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ARTICLE

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Insights from the new horizons in biochemistry and molecular biology education conference. September 6–8, 2017, Rehovot, Israel

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Abstract

The New Horizons in Biochemistry and Molecular Biology Education Conference was organized by the International Union of Biochemistry and Molecular Biology (IUBMB) in collaboration with the Federation of European Biochemical Societies (FEBS), and the Weizmann Institute of Science (Israel) and held in Rehovot, Israel, on September 6–8, 2017. The program covered the entire lifespan of students/scientists from the school level to undergraduate, graduate, and post-doctoral levels and brought together 130 international participants. This article provides an overview of the major issues and topics discussed at the conference and suggestions for the way forward.

KEYWORDS

Conference, education, FEBS, Israel, IUBMB, Weizmann

The International Union of Biochemistry and Molecular biology (IUBMB) in collaboration with the Federation of European Biochemical Societies (FEBS) and the Weizmann Institute of Science (Israel) jointly organized the New Horizons in Biochemistry and Molecular Biology Education Conference (http://www.weizmann.ac.il/conferences/NHBMB2017/), which was held at the David Lopatie Conference Center of the Weizmann Institute of Science, Rehovot, Israel, during September 6–8, 2017. The conference program included plenary lectures, mini-symposia, workshops, and poster sessions. The sessions covered the lifespan of students/scientists from the school level to undergraduate, graduate, and postdoctoral levels. The exciting program brought together 130 participants, including lecturers from around the world. The conference started with the opening words of Joan Guinovart, President of IUBMB, and Israel Pecht, Former Secretary General of FEBS, followed by introductions and welcomes from Anat Yarden (Host and Co-Chair) and Co-Chairs Janet Macaulay (Chair, IUBMB Education Committee) and Gül Güner Akdogan (Chair, FEBS Education Committee). Bruce Alberts (UCSF, USA) then set the scene for the conference with the opening plenary session entitled "Why science education is more important for the world than most scientists realize?" Bruce talked about the many roles he has had in science including—from pure research to textbook writer to editor in Chief of Science and President of the National Academy of Sciences in the U.S. He discussed the importance of science to our communities and the importance of students learning how to think like scientists in everyday life—using evidence and logic for decision-making.

The other plenary speakers were Robert Harris (Karolinska Institute, Sweden, see below) and Nobel Laureate Ada Yonath (Weizmann Institute of Science). Robert Harris gave an enthusing talk on "The Future of the Doctorate"—blending his experience as Director of PhD Studies at Karolinska Institute, with his leadership

at ORPHEUS (Organization for PhD Education in Biomedicine and Health Sciences in the European System). Ada Yonath closed the conference with a fascinating presentation about the "Next-Generation Environmental Friendly Antibiotics," which showed us all how complex scientific research can be explained in a way that is easily understood.

The conference program also included 13 other invited lectures and a series of mini symposia covering (in a chronological order) the areas of: Preuniversity biology education, Key knowledge and skills for molecular life scientists, Research in undergraduate education, PhD training—new prospects, and Rethinking postdoctoral training. The interactive workshops ran in parallel sessions forcing the conference participants to make difficult choices between several interesting topics, such as "*Lecture 3.0*: *Activating your lectures to engage all learners"*, given by Robin Wright (University of Minnesota), to *"Team based learning*: *Where the magic happens with group work that works!"* given by Ferhan Sagin (Izmir University, Turkey) and many more. The detailed program is available at http://www.weizmann.ac.il/conferences/NHBMB2017/. The following sections describe in a chronological order highlights from the conference.

1 | PREUNIVERSITY BIOLOGY EDUCATION

From a lifecycle perspective of the student/scientist the conference started with Preuniversity Biology Education. This mini-symposium, Chaired by Anat Yarden (Weizmann Institute of Science, Israel) focused on discussing the means of teaching and learning of molecular biology in primary and secondary schools with the aim of forming the basis for students' future learning beyond schooling and throughout their life. Ravit Golan Duncan (Rutgers University) outlined how learning progressions can inform the teaching and learning of molecular genetics. She presented several learning progressions for genetics that together span elementary to twelfth grade. She explained how research on these progressions provides insights about student learning in genetics, in particular, what are the productive intermediate ideas on route to normative understandings, and how can we support deep and meaningful learning in this domain. Jo Ellen Roseman's (AAAS) presentation described principles for designing K-12 curriculum materials to promote literacy in biochemistry and molecular biology, and illustrated the use of these principles in the design of an eighth grade curriculum unit. After a multiyear iterative design/test process, the *Toward High School Biology* curriculum unit (AAAS/Project 2061, 2017) showed promise in promoting student learning of ideas about atom rearrangement and conservation and their use in explaining the growth of living things.

