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New Challenges of Knowledge Transfer in Veterinary Physiology in a Changing Educational Environment: An Overview of Physiology Teaching in USA and Non-USA Colleges and Schools

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ABSTRACT

Veterinary physiology education, faces new challenges in a rapidly changing information technology-based world. The main factors interacting and affecting the veterinary medical education are: the subject matter itself, the new generation of students, new definitions available for knowledge, and the different teaching methods. The objectives of this work were triple. Firstly, to review the factors that impact teaching and learning; Secondly, to provide insights based upon more than twenty years of experience in teaching veterinary physiology to veterinary students at Purdue University, USA, and the University of Veterinary Medicine, Budapest. Thirdly, a) To gain an understanding of the physiology teaching in USA and non-USA Colleges through analyzing veterinary physiology topics as well as related subjects and factors; b) To examine the contents of the widely used textbooks. Physiology courses data were collected from schools` public websites of the 28 accredited USA veterinary schools, and selected colleges outside the USA, and analyzed. . Course comparisons included the topics taught in the veterinary physiology courses, number of credit hours, signs of tracking, presence or absence of neurophysiology, clinical physiology, pathophysiology, comparative physiology, and the presence or absence of laboratory practical sessions. The contents of most popular text book were analyzed and compared. Our results showed that there were substantial differences in teaching veterinary physiology and related subjects, such as neurophysiology, pathophysiology, comparative physiology, biochemistry, and clinical sciences within and outside the USA. It was observed that not all (only 36%) physiology courses are coupled with labs, especially wet labs. It worth mentioning here that the order of topics within each physiology textbook is not the same and the depth of coverage of different chapters vary, and some of the topics are underrepresented. Interestingly, veterinary students in developed countries are committed to become veterinarians and are highly motivated. This motivation is reflected on better learning. In addition, these students have the opportunity to select during their studies a career path or track such as small animal. Currently, no track-related physiology courses exist in most curricula. Physiology education could benefit from new technologies and interactive learning approaches such as case-based and g, team-based learning, peer instruction, and the flipped classroom. In addition, the use of e-learning management systems would facilitate the learning process, and the interactions between peers and with the instructor. Further, aligning and integrating basic medical sciences and providing clinical correlations would encourage the application of physiological concepts to solving clinical cases.

Key words: Veterinary physiology, Veterinary schools, Y Generation, Meaningful learning, Learner-centered teaching, Institutional design, Interactive learning, Case-based learning.

INTRODUCTION

Physiology is crucial to the understanding of other important basic and applied veterinary medical sciences. In addition, physiology having an interdisciplinary character is indispensable for the teaching of biomedical sciences and biomedical engineering (Clase et al., 2008). Veterinary physiology differs from both classical mammalian physiology and medical physiology. It has to prepare students for the practice of veterinary medicine that deals with a wide range of species, specialties, and tracks. It has to help students in solving clinical cases, and understanding issues related to animal wellbeing and veterinary public health. Veterinary physiology is expanding due to the expanding research areas (Blumberg, 2005; Forrester, 2006; Murray and Sischo, 2007; Lane, 2008; Summerlee, 2010; Habtemariam, 2012; Warren and Donnon, 2013 and Salomäki et al., 2014). To cope with the new knowledge, intellectual learning must be the focus of education instead of classical methods based on gathering and memorizing facts (Hoover and Pelaez, 2008). It could be noted that college curricula are being revised to accommodate the knowledge expansion and information overload. However, it could be noted that ensuring students' in-depth knowledge in all aspects of veterinary medicine is

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getting more and more impracticable (Eyre, 2011). Traditional facts-stuffed curricula may have made pre-clinical courses boring and often perceived as irrelevant to the practice of veterinary medicine. On the other hand, lifelong learning, problem-orientated approach, communication skills, critical thinking, and information management skills have become indispensable for the practice of veterinary medicine and its specialties (Blumberg, 2005; Forrester, 2006; Murray and Sischo, 2007 and Lane, 2008). Understandably, clinical correlations and problem-based curriculum motivate students to learn basic relevant physiological concepts.The objectives of this work were triple.Firstly, to review the literature on the factors that impact teaching and learning (the new generation of students, the concepts of knowledge and meaningful learning, and the ways and means used to realize meaningful learning). Secondly, to provide insights based upon more than 20 years of experience in teaching veterinary physiology to veterinary students at Purdue University (Lafayette, Indiana, USA) and the University of Veterinary Medicine (Budapest, Hungary). Thirdly, a) to gain a better understanding of the physiology teaching in USA and non-USA Colleges through analyzing veterinary physiology curricula topics being taught in veterinary schools and colleges, as well as related subjects and factors that affect the success of teaching veterinary physiology. These factors include integration and alignment, the biochemistry factor, physiology textbook topics, and the presence or absence of laboratory practical sessions b) to examine the contents of the widely used text books in order to identify current trends in veterinary physiology teaching worldwide. The study proposed an integrated approach to knowledge transfer in veterinary physiology within the current educational environment that is characterized by curricula revisions, including learning outcomes.

MATERIALS AND METHODS

An extensive review of the literature was carried out using current and relevant publications on the following: 1) characteristics of the new generation of veterinary students, differentiated curricula (tracking) and physiology teaching, new knowledge definitions and the teaching and learning of physiology, and ways of teaching and learning, 2) veterinary physiology teaching in the USA veterinary schools and colleges, and related factors affecting the success of teaching veterinary physiology. On the other hand, physiology courses in the 28 accredited USA veterinary schools (Smith and Fenn, 2011; Roush et al., 2014 and American Veterinary Medical Association, 2016) were reviewed (Table 1). Professional curricula data were collected in 2014 from the veterinary colleges' and schools` public websites in the USA and outside the USA and comparisons were made. Course comparisons included the following: topics taught in the veterinary physiology courses, number of credit hours, signs of tracking, presence or absence of neurophysiology, clinical physiology, pathophysiology, and comparative physiology courses. In addition, the related factors affecting the success of teaching veterinary physiology were evaluated. These related factors include integration and alignment, the biochemistry factor and physiology textbook topics.

Ethical approval

The research in this study was conducted according to normal educational practices. It involved comparisons of curricula, instructional techniques, and classroom management. The research received Exempt Status from Institutional Review Board because 1) It did not involve human participants or animals; 2) It did not involve student-related data or records or face-to-face interactions with students. The research was conducted ethically in a way that promotes understanding of educational practices and veterinary curricula in different colleges and schools in the USA and outside the USA using publically available information.

Table 1A. American Veterinary Medical Association-accredited colleges of veterinary medicine in the USA

ALABAMA **Auburn University** College of Veterinary Medicine Auburn University, AL http://www.vetmed.auburn.edu **Tuskegee University** School of Veterinary Medicine Tuskegee, AL http://tuskegee.edu	**ARIZONA** **Midwestern University** College of Veterinary Medicine Glendale, AZ http://www.midwetern.edu
CALIFORNIA **University of California** School of Veterinary Medicine Davis, CA http://www.vetmed.ucdavis.edu **Western University of Health Sciences** College of Veterinary Medicine 309 E Second Street - College Plaza, Pomona, CA http://www.westernu.edu/veterinary	**COLORADO** **Colorado State University** College of Veterinary Medicine and Biomedical Sciences Fort Collins, CO http://www.cvmbs.colostate.edu
FLORIDA **University of Florida** College of Veterinary Medicine, Gainesville, FL http://www.vetmed.ufl.edu	**GEORGIA** **University of Georgia** College of Veterinary Medicine Athens, GA 30602 http://www.vet.uga.edu

