional data

Lesson 7: The Target
Description: Canonical targets and the druggable space, PPI as drug targets, HIF2a case

Module 3 - Models and Assays for HTS

Lesson 8: Biochemical assays
Description: Affinity vs efficacy, Measures of binding affinity, Choice of the right assay for the right target

Lesson 9: Biophysical techniques
Description: Characterization of target molecule, Basics of target-compound interaciìtion, Overview of biophysical techniques, High Throughput biophysical techniques

Lesson 10: Cell-based assays
Description: Approaching the cell-based screening in three steps: choice of the cell model, choice of the assay, assay optimization, Cytotoxicity/Viability/Apoptosis assays, Reporter gene assays, Cell-based screening case

Lesson 11: Innovative cellular models
Description: Stem cells, iPS cells, 3D models: organoids

Module 4 - High Content Screening and Functional genomics

Lesson 12: High Content Screening
Description: Target based vs phenotypic screening, HCS workflow, HCS instrumentation and software, High Content Analysis, staining dyes, application cases

Lesson 13: Functional genomics
Description: Functional genomics, RNA interference, miRNA regulation, CRISPR/Cas9 technology, RNAi screening: arrayed and pooled, assay development, Screening cases

TEACHERS

Alessandro Provenzani

Full professor at DeCIBIO, he has been PI of the Genomics screening Lab since 2008. His lab has performed many screenings, spanning from biochemical,

biophysical and cell-based screenings, publishing high impact publications and filing several patents.

Valentina Adami

Core Facilities coordinator at DeCIBIO, she has set up and managed the HTS core facility since 2009, performing mostly cell-based screenings. With a background training in Pharmaceutical chemistry, she has stretched her skills towards med chem and biochemical assays.

Miguel Mano

Group leader of the Functional Genomics and RNA-based Therapeutics laboratory at the CNC (Center for Neuroscience) of the University of Coimbra, Portugal, Miguel Mano's research is focused on two main areas: RNA-based therapeutic strategies for cardiac regeneration and repair, and the development and application of high-throughput and high-content screening technologies using genome-wide siRNA, miRNA and CRISPR libraries.

Joseph Houser

Staff scientist in the Biomolecular Interaction and Crystallization Core Facility and researcher in the Glycobiochemistry group at CEITEC, Brno (Czech Republic). His main fields of interest include biophysical techniques for protein characterization, X-ray crystallography and bioinformatics, scientific topics focus on fungal and bacterial lectins and their interaction with carbohydrates.

Marina Cardano

Cell Technology Core Facility manager at DeCIBIO, she has a long lasting experience of stem cells culture and reprogramming, allowing advanced manipulation of cells from primary sources, including genome editing and organoid production.

Pamela Gatto

HTS Core Facility manager at DeCIBIO, she joined the facility in 2013, specializing in cell-based assays, High Content Analysis and 3D models for screening. Before joining the HTS facility, she has carried out research activities in the nutrigenomics field.

MODULE Learning Outcomes

Module 1
Upon successful completion of this module, students should:
Know the main steps of the Drug Discovery process
Distinguish among different approaches
Learn from the example of the discovery of Gleevec
Know about paradigm shift in innovation: from closed innovation to open innovation
Familiarize with High Throughput Screening terminology
Explain the differences between experiments on the bench and in HT setting
Understand the rationale of HTS in academia

Module 2
Upon successful completion of this module, students should:
Know about the main players of the HTS process
Familiarize with the library formats, miniaturization and Microplates choice
Understand the principle of liquid handling technologies
Learn about a pooled screening approach: DNA Encoded Libraries
Illustrate the requirements of a Bioassay for HTS and the possible classification
Apply different detection methods to the correct assay
Be able to go through the data analysis process
Be aware of the methods for multidimensional data analysis
List the canonical targets of common drugs and be aware of the druggable space
Learn from the example of HIF2alpha

Module 3
Upon successful completion of this module, students should:
Distinguish between biochemical and cell based assays
Be able to choose the right assay for the right target
Know the basics of target-compound interaction
List the existing biophysical techniques for molecules interaction
Design a cell-based screening
Describe the strategy to assess Cytotoxicity/Viability/Apoptosis
Illustrate the modern tools for reporter gene assays
Learn from a reporter screening case
Familiarize with advanced models for cell-based screening assays: stem cells, iPS cells, 3D models

Module 4
Upon successful completion of this module, students should:
Distinguish between target based and phenotypic screening,
Know about High Content Screening: the workflow, instrumentation and software
Understand the principle of High Content Analysis
Apply the right staining to the right assay

Learn from HCS cases
Know about the principle of functional genomics
Describe the tools for RNA interference, miRNA regulation, CRISPR/Cas9 technology
Familiarize with RNAi screening: arrayed and pooled
Learn from RNAi screening cases

METHODOLOGY
The course is a self-learning course and includes:
14 hours of videos
individual study and preparation of the final project.
You can attend it in complete autonomy.

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Any doubts or questions about the contents of the course can be addressed directly to the coordinator of the course. (email?)