Current needs in Europe for bioinformatics professionals

what should be taught in BSc and MSc courses

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Disclaimer

- I am involved in Bioinformatics Training as an instructor and mainly as a course program organiser
- I co-designed a MSc in Bioinformatics course in 2001
- I provide advice on curricula and course plans
- I am an enthusiastic practitioner of
  - Active (participatory) learning, peer instruction
  - Distance learning (Medical School, Univ. Porto)
  - Open Educational Resources (OER)
  - Connectivism (S. Downes and G. Siemens)
  - Flipped-Class education

Premises

- Education will need to adapt better to the 21st century
- Most of our students are already there (digital divide)
- Sadly, education needs to deliver learning very massively
- Education needs to ensure quality and a good propagation
- Academic environments need to join forces
- Industry needs to provide better support to academia
- Society needs to better understand science and collect the benefits of education in a much more efficient way
- Universally affordable education should simply exist
- Ignorance is much more expensive than education

Bioinformatics professionals

- Common demands
  - Up-to date with technology
  - Connected (networked) knowledge
  - Historically sound scientific culture
- Academic demands
  - Ability to teach and communicate
  - Development, teaching and writing skills
- Industry & health sector demands
  - Development, production driven skills

Historical Bioinformatics needs

- Arose from the emergence of molecular approaches in the Life Sciences

Biology – Genetics - Medicine - Environment (Ecosystem)

- Connected to major driving forces, easy to relate to buzzwords (in EU projects)
  - 1985 Biotechnology
  - 2000 Personalised Medicine
  - 2010 Environmental Issues
  - 2015 Precision Medicine & Systems Biology
  - 2020 Societal (remediation) needs ?

Core Competences (ICSB, 2014*)

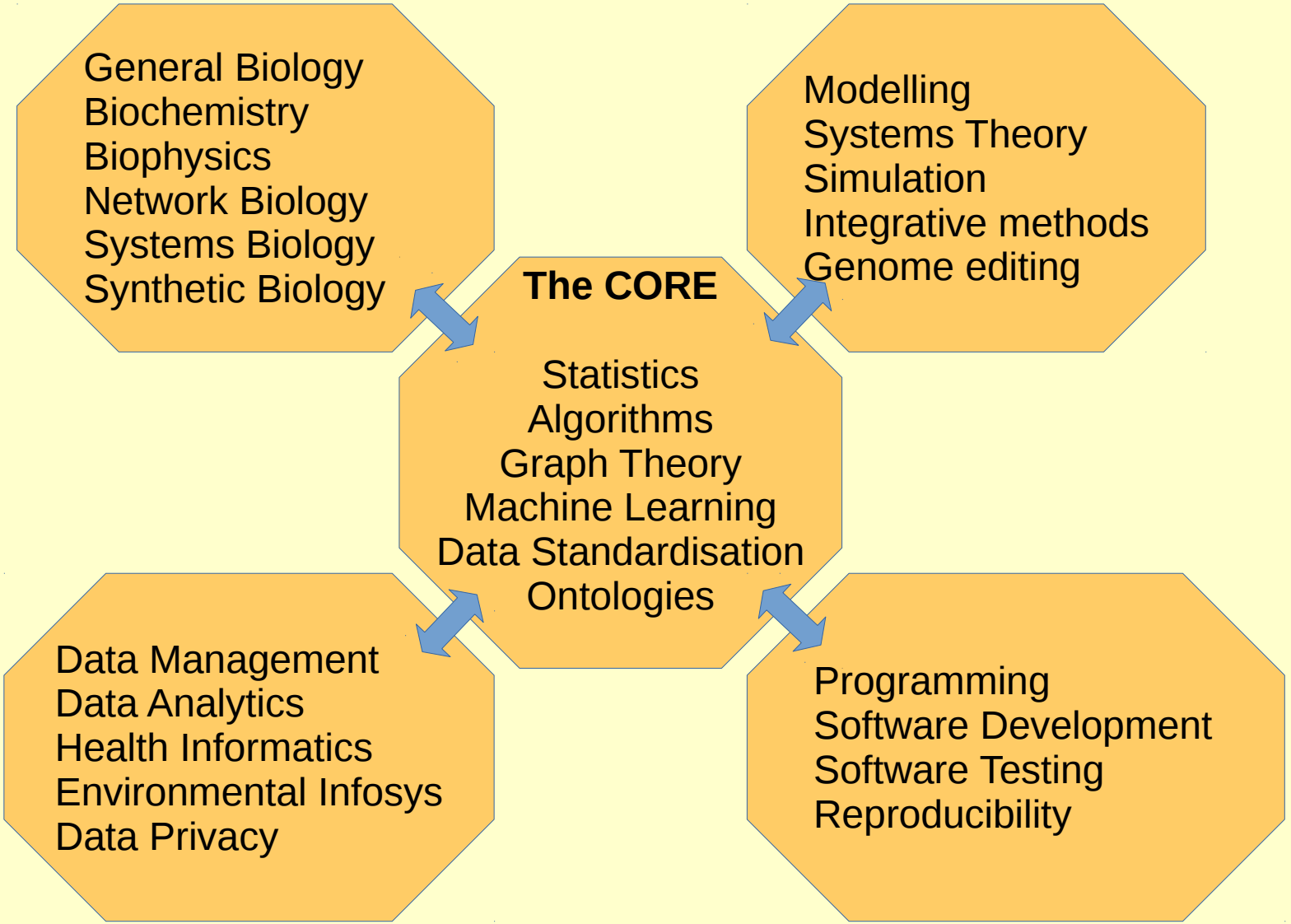