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ILLINOIS **University of Illinois** College of Veterinary Medicine, 2001 South Lincoln Avenue Urbana, IL http://www.cvm.uiuc.edu	**INDIANA** **Purdue University** College of Veterinary Medicine, 1240 Lynn Hall West Lafayette, IN http://www.vet.purdue.edu
IOWA **Iowa State University** College of Veterinary Medicine Ames, IA http://www.vetmed.iastate.edu	**KANSAS** **Kansas State University** College of Veterinary Medicine Manhattan, KS http://www.vet.ksu.edu
LOUISIANA **Louisiana State University** School of Veterinary Medicine Baton Rouge, LA http://www.vetmed.lsu.edu	**MASSACHUSETTS** **Tufts University** School of Veterinary Medicine 200 Westboro Road North Grafton, MA http://www.tufts.edu/vet
MICHIGAN **Michigan State University** College of Veterinary Medicine G-100 Veterinary Medical Center, East Lansing, MI http://cvm.msu.edu	**MINNESOTA** **The University of Minnesota** College of Veterinary Medicine St. Paul, MN http://www.cvm.umn.edu
MISSISSIPPI **Mississippi State University** College of Veterinary Medicine Mississippi State, http://www.cvm.msstate.edu	**MISSOURI** **University of Missouri-Columbia** College of Veterinary Medicine Columbia, MO http://www.cvm.missouri.edu
NEW YORK **Cornell University** College of Veterinary Medicine Ithaca, NY http://www.vet.cornell.edu	**NORTH CAROLINA** **North Carolina State University** College of Veterinary Medicine 4700 Hillsborough Street Raleigh, NC 27606 http://www.cvm.ncsu.edu/
OHIO **The Ohio State University** College of Veterinary Medicine 1900 Coffey Road Columbus, OH 43210-1092 http://www.vet.ohio-state.edu	**OKLAHOMA** **Oklahoma State University** College of Veterinary Medicine Stillwater, OK 74078 http://www.cvm.okstate.edu
OREGON **Oregon State University** College of Veterinary Medicine Corvallis, OR http://www.vet.orst.edu	**PENNSYLVANIA** **University of Pennsylvania** School of Veterinary Medicine 3800 Spruce Street Philadelphia, PA 19104-6044 http://www.vet.upenn.edu
TENNESSEE **University of Tennessee** College of Veterinary Medicine 2407 River Drive Knoxville, TN http://www.vet.utk.edu **Lincoln Memorial University** College of Veterinary & Comparative Medicine 6965 Cumberland Gap Pkwy Harrogate, TN http://www.lmunet.edu	**TEXAS** **Texas A&M University** College of Veterinary Medicine & Biomedical Sciences College Station, TX http://www.cvm.tamu.edu
VIRGINIA **Virginia Tech** Virginia-Maryland Regional, College of Veterinary Medicine Blacksburg, VA http://www.vetmed.vt.edu	**WASHINGTON** Washington State University College of Veterinary Medicine Pullman, WA http://www.vetmed.wsu.edu
WISCONSIN **University of Wisconsin-Madison** School of Veterinary Medicine 2015 Linden Drive West Madison, WI http://www.vetmed.wisc.edu	

https://www.avma.org/.../Colleges/Documents/colleges_accredited.pdf ; Last accessed June 20, 2016

Table 1B. Nationally-accredited colleges of veterinary medicine outside the USA

STATES	Colleges of veterinary medicine
MEXICO	**Universidad Nacional Autonoma de México** Facultad de MedicinaVeterinaria y Zootecnia, Coyoacan Web site: http://www.fmvz.unam.mx/
THE NETHERLANDS	**State University of Utrecht** Faculty of Veterinary Medicine Utrecht, Web site: http://www.uu.nl/faculty/veterinarymedicine/en/pages/default.aspx
NEW ZEALAND	**University College of Sciences** Institute of Veterinary, Animal, and Biomedical Sciences Palmerston North http://ivabs.massey.ac.nz/
SCOTLAND	**University of Glasgow** Faculty of Veterinary Medicine Bearsden Road Glasgow G61 1QH www.gla.ac.uk/Acad/FacVet **The University of Edinburgh** Royal Dick School of Veterinary Studies Summer Hall Edinburgh EH9 1QH www.vet.ed.ac.uk
WEST INDIES	**Ross University** School of Veterinary Medicine Basseterre, St. Kitts http://www.rossu.edu/veterinary-school/ **St. George's University** School of Veterinary Medicine Grenada West Indies 800-899-6337 http://www.sgu.edu/school-of-veterinary-medicine/index.html

https://www.avma.org/ProfessionalDevelopment/Education/Accreditation/Colleges/Documents/colleges_accredited.pdf. Last accessed June 20, 2016.

Characteristics of a new generation of veterinary students, and teaching and learning of physiology

New generation of veterinary students

Colleges teach physiology to veterinary students who aspire to become veterinarians capable of providing quality veterinary medical care, or engage in disease diagnosis and research. A question is often asked by instructors: do we really know the characteristics of veterinary students who have the desire to become veterinarians? College and university students, including veterinary students, are changing in parallel with the changing world around them, and this leaves a "generation gap" between faculty and the students. Current veterinary students, who are computer literate, belong to the so-called generation Y, the millennial or global generation, or the "digital natives" as characterized by Prensky (2001). This generation Y is used to the Internet, computer games (deBie and Lipman, 2013), "instant gratification, multitasking, and short focusing periods" (Salisbury, 2008). Oblinger and Oblinger (2005) noted that this "Net (Internet) Generation " possess the following attributes "Ability to integrate the virtual and the physical, learning better through discovery than by being told, rapidly shifting attention, quick responses and expectation of the same quick response; immediacy, social activities in the e-sphere (instant messaging, virtual games, blogging etc.), and needed structuralizing in order to be able to understand the rules". On the other hand, continuing education is important for the practice of veterinary medicine. The spirit of lifelong learning is indispensable to coping with a changing work environment, and the new knowledge that is constantly emerging. For the licensure to practice veterinary medicine in the USA, formal life-long learning is expected. With Continuous Professional Development (CPD), one can keep up with the recent developments in veterinary clinical sciences, improve his/her professional skills, and become a better board certified clinician in a specialty of veterinary medicine. Outside the USA, there are veterinary colleges, such as the Royal College of Veterinary Surgeons, RCVS, UK, that also made CPD obligatory for its members. Recently, computer-based and online resources such as videos, audio presentations, CD-ROMs, and web-based courses, as those provided by Veterinary Information Network, VIN, are increasingly used instead of the traditional methods of instruction (face to face courses, conferences, seminars, journals, textbooks). According to Short et al. (2007), RCVS has developed its own e-CPD model based on a known and effective adult distance learning method that recognizes that several steps are occurring in the learners: "self-motivation and ability to access the material, online socialization, information exchange, knowledge construction, and development". Expectedly, an increasing number of veterinarians will take part in the e-courses for CPD (Short et al., 2007).

In general, veterinary students, especially in developed countries, are highly motivated (Salomäki et al., 2014), committed to being veterinarians, and are ready to utilize their time and resources to earn their degree. However, their motivation can originate from their deep interest in their studies, as well as external factors, such as having a profession and an associated prestigious status in the society, and most importantly an interest in animals. Motivated students tend to achieve high-quality learning, while current study practices might result in superficial/rote learning (Mikkonen and

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Ruohoniemi, 2011). In developing countries, such as those in Africa, most students opt for studying veterinary medicine when their grades are not competitive for their admission into the medical or pharmacy colleges.

Differentiated curricula (tracking) and physiology teaching

By and large veterinary schools in the USA offer differentiated curricula (tracking) so students can learn disciplines that are needed for their chosen career path (i.e. small animals, equine and large animal, mixed practice etc.). Tracking is a common practice that might reduce content overload while increasing students' interest in learning specific topics (Ruohoniemi et al., 2010; Eyre, 2011; Mikkonen and Ruohoniemi, 2011). All students, regardless of their tracks, go through a core curriculum that is required for earning a Doctor of Veterinary Medicine degree (DVM). Tracking requires certain electives. Interestingly, many veterinarians who change their tracks emphasis after graduation and during their career would prefer a more general education (Summerlee, 2010). Tracking choice and change were investigated by the school of veterinary medicine of the University of California, Davis, USA. This investigation documented that, at the time of admission, veterinary school students choose a track primarily based on their previous experience and personal preferences or other factors (Chigerwe et al., 2010). Nevertheless, during veterinary school years, 27.4% of the students changed their track choice. The major causes for that change were: further experience during the first two years of the veterinary school, anticipation of better job opportunities and competitiveness, and personal factors such as interest in veterinary public health, or in different species (Chigerwe et al., 2010).Toward this end, the topics covered physiology courses are not only expected to help a student prepare for his/her core curriculum and selected track, but also support track changes as well.