The second part of the mini-symposium hosted by the Head of the Science division in the Pedagogical secretariat of the Israeli Ministry of Education, Gilmor Keshet; the Chief Supervisor of High-School Biology Education in the Israeli Ministry of Education, Irit Sadeh; and four outstanding high-school biology teachers from Israel. The team outlined the molecular biology aspects of the high-school biology majors program in Israel (10–12th grades), which can be realized in various laboratory activities and an inquiry project, according to each teacher's preference and the equipment that is available for them in their schools. Four case studies were presented by the four teachers: (a) an escape room which was designed by the teacher herself (Maya Mayrose, Hadash Holon in the spirit of HTH) supported inquiry that involved molecular biology and bioinformatics, supervised by scientists from the Compugen Israel biotech company which is located nearby the school; (b) simulations and games that are used for supporting comprehension and exemplifying abstract molecular concepts and processes (Nadira Sahaka, Al-Nahdah Al-Ahliyya Ateed School, Kfar Qara); (c) scientific articles that were adapted to the knowledge level of high school students are used for exposing students to topics that are familiar to them from their everyday lives (e.g., gene therapy) and can familiarize the students with current molecular methods with the aim of reaching in depth understanding of scientific thinking (Omer Choresh, Harishonim High School, Herzliya); and (d) hands-on molecular biology inquiry is carried out by the high school students in the school laboratory in the framework of the international citizen science project Walbachia (Shiri-Rivka Masa' Hashalom high-school, Mitzpe-Ramon).

2 | UNDERGRADUATE EDUCATION

The next stage in the student/scientist lifecycle is undergraduate education. The Key Knowledge and Skills for Molecular Life Scientists were discussed in a mini-symposium, chaired by Keith Elliot (Manchester University, UK) which focused on the information and competencies that molecular life sciences graduates need to possess to be successful in their careers. It was noted that depending on the countries, up to 75% of these students are going to pursue careers outside academia.

Robin Wright (University of Minnesota) set the scene for this topic with a discussion of "Scientific teaching: Strategies for applying education research to improve

student engagement and performance in science classes." Robin stated that scientific teaching, using science to teach science, can solve classroom challenges, from student motivation to deep learning. This talk introduced key principles of scientific teaching: learning objectives, assessment, and inclusive teaching. She then considered how findings in cognitive science require us to provide social and emotional support in science classrooms. She ended with a review of the Biochemistry and Molecular Biology learning outcomes developed by the American Society for Biochemistry and Molecular Biology, as formatted for the journal, *CourseSource*.

Frank Michelangeli (Chester University, UK) continued the discussion of undergraduate education by stating that both students and employers require that university education should equip students with the essential skills and information to support them in their careers. He emphasized the fact that in any academic discipline, there are three basic areas that students need to be trained in:

1. Transferable and employability skills such as, mathematical, communication (writing and oral), problem-solving, team-working, time-management, critical analysis and IT skills.
2. Subject-specific knowledge which is dependent upon the specific area being studied.
3. Subject-specific practical skills. As molecular life sciences is a practical based subject, learning and being proficient in practical skills would be essential.

Frank recommended that all three areas above should be given sufficient weighting within the degree programme. Furthermore, in order to improve the student's chances of gaining graduate level employment at the end of their studies, students would also benefit from training in CV writing, application form filling and interview techniques.

Ross Nehm (Stony Brook, NY) brought the discussion of undergraduate education to a close with an overview of assessment models for large lecture courses. He provided, illustrated examples of how assessment tools may be employed within these models, and examined case studies showing how these models and tools may be used to help instructors teaching large lecture classes. Post-secondary biology faculty commonly employ instructional models that lack attention to students' ideas, mental models, and intuitive reasoning strategies even though a half century of research has clearly demonstrated that young children build naïve mental models of many phenomena and college students continue to utilize these models. A sampling of pre-assessments was provided, along with examples of how biology faculty could use these assessments to reveal student thinking about core ideas and design curriculum aligned with student ideas. Assessment was emphasized as an evidence-based, data-driven strategy essential to scientific teaching. Given the importance of assessment to biology teaching and learning, and the prevalence of faculty misconceptions about assessment, Nehm recommended that professional development opportunities (e.g., workshops, short courses) at major conferences should be provided for faculty.