Competency	Bioinformatics user	Bioinformatics scientist	Bioinformatics engineer
User competencies			
Apply knowledge of computing appropriate to the discipline	WK	WK to S	WK
Apply knowledge of biology appropriate to the discipline	S	WK	WK
Ability to use current techniques, skills, and tools necessary for computational biology practice		WK	
Understanding of biological data generation technologies	WK	WK to S	
Understand the limitations of bioinformatics tools		A	WK to S
Scientist competencies			
Use a computer-based system, process, component, or program to meet needs		A to WK	
Evaluate ability of a computer-based system, process, component, or program to meet needs	WK	WK to S	WK to S
Apply statistical research methods in the contexts of molecular biology, genomics, genetics research		A	
Knowledge of general biology, in-depth knowledge of at least one area of biology		N/A to A	X
Appreciation of algorithms to make informed decisions on their suitability to solve a research problem	S	A to WK	
Engineer competencies			
Analyse a problem, identify and define the computing requirements appropriate to its solution		N/A to A	WK
Design and implement a computer-based system, process, component, or program to meet needs	WK	WK	X
Apply mathematical foundations, algorithmic principles, and computer science theory in the modelling and design of computer-based systems		N/A to A	
Apply design and development principles in construction of software systems of varying complexity		A	
Generic competencies			
Function effectively in teams to accomplish a common goal	S	A to WK	
Understand and uphold professional, ethical, legal, security, and social issues and responsibilities		A to WK	WK to S
Communicate effectively with a range of audiences, including, other bioinformatics professionals	S	WK	
Analyse impact of bioinformatics and genomics on individuals, organizations, and society	WK	A	
Engage in continuing professional development		WK to S	
Detailed understanding of the scientific discovery process and of the role of bioinformatics in it		WK	