A balanced coverage of important physiology concepts should provide an overview of the comparative physiology of different species during the first year of the curriculum. Later, additional specialized physiology courses that would serve specific tracks may also be offered as electives or required courses (e.g. avian or pet bird physiology, zoo and wildlife physiology, reptiles, amphibians, fish, and pet rodent physiology, laboratory animal physiology, clinical physiology). Tracks choices generally reflect jobs available in veterinary practices in a given country (i.e. equine, food animal and poultry, large animal, small animal, and exotic and aquatic animals, and wildlife). Generally in most colleges, physiology teaching supports the core curriculum and not the elective courses needed by the tracks. If available, the physiology courses for a particular track should include both the basic physiological concepts as well as physiological concepts that support the track-specific elective courses. For example, a student opting for small animal track would be expected to take the two core physiology courses plus canine and feline physiology and exotic animals or lab animal physiology courses. The elective courses may be taught as clinical physiology courses with emphasis on the track options, for example, clinical physiology of small animals.

Emerging tracks such as exotic or wild animals have recently become very important for the practice of veterinary medicine, and have been attracting students' interests. Learning the physiology of exotic or wild animals can help veterinary students become better veterinarians for the praxis market. These tracks should be taken seriously and should be emphasized in the core subjects. Currently, no such track-related physiology courses exist in most curricula. On the other hand, the new challenges that originate from the One Health/ One Medicine Initiative, which promotes linking human health, animal health and the environment, need to be addressed by designing interrelated tracks so that students could gain knowledge and experience in the ecological, social, and political aspects of veterinary medicine and its relationship to human health and the ecosystem (Chaddock, 2012 and Mor et al., 2013).

New knowledge definitions and the teaching and learning of physiology

Recognizing that veterinary physiology is a continuously evolving interdisciplinary subject that should be taught to a new generation of veterinary students, the question that arises is what to teach the students? Do students need to be taught physiology just for the knowledge sake, or for its application in solving clinical cases or answering research questions? Basically, teaching and facilitated learning should address all of the above points and provide the students with adequate coverage and in depth knowledge of physiology. However, it depends on what knowledge means. The definition of knowledge has undergone a fast evolution in the past decades and is not simply equivalent to learning the subject matter now; it is rather a mixture of factual knowledge, skills, abilities, interdisciplinary approach, and information literacy. The Association of college and research libraries set five IT-literacy requirements (Blumberg, 2005): "determining information needs, acquiring information effectively and efficiently, critically evaluating information and its sources, incorporating selected information into one's knowledge base, and using information legally and ethically." In addition, students should have the following competences: problem-solving, team work, effective communication, ability to assess themselves and their peers, and apply self-directed learning (Lane, 2008). Critical thinking, information management skills, lifelong learning ability and creative thinking have also become indispensable for the practice of veterinary medicine (Forrester, 2006 and Clase et al., 2008). The 2010-2014 strategic plan of the association of American veterinary medical colleges lists among the goals and objectives the following: "Lead efforts to review, evaluate and improve veterinary medical education in order to prepare graduates with the competencies needed to address societal needs" (AVMC, 2009). Therefore, in teaching physiology, it must be recognized that the term "knowledge" is also changing and the classical knowledge and basic literacy may no longer be enough for current and future professionals (Hodgson et al., 2013).

The Pew national veterinary education program report emphasizes that biomedical knowledge should originate from problem solving and information gathering skills instead of a comprehensive knowledge of biomedical facts (Warren and Donnon, 2013). Therefore, the new knowledge model needs a new definition for learning in the 21th century. Pelaez and Gonzalez (2002) summarized learning as a process that requires the following: "critical thinking, the

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evaluation of information, synthesis of ideas, the testing of ideas and data through comparison against pre-existing models, and the development of new models". Teachers in the 21st century, including instructors of physiology in veterinary schools and colleges, must facilitate students-centered learning instead of using teacher-centered instruction (Mayer, 2010).

Ways of teaching and learning

The criticism of classical teaching methods lists the following: preference of lectures for the lecture-based delivery, focusing on facts, lack of problem-solving exercises and small group learning, emphasis on teaching instead of learning (Abrahamson, 1990). However, the famous Confucius quote says "Tell me and I will forget; show me and I may remember; involve me and I will understand". Therefore, teaching that involves students (e.g. interactive learning) is expected to be superior to lecturing at the students. Innovations, conceptual and methodical revolutions in teaching and learning, and responses to criticism are not unique in educational history. As an example, the "chalk and board" method that is nowadays referred to as traditional or obsolete appeared in the mid-1800s in the USA as an innovation in teaching. That new method spread quickly and teachers needed only a short period of time to use it in their teaching (Abrahamson, 1990). As a result, the efficiency and dynamics of teaching then increased rapidly. Today technical changes and inventions offer an opportunity for bigger leap toward increasing learning success and efficiency. Even the idea of the good old chalkboard is not thrown away; but was transformed into the "new" interactive whiteboards (Ragan, 2007). Teaching/learning innovations does not necessarily mean throwing away the old and replacing it by the new. It should focus on what would the best approach and what technology integration is needed that would help students learn.

A question may be asked: what is the result of the classical way of teaching physiology? It was observed that students tend to see physiology as a pile of factual information that only needs cramming/memorizing instead of digestion and utilization for solving problems or clinical cases (Pelaez, 2002). However, rote learning does not provoke meaningful learning (Pelaez, 2002 and Hazel et al., 2013). There are several effects of rote memorization and consequently surface learning such as aimlessness, mere memorization, sticking to the syllabus, and focusing on passing the exam (Ryan et al., 2009).

Learner-cantered teaching

The root of the change to learner-centered-teaching is a shift from teaching-focused pedagogy to a learner-centered andragogy (Pirkelbauer et al., 2008). The role of teachers is no longer viewed as a simple one way of conveying information to students (teacher-centered) but rather facilitation of students' learning and acting as a "partner" in the learning process (Miflin, 2004). However, to make this shift to learner-centered teaching, one should remember that as teachers tend to adhere to their teaching routines, students are often resistant to changing their usual and previously successful learning habits (Pirkelbauer et al., 2008). On the other hand, pre-professional university education has a profound effect on the ability of students to adapt to the professional education environment, such as veterinary medicine, and the learning methods; since they are expected to be successful in a challenging professional (Rutland et al., 2016). It worth mentioning here that before students are accepted in DVM programs in the USA, they have to complete pre-veterinary university education (2-4 years).

Recent findings (Abrahamson, 2007) about learning principles in educational psychology give more "handholds" or guidelines to understanding what critics of the teacher-centered approach mean. These "handholds" are described as follows: "No two people learn in exactly the same way; learning is facilitated by motivation; learning is incentive, therefore, should be based on the true motivation of the learner; incentives work best (i.e., promote true learning) when they are positive not negative; and learning is much more effective if we begin where the learner is, not where we wish he or she were". Acor (2005) noted that the concept of "good teaching practice" was created and could be developed further for quality assessment in teaching in a similar fashion in which "good laboratory practice" has been used in the pharmaceutical industry). Good teaching practice is expected to "encourage student-faculty contact and cooperation among students, and active learning. It gives the learner prompt feedback, emphasizes time on task, transmits what is expected of students, considers talents, and ways of learning. "Kolb's learning cycle also points out the importance of the active and constructive mental participation of students in the learning process" (Buur, 2013). It is also highlighted that active learning takes place if the teaching is student-focused and induces students to consider what they are doing (Keegan et al., 2012).

The goal is meaningful learning

Michael (2004) defined meaningful learning as "learning with understanding". As a result of meaningful learning, students can retrieve previous knowledge, they can combine the previous and new knowledge, and they can solve new tasks and problems based on their knowledge. As for medical (either human or veterinary) students, they must recall and use their basic medical science knowledge in order to become successful in practice. Notably, meaningful learning cannot miss the accumulation of facts and the ability of using them (Michael, 2004). However, the students` previous misconceptions also interfere with successful learning (Pelaez, 2002).