The importance of, and potential ways in which undergraduate students can have worthwhile, authentic research experiences was also a topic for another minisymposium chaired by Janet Macaulay (Monash University, Australia). Erin Dolan from the University of Georgia, USA argued for the importance of undergraduate students participating in research as a way of engaging them in the "practice of science." Erin presented Course-Based Undergraduate Research Experiences (CUREs) as scalable models for providing a research experience for large numbers of students, thus avoiding the limitations of the traditional "apprenticeship" style model, which is limited by the number of students who can be placed in research labs. A number of examples of CUREs were presented. Of particular importance was the discussion of the question of what is "success" and how to measure the impact and success of CUREs. Erin presented data from studies analyzing the impact of CUREs.

Susan Rowland (University of Queensland, Australia) who has had experience running UREs moved the focus to a new model by which the University of Queensland is addressing Work Integrated Learning (WIL) for science students. Through a program called SCIWILWORK they have been addressing the limited access of science workplace opportunities for students by enabling students to use their nonscience paid work for WIL. The program was developed to improve students' skills in a range of areas including awareness of careers, management of their own careers and awareness of their own strengths and skills which are important in the workplace. Susan also raised an important fact that is often not seen by scientists—that research labs are "the workplace" and that UREs are therefore also a form of WIL.

The final aspect of undergraduate programs discussed in this session was "Research as a transformational educational resource" in which Jane Saffell (University of London, UK) discussed how students own identities, thinking processes and individual experiences transform their learning. Jane presented examples from her own teaching to illustrate the types of student learning opportunities which can transform the educational experience. Three examples were (a) whole-class, teams mini research projects with both wet and dry lab phases for

TABLE 1

Team based learning: Where the magic happens with group work that works! (workshop)	Ferhan Sagin (Ege University, Turkey)
Lecture 3.0: Activating your lectures to engage all learners (workshop)	Robin Wright (University of Minnesota)
Enlightening macromolecular structure function relationships with Proteopedia (workshop)	Joel Sussman (Weizmann Institute, Israel), Angel Herraez (University of Alcalá, Spain) and Jaime Prilusky (Weizmann institute, Israel
Teaching the physics behind cell biology in introductory level courses (roundtable discussion)	Sam Safran and Edit Yerushalmi (Weizmann institute, Israel)

exploring design and data analysis with a focus on working as a team, (b) Scholarship—writing an article—authentic assessment, and (c) sociopolitics—in which students are exposed to "behind the scenes of research" as researchers tell the story of how a paper they have authored came into being.

Undergraduate education was also discussed in depth in a number of workshops, roundtable discussions and poster presentations including those listed in Table 1.

3 | PHD TRAINING

Moving through the student/scientist lifecycle the conference also focussed on PhD training. A mini-symposium on "PhD training—New prospects" was preceded by a plenary talk by Robert Harris (Karolinska Institute, Sweden, and ORPHEUS. Harris pointed out that doctoral training has changed radically with regard to expectations of both PhD students and supervisors, and that here are increasing demands for innovation, publication excellence, and global competition, increasing numbers of cases of scientific fraud and worsening economic prospects for safe career development. Harris suggested that taken together these developments provide both institutions and individuals with several new challenges regarding quality assurance and requirement for individual professional development. His recommendations to the target population: Institutions, supervisors and PhD students were that: (a) Doctoral training cultures should be modernized so that the expectations of the current PhD students are more aligned with the current understanding of the older generation decision-makers; (b) Since the skills sets required for PhD supervisors has greatly increased, formal, professional training is one recommended way to provide the knowledge required to learn these skills; (c) Quality assurance and feedback systems are imperative within doctoral training to provide data that allows for continued development; and (d) Professional conduct and mutual feedback should be standard within doctoral training cultures.