A: Awareness: the professional appreciates what is possible in this area and how the area impacts on their own work

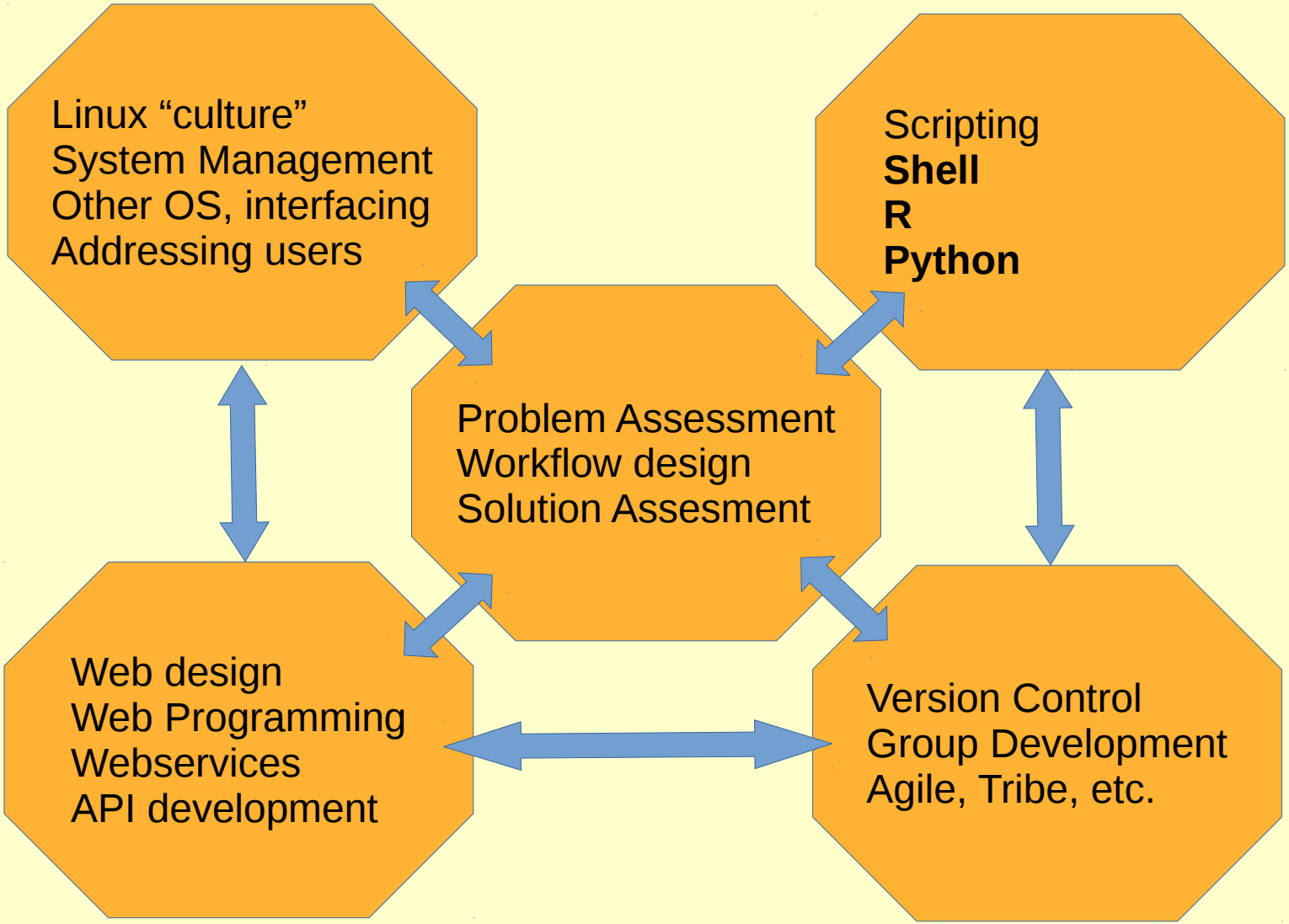
WK: Working knowledge: the professional has a firm underpinning knowledgebase in this area and applies it effectively in his or her day-to-day work

S: Specialist knowledge: the professional actively contributes to advancement of the area, generating new understanding or new technology