The opposite of the meaningful learning is rote learning, or rote memorization, when students simply memorize facts and new information without trying to integrate them into their previous knowledge (Diwakar et al., 2007). Meaningful learning can help in setting up mental models (Michael, 2004) that resemble concept maps (Newman, 2005). Mental models help with prediction, calculation, and explanation; a reflection of student's understanding. It goes without saying that for meaningful learning to occur, an environment conducive to active learning must be created, where students can collect information, their knowledge can be facilitated, tested and refined, and where they can learn how to

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use the knowledge to solve problems (Michael, 2004). Without these possibilities, a student may seem to be active but will not undergo a meaningful learning process. Last but not least, it is important to note that the learning process occurs exclusively in the learner (Simon, 2001).

To understand the current situation of veterinary physiology education, this study examined the professional veterinary curricula in all accredited USA and in selected non-USA veterinary schools, focusing on veterinary physiology and related subjects. The curricula are at different developmental stages and revisions in order to respond to the new challenges in different ways. However, we are hoping by this analysis to promote veterinary physiology education globally. In addition, since the world's best ranked veterinary medical colleges are found in the USA, comparing USA and non-USA curricula might yield additional ideas and information for improving veterinary physiology teaching and learning.

RESULTS

Veterinary physiology teaching in the USA veterinary schools and colleges

All available USA curricula contained at least one obligatory (core), *solo* or integrated physiology course. If the physiology core is more than one semester long, the courses are either numbered sequentially or named after the sub-topics of physiology (e.g. digestive, renal, respiratory, etc.). Physiology courses were typically offered at the beginning of the professional curriculum between year 1 (Fall/1st semester) and year 3 (Fall/5th semester). Based on the available information, we found that veterinary physiology course credits/credit hours vary between 3 and 12, most commonly 4 credits. Generally, physiology is not a required course in the pre-veterinary curriculum in the USA. However, undergraduate students usually may take human or mammalian physiology offered by a biological sciences or animal science departments. Nevertheless, students taking these pre-veterinary physiology courses might not know how to relate the physiological concepts they learned to veterinary medicine. The impact of pre-veterinary physiology information and any misconception on learning veterinary medical physiology need to be further investigated.

The topics taught in the veterinary physiology courses are highly variable. Some courses cover the classical physiology content, which starts with homeostasis/nervous system/blood/cardiovascular system and ends with reproduction, renal and acid-base balance. Other courses deal with only some topics of interest, such as cardiovascular physiology, while omitting physiology of the integumentary system, bone or the immune system. However, these topics might be included in the pre-veterinary physiology courses or might be included within other subjects, such as anatomy, animal husbandry, cell biology, immunology etc.

Based on the available course descriptions, 85 professional veterinary physiology courses were investigated, from which 51 courses were available with descriptions. Classical topics in these physiology courses were analyzed. Table 2provides a summary of the physiology topics taught in schools and colleges of veterinary medicine in the USA, and the percentages of courses that address a given topic are presented. It is worth mentioning here that, in some cases course descriptions were not available at all; in other cases they were not detailed enough. In horizontally and vertically integrated curricula, the classical physiology topics were merged with those of other courses so they could not be identified clearly. The latter factor produced relatively strong limitations for comparison of course topics and resulted in relatively low percentage ratios.

Table 2. Physiology topics taught in schools of veterinary medicine in the USA and the percentage of courses that address the given topic (Year of the survey, 2014).

Topic	Percentage of courses that included the topic (total number of courses with topics: 51)
Homeostasis	14%
Blood	14%
Immunophysiology	4%
Cardiac Physiology	24%
Circulation	27%
Respiration	25%
Renal Physiology	27%
Gastrointestinal Physiology	27%
Metabolism	10%
Thermoregulation	2%
Bones	8%
Muscle Physiology	27%
Endocrinology	27%
Reproduction	24%
Nervous System	29%
Senses (vision)	8%
Acid Base Balance	6%
Integumentary System	6%

Calculation of percentages were as follows: We added up the number of physiology courses with available topic lists. (Several curricula do not contain the list of topics taught in a course just the title of the course and credit hours.) There were 51 such courses among USA ones. From the 51 courses, 15 courses (that is the 29% of 51) included neurophysiology as a topic. The same way, only one course (that is the 2% of the total 51 courses) included thermoregulation.

The most common classical topics taught in the veterinary physiology courses were: neurophysiology (29%), endocrinology, muscle physiology, gastrointestinal physiology, renal physiology, circulation (27% each), respiration (25%), cardiac physiology (24%), and reproduction (24%). Several physiology courses deal with the blood and homeostasis (14% each). However, metabolism (10%), bone physiology, special senses (8% each), acid base balance (6%), integumentary system (6%), immunophysiology (4%), and thermoregulation (2%) are underrepresented in the USA curricula. Calculation of percentages was done as follows: The number of physiology courses with available topic lists was added up. It worth mentioning here that several curricula do not contain the list of topics taught in a course; they provide just the title of the course and credit hours. There were 51 such courses among USA ones. From the 51 courses, 15 courses (that is the 29% of 51) included neurophysiology as a topic. The same way, only one course (that is the 2% of the total 51 courses) included thermoregulation.

Most schools divide the physiology instruction into separate modules or units, where each one can be completed by passing an exam before moving to the second unit, etc. Some schools offer a set of physiology courses focusing on one or two subtopics of physiology. These courses can usually be taken in parallel. On the other hand, some course topics are offered in pairs such as muscles and bones, kidney and body fluids/acid-base balance, respiration and kidney, cardiac and vascular physiology, digestion and metabolism, homeostasis and blood, endocrinology and reproduction.

Obesity, nutritional, and metabolic disorders are emerging problems in the 21st century not only in human populations but among pet animals as well. The necessity of teaching intermediary metabolism to DVM students, is therefore an urgent issue. Some physiology courses and textbooks have separate chapters on metabolism and/or the regulation of feed intake. However, most of the books do not discuss metabolism. Naturally, metabolism can be taught not only in the frames of physiology instruction, but it can also appear in biochemistry, nutrition, or in endocrinology sections. It may be taught as part of digestive physiology section that deals with nutrients utilization during the absorptive and post absorptive states, as in the case of Purdue University, USA.

Acid-base balance rarely forms a separate chapter in most books, but it is usually mentioned (at least partly) as a part of introduction to homeostasis, kidney function, and respiratory system physiology. Interestingly enough, temperature regulation is the most common small topic taught in physiology courses and mentioned in physiology textbooks. It is hard to understand, however, why such topics as physiology of the bones and the integumentary system are often neglected when skin problems, for example, are most frequent cases seen in patients visiting small animal practices in USA, and in other parts of the world. Moreover, a basic knowledge of these two topics is important for understanding pathology or internal medicine topics. Although the structure of the integumentary system and bones are taught in gross anatomy and histology in details, their physiology is not a part of any of the physiology courses examined.

The immune system might be a part of microbiology or it can also be offered as a separate course. However, this study did not investigate this matter. Nevertheless, white blood cells, innate and acquired immunity are often briefly covered in blood physiology, as in the case of Purdue University, USA. On the other hand, metabolism, thermoregulation, and the physiology of bones would deserve more emphasis in physiology courses because they help students understand basis of nutrition, internal medicine, and animal husbandry, and are helpful to soft tissue and bone surgery. The physiology of special senses and sensation has been treated with benign neglect in physiology courses, and if it appears in the course description, it usually focuses only on vision (table 2). Among the usual physiology topics, the emphasis on reproduction could perhaps be a little bit decreased since it will be dealt with in details in theriogenology. All the other topics, however, are reasonable to be taught. For providing a solid basis for many succeeding courses such as pathology, pharmacology, medicine etc., a physiology course must overview all the main topics.

Sixteen out of the 28 schools in the USA (57%) offer a separate neuro course, such as neuroscience, neurobiology, or neurophysiology, regardless of the topics taught in veterinary physiology. In the USA, neurophysiology courses are not usually offered to make up for lack of coverage of the nervous system's physiology in a veterinary physiology course but rather offered independently to cater for the need to expose the students to neuroscience before they take courses in clinical sciences. As an example, Purdue University carved a credit hour from the freshmen' physiology and another credit hour from another course to create a neuroscience course in order to provide students with a basic understanding of nervous system physiology, functional anatomy, and the basis of neurological diseases. The course is taught by a neurologist in the department of veterinary clinical sciences, with a joint appointment with the department of basic medical sciences. Nervous system physiology does not receive additional coverage in the two mammalian physiology courses taught to DVM students at Purdue University, USA.