The issues of PhD training were further addressed in the mini-symposium chaired by Gul Akdogan Guner (IEU School of Medicine, Izmir, Turkey) with the aim of bringing forward the rising importance of effective PhD training, taking into consideration the new challenges such as, the increasing demands for innovation, and publication excellence as well as global competition. In addition, the session took into consideration that up to 90% of the PhD holders in certain countries may pursue careers outside the academia.

Michael Mulvany (Aarhus University, Denmark) spoke about "Trends in PhD training in Europe and North America" and informed the audience that while there is a general agreement that the degree is awarded in recognition of successfully completed research training there have been significant differences in the way doctoral training programs have developed in different countries. There is, however, a clear global tendency to follow the programs currently used either in the US or in Continental Europe. To determine more clearly how US and European PhD programs are both similar and different, Mulvany and his team analyzed biomedical PhD programs in four representative institutions at U. Vanderbilt, U. Manitoba, Karolinska Institute and Medical U. Graz. The analysis is based on 63 detailed questions concerning the research environment, outcomes, admission criteria, content of programs, mentoring (Europe: supervising), the PhD thesis, assessment of the thesis and PhD school structure. The results reveal that while there is a considerable overlap in the aims and content of PhD programs there are also considerable differences regarding the structure of PhD programs, mentoring, and assessment of PhD theses. These differences were analyzed in detail in order to provide a foundation for discussion of their relative advantages and disadvantages (Barnett JV, Harris RA, Mulvany MJ. FEBS Open Bio. September 2017).

Mulvany pointed out that comparisons such as these provide a solid platform for discussion of best practices and will be of importance in the continued development of global discussions about development of doctoral training. The approach described has the advantage of cost-effectiveness since data acquisition can be performed locally, and the comparisons are presented as the basis of discussion between the institutions concerned.

Suzanne Ortega, (Council of Graduate Schools) contributed to the discussion of PhD training in her presentation about "Preparing versatile scientists." To successfully prepare the next generation of scientists, Ortega voiced her opinion that we must deepen our understanding of the quality and breadth of scientific careers (not just the careers we imagine our PhD alumni to have) and the quality of the professional preparation our students receive while in graduate school. She argued that a lack of information currently hampers the preparation of scientists for a full range of important and rewarding careers, especially for those who pursue careers outside of academia. Changes in the way that research is funded, produced, and disseminated, along with changes in the structure of the workforce, make it all the more important that we understand gaps in student preparation. To address these gaps, she recommended that universities collect PhD career pathways information beyond initial placements, which typically give us an incomplete picture of the nature of scientific work over the long term. She also recommended that we build professional development programs that address specific skills gaps in the biomedical and STEM workforce, including skills that will allow students to adapt to—and lead—new workforce trends.

PhD training was also discussed in depth in a number of workshops and poster presentations including those listed in Table 2.

4 | POSTDOCTORAL TRAINING

Our students work hard to achieve their PhDs and become "scientists" but they still have much to learn and postdoctoral training can make or break their careers. "Rethinking postdoctoral training" (Chaired by Mike Walsh, University of Calgary) was the last stage in the student/scientist lifecycle discussed at the conference. Uri Alon (Wiezmann Institute of Science, Israel) launched this topic with a discussion of "Into the unknown together." Alon discussed how, when we are learning science, we only learn about the results and are rarely taught about the process of science. No one tells new PhD students of the rocky road ahead—the successes and failures or how to cope with these. Alon related to the story of how while doing his PhD, he felt like a failure—"felt unworthy"—felt that he could not be a scientist as he could not produce results. While completing his PhD he also studied Improvisation Theater and this has had an enormous impact on his mental attitude. He believes that Improvisation Theater is like science—"not knowing where you are going." He discussed how when we publish papers we present them as: I started with my question and went straight to the answer—but this is rarely the case—the path is often very convoluted and we can get stuck in what Alon calls "the cloud." He likens "being in the cloud" to despair but knowing that "the cloud" is normal and that you will get out of it and that it can lead to fascinating places and discoveries is critical. Alon discussed the important role of scientists as mentors to students and post-docs yet most receive no training to be mentors. He is passionate about mentoring and tells his students from day one what research is really like and encourages them "to go together with him into the unknown." Alon is passionate about the emotional and subjective things that happen to scientists and how we deal with them. Alon had his guitar with him and interspersed his presentation with engaging songs including "I've been scooped again." A 15 min version TED talk of a similar presentation by Uri Alon is available.