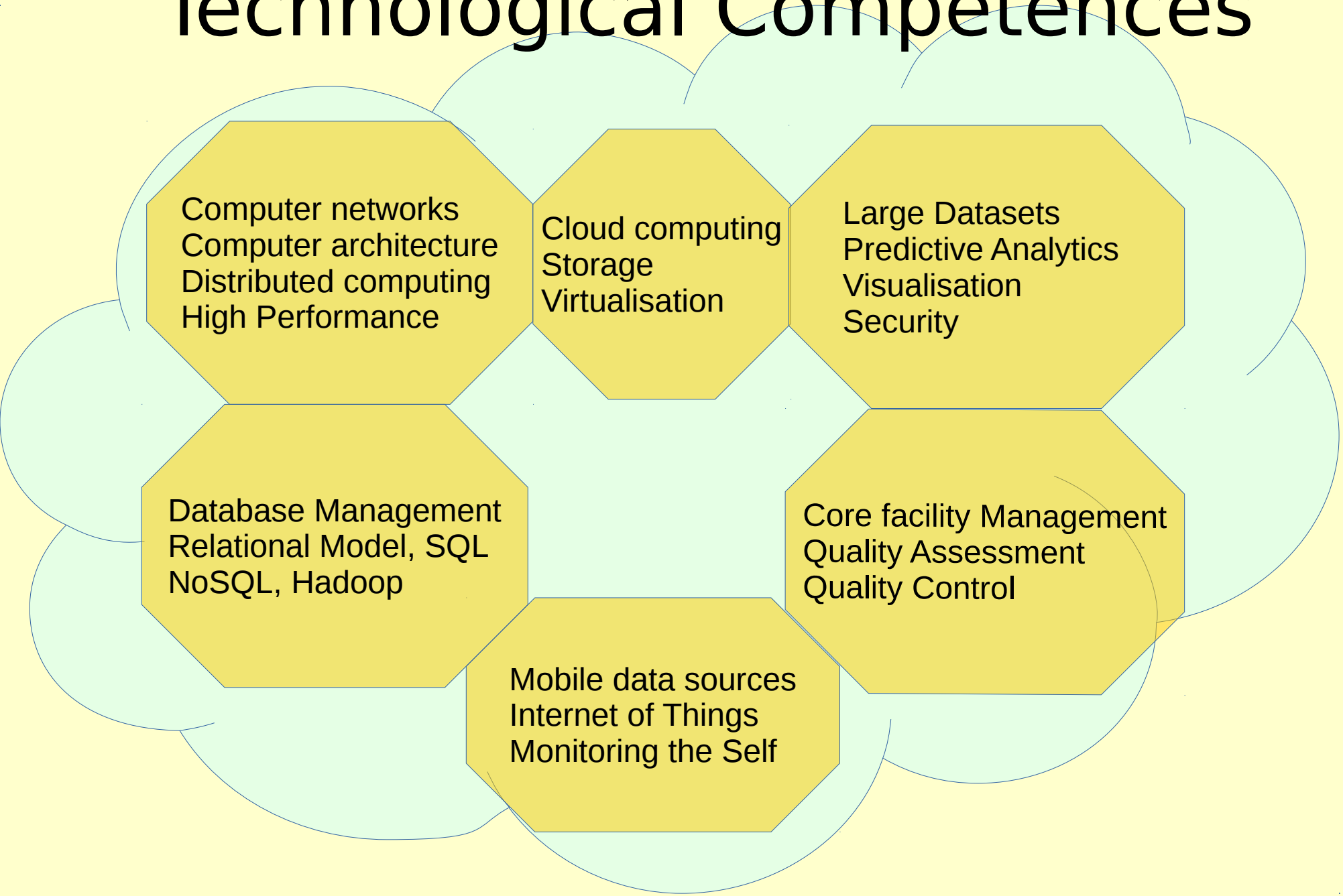
Present needs – Conceptual Foundations



Present needs – Underlying Competences



Technological Competences



Statistics, the “main obstacle”

- Bad preparation is Statistics can always be traced to deficiencies in batchelor degrees. Exceptions exist but are not abundant
- In the worst cases, we find students that have not fully understood that the generation and testing of well formulated hypotheses is at the root of the scientific method itself
- In any case, these students are unfit and the situation needs a correction

Sequencing and the NGS menace

- Courses need to offer knowledge in all the “omics” areas
- The overwhelming weight of Genomics, mostly due to the advent of Massively Parallel Sequencing of DNA (commonly named NGS) is a serious risk in what concerns unbalancing curricula
- Proteomics and Metabolomics are still not sufficiently massified due to the high cost of experimentation
- This calls for a consistent reinforcement of other “omics” areas and systems approaches in Bioinformatics education
- Integrative methods are indispensable in curricula

Genome / Phenome gap

- If well steered, students will acknowledge that extra efforts are needed bridge the gap between Genomes and Phenomes. In the absence of trustworthy mechanistic models of health and disease, one must attempt to infer rules from massive data
- Machine learning, namely the so called deep learning, is applicable to such problems, but requires a serious educational effort, actually very appropriate for ambitious MSc courses.

BSc level teaching

- The preparation at the BSc needts to match the entry level to a MSc course
- Traditionally two profiles emerge in the candidates: Life Sciences and Tech. Computing.
- Universities should offer a Bioinformatics 101 course on both tracks
- Statistics needs to be reinforced
- Better informed decisions on entry to MSc

A MSc Format – suggestions (I)

- Class delivery should move in the direction of active learning – learning by doing.
- Some MOOCS are a huge source for selecting pre-class material for visualization
- A strong push in student quality is given by assigning presentations in journal clubs
- Technology can be used to exchange teaching offerings between universities at a ridiculously low cost

A MSc Format – suggestions (II)

- The promotion of critical thinking at all stages is a must – problem-based methods
- While practising in data driven science, students need to understand how multiple hypotheses are easily generated and how they can be selectively excluded
- Critical thinking easily emerges from this but students need to learn to notice it

MSc course designs

- Carnegie-Mellon - http://www.cmu.edu/ms-compbio/
- Harvard School of Public Health - https://www.hsph.harvard.edu/sm-computational-biology/
- Université de Fribourg, Suisse - http://studies.unifr.ch/en/master/sci/bioinformatics/

In Europe, almost every country offers courses that are usually good in subject coverage. But most of them follow lecture-based conventional designs. The european offer would gain a lot in competitiveness if novel teaching methodologies were introduced.