A separate pathophysiology course, containing pathophysiological issues such as the biology of disease or pathobiology exists only in six schools (21 %). However, pathophysiology is a very important link between physiology and internal medicine. Alternatively, pathophysiology might be incorporated in the core physiology or pathology course(s) or in integrated courses in order to enhance understanding of clinical correlations. However, this subject should be taught in cooperation with clinicians for the maximal clinical relevance. It could be argued that pathobiology is essentially learnt in case-based learning courses such as the Application and Integration (A&I) courses at Purdue University, USA.

This study could not find any classical comparative physiology courses but some physiology courses have comparative features (most common ruminant, equine, and avian physiology, but one of the courses deals with reproduction, zoo animals and fish as well). Comparative aspects are usually embedded in integrated curricula. Avian physiology and zoo medicine are offered as elective courses in some schools. In one school a "comparative biology of disease" course is offered.

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It was observed that not all (only 36%) physiology courses are coupled with labs, especially wet labs. This is quite interesting since physiology is an experimental subject, and lab work is expected to enhance the understanding of difficult physiological concepts. Indeed, some physiological laboratory classes might appear as a part of laboratory courses of other subjects. Labs may include wet labs, team-based learning exercises, and physical exam as related to physiology, and demonstrations and tutorials. It may utilize, as done at Purdue University, USA, ultrasound and endoscopy.

In spite of the fact that tracking is present in most of the USA veterinary colleges, the authors could not find any signs of tracking in the physiology courses syllabi they examined. Choosing a track might be available option for the students after the first half of their veterinary studies.

Additional physiology topics may also be considered based on the interest of students in emerging tracks or areas of veterinary medical practice or research. New topics, covered in some physiology books, include space physiology, deep-sea diving physiology, exercise physiology, avian physiology, wildlife physiology, etc. Tracking emphasis would be also enhanced by offering separate courses on small animal, large animal, or wildlife physiology, etc. Alternatively, physiology courses can be organized according to species, like horse-, ruminants, swine, poultry physiology, etc. Generally, structuring the physiology courses is a matter of concept that affects the whole institutional/curriculum design. Efforts are being made in system-based teaching or integration of anatomy, physiology, and histology in teaching different topics. Several schools are currently looking at their curriculum and making revisions to better integrate basic sciences topics. Some schools are seriously considering transformative teaching including adopting flipped classroom approach where students have more time for learning through activities in the classrooms. Students read textbooks, assignment, watch lectures online before coming to the classroom and engage in interactive sessions. Problem-Based Learning (PBL), Team-Based Learning (TBL), and Peer Instruction (PI) are approaches that use cases and clinical correlations to promote interactive learning, use of information, and retention of what is learnt.

Problem-based learning: case studies and clinical correlations in teaching veterinary physiology

In some USA veterinary schools such as Cornell University College of Veterinary Medicine and the University of Illinois Urbana-Champaign college of veterinary medicine, physiology (and the basic medical sciences) are embedded in a problem-based learning program, which includes clinical cases which discuss the anatomy and physiology of the organism in context of the case in order to demonstrate the clinical relevance of a concept (Newman, 2005). Such a combination may affect the balanced and in-depth coverage of all the physiology topics, and one might ask whether the integration of clinical examples distract students from basic medical sciences or not? Since Cornell University CVM is a top ranked college, their approach and success might answer the above question. The University of Illinois Urbana-Champaign CVM will be another good candidate to test the effects of the combined program. The results of this integration will take a few years to be evaluated.

The University of California-Davis school of veterinary medicine has recently introduced a new, integrated and comparative curriculum for the class of 2015 and beyond. It ranked among the best three veterinary schools in the USA in previous years. The effect of the introduction of the new curriculum might be seen in several years. The Western University of Health Sciences CVM follows an integrated, problem-based curriculum that comprises of self-directed study, case studies, teamwork within an interdisciplinary environment. The college is not highly ranked, however, it might be due to the fact that it is the youngest accredited USA College of veterinary medicine.

Purdue University has created application and integration courses that present students with clinical cases to help them better understand the physiology, anatomy, histology, pharmacology, pathology, and neuroscience. Basic medical sciences concepts are integrated with clinical aspects to help students solve clinical cases. The cases were designed to follow the materials covered in the basic sciences courses. Cases usually take 2-3 weeks to complete. Students work in groups of seven and each group has a tutor. On the other hand, in the fall's freshmen physiology course at Purdue University, three lab periods (2hrs each) have been, for the last eight years (2007-20015), devoted to an adapted version of TBL. TBL, a form of small group learning, is becoming increasingly popular in different disciplines including medical sciences. The topics addressed in the freshmen's veterinary course TBL sessions are: body fluids and fluid therapy; Neuro Muscular Junctions (NMJ); and associated problems clinical cases related to the pancreas. The class is randomly divided into groups, 7 students each. The format used includes giving students a reading assignment which they study before coming to the TBL session, followed by individual quiz ("Individual Readiness Assurance Test or IRAT"), after that the students, as a group, will take the same quiz("group readiness assurance test or GRAT"). When the quiz answers were discussed, each group will show a colored board with their answers. A discussion may follow each question to make sure the students fully understand the physiology basic concepts. A case will then be presented and students will be asked a question that they will answer as a group. Each group will show their answer and discussions will follow. Each case may have four to five questions, and each TBL session may have more than one case. The latter part is called application exercise. In addition, before presenting a fluid therapy case, students will have on their table samples of all types of replacement and maintenance fluids, and potassium used in the school's veterinary hospital. The session will jointly be presented by a physiologist and a clinician. Critical care clinicians are the ones involved in the fluid therapy TBL session, while a neurologist is involved in the NMJ TBL session, and the clinical pathologist is involved in the pancreas TBL session. At the end of each TBL session, students will individually fill an evaluation form. The evaluation requests the assessment of the reading assignment, the quizzes, the case presentation and its questions, as well as working as a group and the individual's contribution to the group. The lab grade is an average of their scores in the individual and group quizzes, the application exercises, and completing the evaluation form. In addition to TBL sessions, there are regular wet labs, and ultrasound demonstration of motility of stomach and intestines, and internal organs. An

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endoscopy of the normal equine gastrointestinal track (with emphasis on the esophagus, stomach and duodenum) is organized and videotapes of clinical cases are presented and discussed.

Veterinary physiology teaching in non-USA veterinary schools

Based on the latest rankings of universities, sixteen non-USA veterinary schools representing all continents (Table 3). Data were collected from the national language or English version of the selected accredited veterinary schools` public websites (American Association of Veterinary Medical Colleges, 2009). Some schools do not provide full or any public information on their professional curriculum or their course contents, just like several schools in the USA. This has resulted in certain limitations during the examination of physiology courses. The authors are aware of the fact that there are considerable structural and organizational differences between the educational systems in the USA and in other countries. However, the Bologna process that resulted in agreements between European countries has enforced that at least the educational structure (BSc–MSc–PhD pyramid) must be similar within the European Union. Nevertheless, it is believed that factors such as topics, credit hours, signs of tracking, presence or absence of neurophysiology, clinical physiology, pathophysiology, and comparative physiology courses, are independent from the above differences. In other words, the study has selected some detached features of the curricula but did not evaluate them as a part of the whole educational system.

All available non-USA curricula contained at least one obligatory (required, core) physiology course. If the physiology course is more than one semester long, the courses are either listed sequentially or named after the sub-topics of physiology. Physiology courses were offered at the beginning of the professional (DVM/BVMS/BSC-Vet/BVM) curriculum, between year 1 Fall/1st semester and year three Spring/6th semester. The course credits/credit hours vary between three and eighteen (most commonly three or eight). The topics of the courses are highly variable. Some courses cover the classical physiology content, while others deal with only some subtopics such as homeostasis, physiology of reproduction and lactation, or the physiology of productive processes. However, this might depend on the prerequisite pre-veterinary physiology courses completed before the student was admitted to a veterinary program in Australia or UK where the educational structure is similar to that in the USA.