Beata Vertessy (Budapest University of Technology and Economics, Hungary) continued this discussion with the topic "There is a tide: Tasks and responsibilities of supervisors and young scientists during the postdoctoral stage". Beata acknowledged the complexity of research as a career, which requires individuals to take a logical, systematic and evidence based approach to their research while also recognizing the passion and commitment which drives many researchers. She discussed that the postdoc stage is a high pressure stage of researchers' careers as they are attempting to manage the many demands, pressures and emotions while building their research output, potentially considering various career paths and facing personal pressures such as young families.

TABLE 2

Training the PhD trainers (workshop)	Robert Harris Karolinska Institute, Sweden) and Michael Mulvany (Aarhus University, Denmark)
On research integrity: Concepts and principles	Tien-Hsien Chang (Academia Sinica, National Yang Ming University, China)

TABLE 3

Students as partners and peer learning: Enhancing students' transferable skills during postgraduate training	Lucian Mello (University of Liverpool, UK)
Challenges for biochemistry and molecular biology education in the developing world	Grace Yu (University of the Philippines, Philippines) and Phillip Nagley (Monash University, Australia)

Postdoctoral training was also discussed in depth in a number of workshops and poster presentations including those listed in Table 3.

Another topic that attracted a lot of interest at the conference was the workshop on Publishing in Education, which was an interactive session hosted by an impressive collection of editors of educational journals which included: Erin Dolan (Cell Biology Education, CBE Life Sciences Education), Phillip Ortiz (Biochemistry and Molecular Biology Education, BAMBED), Angel Herraez (FEBS Open-Bio) and Luciane Mello (FEBS Open-Bio). The presenters discussed the unique requirements of Discipline Based Educational Research and the various types of publications available. The workshop also covered topics of, how to pick your research direction, common errors in education research and how to select the appropriate journal. The value of journal clubs and writing groups to actually get the writing done was highly recommended. A major "take home message" was to use thorough research methods and the importance of evidence.

5 | POSTER PRIZE

Biochemistry and Molecular Biology Education (BAMBED) and Phil Ortiz (Editor in Chief) were strong supporters of the conference and generously supported an Outstanding Poster prize which was won by HK Ngai, SK King, WA Au, FH Lo, and PC Shaw, from the Biochemistry Programme, School of Life Sciences, The Chinese University of Hong Kong for their poster "Development of an e-Learning platform for undergraduate biochemistry courses adopting a flipped-classroom pedagogy."

6 | ISRAEL AND THE WEIZMANN INSTITUTE

In addition to the formal aspects of the conference, there was plenty of time to talk with presenters, reconnect with colleagues, and make new connections. There were two wonderful conference dinners organized by the amazing team at the Weizmann Institute of Science—the highlight being a night in Jaffa with pre dinner drinks at the Ilana Goor museum and dinner at The House of Otzarin, both sitting outside overlooking the beautiful old city of Jaffa, the Jaffa port and the Mediterranean sea. Another pleasant evening was spent in the garden of the Wolfson house, which is located on the grounds of the Weizmann Institute of Science.

7 | CONCLUSIONS AND WHERE TO NEXT—FROM THE CONFERENCE ORGANIZERS

Much discussion was held regarding ideas to improve the current approaches to teaching Biochemistry and Molecular Biology at all levels and potential directions to go in. Although the conference covered the educational spectrum from preuniversity, through to post-doctoral training there were common themes that appeared throughout and which we, the conference organizers, propose we should work toward as the community of Biochemistry and Molecular Biology educators.

- The curriculum must equip students with the skills they will need in the diverse and changing future workplace. *Science content is not sufficient*, *the skills of inquiry*, *problem solving*, *scientific reading*, *writing and speaking*, *critical thinking—thinking as a scientist—and more should be core elements of the curriculum*.
- We must prepare our students for an uncertain workplace. *The workplace and its demands are changing and science graduates will not necessarily work in academia*.
- PhD training should meet the increasing demands for innovation, publication excellence and global competition,
- It is essential that we take an evidence-based approach to education and training at all levels. *We must be scholarly educators who build the curriculum on evidence and collect data to add to the science education research literature.*

There is still much work to do so we look forward to future IUBMB and/or FEBS supported education conferences.

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