Current needs in Europe

- Specific sectors have been requesting high quality professionals in the EU, mainly the biomedical and clinical ones

  http://cordis.europa.eu/programme/rcn/665203_en.html

- H2020 R&D Programs open calls specifying projects that explicitly require workforces with bioinformaticians. NMBP-2016-2017, for example

The role of non-formal education

- Non-formal education (eg. Training) plays a complementary role to formal, degree giving education
- It is mostly directed to the acquisition of skills, much less to knowledge and its accumulation
- Challenges from all sectors reveal the need from both formal and non-formal education

MSc level course participants

While seeking training, they are

- Still defective in Statistics knowledge
- Lost in what concerns knowing the limitations of Bioinformatics approaches
- Missing basic practical skills, such as building turnkey solutions from scratch, using Cloud services, etc.
- Too focused on Genomics, not so keen on Systems, network biology, etc.

The end

Thank you for your attention

To probe further

- Welch L, Lewitter F, Schwartz R, Brooksbank C, Radivojac P, Gaeta B, et al. (2014) **Bioinformatics Curriculum Guidelines: Toward a Definition of Core Competencies.** PLoS Comput Biol 10(3): e1003496. doi:10.1371/journal.pcbi.1003496
- **Developing Clinical Bioinformatics Training in the NHS - a timeline for action** Report of the Clinical Bioinformatics Task & Finish group – February 2015

  https://www.genomicseducation.hee.nhs.uk/images/publications/Developing_NHS_Clinical_Bioinformatics_Training.pdf
- Brazas MD, Ouellette BFF (2016) **Continuing Education Workshops in Bioinformatics Positively Impact Research and Careers**. PLoS Comput Biol 12(6): e1004916. doi:10.1371/journal.pcbi.1004916
- Atwood TK, Bongcam-Rudloff E, Brazas MD, Corpas M, Gaudet P, et al. **GOBLET: the Global Organisation for Bioinformatics Learning, Education and Training**. PLoS Comput Biol. 2015;11(4):e1004143.

Key features of PGBIOINF (Portugal)

- Students of mixed nationalities – teaching in English
- Students of two main profiles, BIO and INFO, brought to the level of being able to attend intensive seminars in 15 weeks
- Series of 14 intensive thematic seminars in the next 15 weeks
- Courses fully taught and documented in English
- Marks standarized in ECTS to ensure mobility
- Small number of students: individual attention
- Problem driven teaching methods
- Literature based presentations and discussions by the students (Journal Clubs)

PGBIOINF – total duration: 30 weeks, 60 ECTS

Part A (Minimum of 30 ECTS)

All courses are mandatory

Lectures, Lab Practicals

*- For **ALL** students*

Introduction to Bioinformatics 60h
Biostatistics 60h
Machine Learning in Biology 30h
Intro. to Evolutionary Biology 30h

*- For students of the **BIO** profile*

Program Development 60h
Intro. to Databases 45h

*- For students of the **INFO** profile*

Molecular Genetics 30h
Genetic Engineering 30h
Biomolecules Structure & Function 30h
Chem. and Biochem. Lab. 15h

Part B (Minimum of 30 ECTS)

Mandatory & optional seminars 35h each

Lectures, Lab Practicals, Journal Clubs

Mandatory

Statistical Methods in Bioinformatics
Biologically Inspired Algorithms
Data Warehousing and Mining
Protein Str. & Funct. Prediction
Funct. & Comparative Genomics
Gene Prediction & Identification
Limits & Expectations in Bioinformatics
Gene Ontology

Optional

Population Genetics
Phylogenetics and Molecular Evolution
Population Dynamics and Epidemiology
Proteomics, Transcript & Metabolomics
Genetic Expression and Microarrays
Quantitative Human Genetics

Ten commandments for a teacher

- Do not feel absolutely certain of anything.
- Do not think it worth while to proceed by concealing evidence, for the evidence is sure to come to light.
- Never try to discourage thinking for you are sure to succeed.
- When you meet with opposition, even if it should be from your husband or your children, endeavor to overcome it by argument and not by authority, for a victory dependent upon authority is unreal and illusory.
- Have no respect for the authority of others, for there are always contrary authorities to be found.
- Do not use power to suppress opinions you think pernicious, for if you do the opinions will suppress you.
- Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric.
- Find more pleasure in intelligent dissent than in passive agreement, for, if you value intelligence as you should, the former implies a deeper agreement than the latter.
- Be scrupulously truthful, even if the truth is inconvenient, for it is more inconvenient when you try to conceal it.
- Do not feel envious of the happiness of those who live in a fool's paradise, for only a fool will think that it is happiness.

From "A Liberal Decalogue", Bertrand Russel, Autobiography (1969)