Table 3. Selected Veterinary Medicine Schools in different continents that display curriculum on their public websites

Continent	Veterinary School (College or Faculty)
Africa	Cairo University Faculty of Veterinary Medicine, Cairo, Egypt+ University of Cape Town Faculty of Veterinary Science, cape Town, South Africa*
Asia	Bombay Veterinary College Mumbai, Mumbai, India* National Taiwan University School of Veterinary Medicine, Taipei, Taiwan+ Peking University, Peking, China+ University of Tokyo, Graduate School of Agricultural and Life Sciences Veterinary Medical Science/Animal Resource Science, Tokyo, Japan+
Central and South America	National Autonomous University, Mexico City, Mexico* University of Buenos Aires Faculty of Veterinary Sciences, Buenos Aires, Argentina* University of Chile Faculty of Veterinary Sciences and Livestock, Santiago de Chile, Chile* University of Sao Paulo Faculty of Veterinary Medicine and Zootechnics, Sao Paulo, Brasil*
Australia and Oceania	University of Sydney Faculty of Veterinary Science, Sydney, Australia*
Europe	University of Veterinary Medicine, Budapest, Hungary* University of Cambridge Veterinary School Department of Veterinary Medicine, Cambridge, UK* University of Glasgow Faculty of Veterinary Medicine, Glasgow, UK* University of Veterinary Medicine, Hannover, Germany* Utrecht University Faculty of Veterinary Medicine, Utrecht, The Netherlands+

*The national language version of the school's website was investigated; + The English version of the school's website was investigated.

The study investigated what classical topics these physiology curricula cover. Altogether 31 courses were reviewed, of which 26 courses were given with their description (Table 4).From table4 that presents the physiology topics taught in schools/colleges of veterinary medicine outside the USA, and the percentage of courses that address the given topic, the following observations could be made. The most common topics taught are neurophysiology (50%), circulation, reproduction, (42% each), cardiac physiology, respiration, renal physiology, gastrointestinal physiology, endocrinology (35% each), homeostasis, and muscle physiology (31% each). Several physiology courses deal with thermoregulation (23%), blood, metabolism (19%), senses (15%), and acid base balance (12%). Immunophysiology, bone physiology, and the integumentary system appears in the 8% of the available course topic.

Some schools offer unique topics as a part of their core physiology course such as exercise physiology, body growth, physiology of meat, wool and fur production, physiology of milk production, and physiology of behavior in domestic animals. Only one school (6%) offers a separate neurophysiology course (the curriculum is not detailed enough

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so authors do not know whether neurophysiology is a topic in the regular physiology courses in that school). Immunophysiology might be a part of microbiology or the immunology course, or is offered as a separate course. The topics of non-USA physiology courses are more inclusive than those in the USA veterinary schools. Interestingly acid-base balance, metabolism, and thermoregulation are more emphasized in non-USA veterinary schools than in the USA ones. However, USA curricula might incorporate the above topics in other subjects, (e.g. acid-base balance issues might be a part of kidney physiology). It must be remembered that, in contrast to non-USA colleges, USA colleges and schools teach veterinary medical sciences and graduates earn a DVM. A pre-veterinary curriculum is covered in 2-4 years before students are admitted into the DVM program. Therefore, it would be interesting to know that the topics not covered in the DVM physiology courses are not usually covered in the pre-veterinary courses.

In non-USA colleges, the vast majority (92%) of physiology courses are coupled with wet labs as opposed to USA-ones. Laboratory work, however, can enhance understanding of major physiological concepts. As one of our Hungarian students commented on physiology teaching at the university of veterinary medicine, Budapest, Hungary that well-structured and on-line lecture materials make possible learning physiology at home, even without the face to face lectures. However, authors believe, neither lectures nor labs should be thrown away but rather lecture time should be used more creatively for interactive learning such as peer instruction or TBL. Physiology labs are better platforms for building concepts, showing clinical correlations, offering hands-on experiences, and stimulating active learning than classical lectures alone. Similarto USA physiology courses, there are no signs of track-serving physiology courses innon-USA courses. In addition, no core clinical or comparative physiology subjects exist in the investigated and available veterinary curricula neither in USA nor in non-USA colleges.

Separate pathophysiology courses containing pathophysiological issues exist in two (13%) schools outside the USA. From a European perspective, it appears that the US veterinary schools and colleges have more interdisciplinary inclination (e.g. integrating clinical and basic courses) and less coordination (aligning courses, vertical and horizontal integration) in their curriculum. The non-US schools investigated, on the other hand, offer rather classical curricula, where marked distinction can be found between basic, preclinical, and clinical courses. There are only two institutions (University of Cambridge, Cambridge veterinary school, department of veterinary medicine, Cambridge, UK, and University of Sydney, faculty of veterinary science, Sydney, Australia) among the non-USA schools investigated that show certain similarity to the US integrated system. A possible reason for that perhaps is the Anglo-Saxon character of both systems.

However, taking into account the results of university ranking, we must admit that such an integrated curriculum offered by USA veterinary schools are worth consideration by non-USA schools and colleges.

Table 4. Physiology topics taught in schools of veterinary medicine outside the USA and the percentage of courses that address the topic in the veterinary curriculum.

Topic	Percentage of courses that include the topic (total number of courses with topics: 26)
Homeostasis	31%
Blood	19%
Immunophysiology	8%
Cardiac Physiology	35%
Circulation	42%
Respiration	35%
Renal Physiology	35%
Gastrointestinal Physiology	35%
Metabolism	19%
Thermoregulation	23%
Bones	8%
Muscle Physiology	31%
Endocrinology	35%
Reproduction	42%
Nervous System	50%
Senses (vision)	15%
Acid Base Balance	12%
Integumentary System	8%

Calculation of percentages were as follows: We added up the number of physiology courses with available topic lists. (Several curricula do not contain the list of topics taught in a course just the title of the course and credit hours.) There were 51 such courses among USA ones. From the 51 courses, 15 courses (that is the 29% of 51) included neurophysiology as a topic. The same way, only one course (that is the 2% of the total 51 courses) included thermoregulation.

Central European experience (the Budapest example)

The University of Veterinary Medicine, Budapest in Hungary is one of the oldest veterinary schools in Europe following primarily conservative, continental European traditions with a quite rigorous and rigid curriculum offered to the veterinary students. It does not provide possibility for case-based learning in the first four semesters. Instruction begins with solid basic science courses throughout the first two years, followed by preclinical and clinical subjects. One of the reasons is the genuine structural difference between the continental European and the Anglo-Saxon higher

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education prior to the Bologna process and the structure that recently being introduced in Europe. It means that veterinary students start their university education right after they graduate in high school because there is no pre-veterinary requirement before a student starts veterinary studies. Therefore, clinical studies must be introduced in the first semesters when teaching basic courses such as Chemistry, Biochemistry, Physics etc.. This makes the foundational courses in basic sciences curricula rather crucial. In addition, the quite traditional primarily classroom-based teaching methods, and the oral exams which are almost exclusively required, create an atmosphere with very little interaction and flexibility. Students, on the other hand, frequently demand getting involved in clinical aspects as early as possible, while the faculty teaching physiology and other basic subjects has very little or no clinical experience. Integration of PBL in basic sciences to provide meaningful learning is yet to be established. The department of physiology and biochemistry currently provides a two semester-long veterinary physiology course based on a comprehensive curriculum that presents the physiology of each organ system in details (including physiology of the nervous system). The physiology course that two of the authors taught for years in Hungary consists of theoretical and practical parts, 2×2 hours lecture and 1.5 hours laboratory session in a week. Animal experiments are no longer the backbone of the laboratories as the practical classes they are supplemented by computer-based learning in Hungary.

Related factors affecting the success of teaching veterinary physiology

When addressing the issue of facilitating meaningful learning of veterinary physiology, related factors affecting the learning success must be considered. Some of these factors, such as integration and alignment, availability of biochemistry courses in the veterinary curriculum, physiology textbook contents, and teaching platforms, are important to consider.

Integration and alignment

To relay on students' previous knowledge as a foundation for learning physiology, the first step is to know and harmonize the topics and materials of prerequisite subjects with that covered in physiology to avoid unnecessary repetitions and contradictions, and to find out the topics that have not previously been covered. Then by highlighting the contact points between the physiology material and those previous subjects, students could be helped to retrieve what they have learned earlier, and gaps in their knowledge base could be revealed. This integration should be done very watchfully because it can easily break down the thread of logic within the material covered and students would end up in a hardly understandable mixture of contents. However, the advantage of this integration process is that students can flourish in a single learning environment.

Alignment, as well as integration, is highly dependent on the institutional structure and interest and willingness of the faculty. If the departments/units are organized according to the classical basic subjects, a very strong and well-coordinated interdepartmental cooperation can be achieved. The major subjects that can be aligned and/or integrated with physiology are: anatomy, histology, and animal husbandry. For explaining clinical correlations, pathophysiology, clinical pathology, pharmacology, and internal medicine can also be partially incorporated, at least in cased-based learning modules.

The biochemistry factor

In the USA, biochemistry is almost exclusively taught in pre-veterinary programs. However, this study could identify only seven of USA veterinary schools that have biochemistry, physiological chemistry, nutritional chemistry, and animal physiological chemistry courses in their professional curriculum. Biochemistry has been pushed out of the DVM curriculum into the pre-veterinary curriculum to make room for new courses (e.g. Integration and application or neuroscience as in the case of Purdue University, USA). This is quite interesting since knowing and understanding the biochemical processes are indispensable for understanding the majority of physiological concepts. DVM students often struggle to recall and adapt what they learned in general biochemistry courses, which include plant and animal biochemistry, to understanding mammalian biochemistry and physiology concepts. On the other hand, in 13 (81%) of non-USA universities, biochemistry is included in the veterinary curriculum. In the USA DVM professional curricula. Biochemistry courses reviewed focus on the basic biochemical structures and mechanisms and intermediary metabolism. Non-USA veterinary biochemistry courses have a much wider scope, spanning homeostasis, enzymes, ribonucleotides, intermediary metabolism, DNA and gene expression, metabolism of ruminants, and vitamins. At the University of Veterinary Medicine, Budapest, Hungary, veterinary students learning basic biochemistry have two semesters to develop a solid foundation for further studies in pharmacology, toxicology, and animal nutrition.

Physiology textbook topics

Physiology materials are traditionally textbook-based although electronic materials are becoming more and more available as well. The authors, however, believe that it is important to compare the contents of the most-known and available textbooks required in the physiology courses. This study investigated the contents of 7 commercial, widely used physiology textbooks (Colville and Bassert 2002; Sjastaad et al., 2003; Berne et al., 2004; Reece, 2004; Reece, 2005; Cunningham and Klein, 2007 and Hall, 2010) written in English (Table 5A, 5B, and 5C).The order of topics within each textbook is not the same and the depth of coverage of different chapters vary. Chapters included: Introduction, cellular, molecular, and chemical bases of physiological function, and the nervous system are usually discussed in the first chapters. However, some books put muscle, blood, respiratory system, kidneys, acid-base regulation, membrane physiology, and body fluids in the first or second chapter. In the middle of the book, cardiovascular physiology is found in most of the books (5 out 7 books, 71%). Among the last chapters, endocrinology

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(in 2 books, 29%), reproduction, clinical correlations, thermoregulation, biogenesis and growth, neuromuscular system, avian anatomy and physiology are found.

Table 5A. Topics covered by seven veterinary textbooks widely used in the world

Sections/units (from all books)	**Cunningham JG and Klein BG (eds.).Text book of Veterinary Physiology, 4th edition (11 sections)**	**Hall JE (ed.) Guyton and Hall Textbook of Medical Physiology, 12th edition (15 sections)**	**Berne RM, Levy MN, Koeppen BM and Stanton BA (eds.). Berne and Levy Physiology, 5th edition (8 sections)**
Basic Chemistry and Physics	–	–	–
Cells and Tissues	X (1)	X (1)	X (1)
The Nervous System	X (2)	X (2, 9, 10, 11)	X (2)
The Senses	–	X (9, 10)	–
The Endocrine System	X (5)	X (14)	X (8)
Bone Tissue and Mineral Metabolism	–	–	–
Muscles	–	X (2, 11)	X (3)
Blood and its Function	–	X (6)	–
Immunology	X (10)	X (6)	–
The Cardiovascular System	X (3)	X (3, 4)	X (4)
The Respiratory System	X (8)	X (7)	X (5)
The Kidneys and the Urinary Tract	X (7)	X (5)	X (7)
Acid-Base Regulation	–	–	–
The Digestive System	X (4)	X (12)	X (6)
Metabolism of Carbohydrates, Proteins, and Lipids	X (4)	X (15)	–
The Skin	–	–	–
Regulation of Body Temperature	–	X (15)	–
Reproduction	X (6)	X (14)	–
Lactation	X (6)	–	–
Biogenesis and Growth	–	–	–
Homeostasis	X (9)	–	–
Clinical Correlations	X (11)	–	–
Introduction to Physiology	–	X (1)	–
Membrane Physiology	–	X (2)	–
Body Fluids	–	X (5)	–
Blood Coagulation		X (6)	–
Aviation, Space, and Deep-Sea Diving Physiology	–	X (8)	–
Sports Physiology	–	X (13)	–
Joints and Synovial Fluid	–	–	–
Lymph	–	–	–
Avian Anatomy and Physiology	–	–	–

X: indicates the presence of the section/unit; (number): indicates number of chapter that deals with the section/unit

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Table 5B. Topics covered by seven veterinary textbooks widely used in the world.

Sections/units (from all books)	**Sjastaad OV, Hove K and Sand O. Physiology of Domestic Animals, 1st edition (20 sections)**	**Reece WO (ed.). Duke's Physiology of Domestic Animals, 12th edition (6 sections)**
Basic Chemistry and Physics	X (1)	–
Cells and Tissues	X (2)	–
The Nervous System	X (3)	X (6)
The Senses	X (4)	X (6)
The Endocrine System	X (5)	X (5)
Bone Tissue and Mineral Metabolism	X (6)	–
Muscles	X (7)	X (6)
Blood and its Function	X (8)	X (1)
Immunology	X (9)	–
The Cardiovascular System	X (10)	X (3)
The Respiratory System	X (11)	X (2)
The Kidneys and the Urinary Tract	X (12)	X (2)
Acid-Base Regulation	X (13)	X (2)
The Digestive System	X (14)	X (4)
Metabolism of Carbohydrates, Proteins, and Lipids	X (15)	X (4)
The Skin	X (16)	–
Regulation of Body Temperature	X (17)	X (6)
Reproduction	X (18)	X (5)
Lactation	X (19)	X (5)
Biogenesis and Growth	X (20)	–
Homeostasis	–	–
Clinical Correlations	–	–
Introduction to Physiology	–	–
Membrane Physiology	–	–
Body Fluids	–	X (1)
Blood Coagulation	–	–
Aviation, Space, and Deep-Sea Diving Physiology	–	–
Sports Physiology	–	–
Joints and Synovial Fluid	–	–
Lymph	–	–
Avian Anatomy and Physiology	–	–

X: indicates the presence of the section/unit; (number): indicates number of chapter that deals with the section/unit

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Table 5C. Topics covered by seven veterinary textbooks widely used in the world

Sections/units (from all books)	Reece WO. Functional Anatomy and Physiology of Domestic Animals. 3rd edition (16 sections)	Colville T and Bassert JM (eds.).Clinical Anatomy and Physiology for Veterinary Technicians. 21st edition (16 sections)
Basic Chemistry and Physics	–	–
Cells and Tissues	–	X (2, 3)
The Nervous System	X (4)	X (6)
The Senses	X (5)	X (12)
The Endocrine System	X (16)	X (13)
Bone Tissue and Mineral Metabolism	X (6)	X (4)
Muscles	X (7)	X (11)
Blood and its Function	X (3)	X (8)
Immunology	–	X (8)
The Cardiovascular System	X (8)	X (7)
The Respiratory System	X (9)	X (9)
The Kidneys and the Urinary Tract	X (10)	X (14)
Acid-Base Regulation	–	–
The Digestive System	X (11)	X (10)
Metabolism of Carbohydrates, Proteins, and Lipids	–	–
The Skin	–	X (5)
Regulation of Body Temperature	X (12)	–
Reproduction	X (13, 14)	X (15)
Lactation	X (15)	–
Biogenesis and Growth	–	–
Homeostasis	–	–
Clinical Correlations	–	–
Introduction to Physiology	X (1)	X (1)
Membrane Physiology	–	–
Body Fluids	X (2)	–
Blood Coagulation	–	–
Aviation, Space, and Deep-Sea Diving Physiology	–	–
Sports Physiology	–	–
Joints and Synovial Fluid	X (6)	–
Lymph	–	X (8)
Avian Anatomy and Physiology	–	X (16)

X: indicates the presence of the section/unit; (number): indicates number of chapter that deals with the section/unit

DISCUSSION

Physiology teaching platforms

The traditional ways of teaching physiology are lectures and practical classes (physiology labs). Physiology laboratories are also called laboratory-based practical classes. These practical classes are designed to illustrate the theoretical concepts covered in lectures. Labs are relatively expensive to run due to the high costs of reagents and other materials, and the high staff to student ratio (Ryan et al., 2009). Another serious concern is the use of live animals in physiology labs and the invasive experiments that have been conducted. Wet labs that involve sacrificing rats, guinea pigs or rabbits are significantly being reduced. Yet hands-on experience is indispensable to improve learning outcomes (Salomäki et al., 2014).

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Although traditional lectures are widely used in teaching physiology (Keegan et al., 2012; Warren and Donnon, 2013), interactive classrooms are being recognized as important tools for meaningful learning. Interactive classrooms reflect the dynamic interaction characteristic of clinic training and related work. It has a positive impact on the students` thinking, problem-solving skills, and motivation (Brown, 2004). The characteristics of an interactive classroom, according to Brown (2004) are summarized as follows: “Students are attentive and intellectually committed to the lecture; students ask questions frequently; the lecturer tries to motivate the students and make them reach their maximum potential but expects excellence; students often prepare for the lecture in advance; students answer the lecturer’s questions freely and thoughtfully; students are expected to attend the class and to arrive on time; students must have willingness for learning; constructive criticism appears on both sides; students often ask for additional material and more challenge; veterinary medicine focused concepts and principles have a privilege over details; exams are challenging and relatively difficult, including so-called open-ended questions such as essays; students may obtain old exams and asking the students for posing questions at the end of a lecture.”

Since a course must suit the Instructional Design (ID) of the school’s curriculum, changing teaching strategies within a course cannot be done without changing/reforming the school’s ID and curriculum expected outcomes. However, there are ways to engage students even in a traditional classroom. This includes flipped classroom learning activities, and Peer Instruction (PI). In these two learning strategies students study the lecture material at home and come to school for engaging sessions focused on applications and solving problems. Students usually work in groups as small as two students per group as in PI. In PI, students try first to answer the question alone, select the answer and send using clickers. If < 70% of the students answer correctly, then the student discusses the question with his/her peer and agrees on and answer and votes again. More weight in the grades is given to the peers answers.

The very diverse composition of veterinary professional curricula and the recent curricular reforms makes curricula and courses almost incomparable. Our results have their limitations. However, we believe that this study succeeded in revealing the main trends, and provided a good overview that may help in future comparisons.

Instructional design

According to Reagan (2007), Instructional design (ID) is the "arrangement of learning events within an educational context"[)], in other words, ID is about "how to help people learn"(Mayer, 2010), while decreasing "extraneous cognitive load" (Khalil et al., 2010). ID can either refer to the developmental process of a course or the organization of a learning event. Teaching faculty who has face to face classroom activities are already applying ID. However, in an online educational environment, there are no ready and consistent teaching protocols. Nevertheless, ID can take place on various platforms, and can start with PowerPoint slides made available on the institutional web sites. PowerPoint is good for including both text and pictures; however, it is not practical for presenting multimedia elements. The website can be designed using HTM or Java languages; however, these require more IT skills. Therefore, the learning or course management systems (Blackboard, Moodle, WebCT, Angel, Desire to Learn etc.) are increasingly used for online instruction ((Bernardo and Malinowski, 2005; Ragan, 2007). On the other hand, we must not forget about social media that has got key role in the life of the millennial generation (Coe et al., 2012). The use of social media in teaching on a Facebook group model was investigated (Kustritz, 2013). Ragan (2007) found that ID has a leading role in the so-called learning effect and the usefulness of incorporating social media in teaching.

Teaching faculty must, therefore, focus on the five primary elements of a teaching and learning: “how content is delivered, how instruction of that content occurs, the role of interactions and communications between class participants, student activities, and evaluation and assessment strategies" (Ragan, 2007). In addition, faculty must avoid the common pitfalls of e-learning and the interesting IDs that some online courses use that tend not to contribute to learning. Bogert et al. (2016) reported that although satisfaction of veterinary students increased with interactive learning their performance in cranial nerves anatomy exams decreased.

Understandably, several teaching tools can be applied in an ID for online courses: synchronous meetings, document sharing, participant video imaging, voiceover internet protocol, group collaboration software, virtual office hours, etc. Ragan, 2007). It goes without saying that, for a successful ID, the natural abilities of the students should also be known and considered. The vast majority of veterinary students use his/her design memory as a primary learning channel while tonal (voice) learning is the least preferred one (Brown et al., 2011). At the North Carolina State university college of veterinary medicine, the learning style of a cohort of 150 veterinary students was investigated; and it was concluded that veterinary students were similar in their learning styles to engineering and health sciences students (Neel and Grindem, 2010).

Practical classes (laboratory sections)

Physiology practical classes play an important role in the successful teaching and learning. Pre-clinical veterinary education surveys revealed a positive correlation between deep learning strategies and the application of practical classes. On the contrary, a negative correlation was found between practical teaching and surface learning (Ryan et al., 2009).

During a laboratory class, unexpected results are obtained and their evaluation mimics real science (Pelaez and Gonzalez, 2002). Practical classes can encourage discovery, critical thinking, and scientific reasoning. The national research committee’s BIO2010 report noted that "Students should be taught the way scientists think about the world and how they analyze a scientific problem in particular"(Clase et al., 2008). This enhances another important skill which is scientific literacy (Pelaez and Gonzalez, 2002).When the national research council’s committee on high school labs allocated the desirable goals of a typical instructional lab, Clase et al. (2008) believe that these goals can also apply to

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veterinary medical education, and to physiology learning in particular: Development of interest in the science of living things and in learning it, the mastery of subject matter, development of scientific reasoning skills and familiarity with how to design experiments, ability to collect and analyze data, the development of teamwork competences, and recognition of the mechanisms of how the complex systems body work. In addition, Clase et al. (2008) found that good undergraduate research laboratories have a several positive outcomes including as increasing interest in opting for a research career and to start graduate studies, increased science knowledge, and acquisition of hands on experiences and ability to work cooperatively in a team, and the motivation to dig deeper in the scientific phenomenon and increase one's understanding of scientific principles. It would be interesting to evaluate the relationship between physiology laboratory practicals and clinical/research skills of veterinary graduates.

CONCLUSION

Although all curricula teach physiology, physiology teaching vary among institutions in the USA and outside the USA. Instructors in veterinary schools and colleges in USA and outside the USA are faced with the dilemma whether they should teach physiology to provide factual knowledge or facilitate its learning by their students. To get a better perspective, the above dichotomy in teaching physiology should be looked at globally. The rather traditional institutions still argue about the necessity of classroom-based teaching based on extensive factual knowledge, while others are introducing different ways to facilitate meaningful learning, where student/faculty interaction and the use of technology receives more emphasis. Another school may prefer passing knowledge to students (knowledge transfer) as a process that would help in adding to existing knowledge and retention of information. Without arguing on the superiority of one over the other, one must realize that rapidly changing IT and students' attitudes towards technology cannot be ignored. Moreover, the globally available advantages of the latest high-tech developments should become an integral part of knowledge providing institutions, and the knowledge transfer process. This certainly requires a paradigm shift in academia. While applying the results of new technology in higher education does not necessarily mean a higher quality instruction, ignoring these opportunities will certainly put the students of such institutions at an unfavorable situation. Here again, global competition is going to sort out which of the models are worthwhile to follow.

When strategic planning for teaching and learning of the revised curricula is on the table, one must take into consideration that new learning systems must be designed for a generation who is not only IT literate, but almost IT addicted (not in any negative sense). Therefore, any veterinary institution determined to fulfill its mission of serving society through teaching the next generation of professionals must reconsider its relationship with the new technologies, and focus on intensive faculty development as well as on redesigning its curriculum that allows for more engagement of students in the learning process. The globally changing educational environment must be taken into consideration in future strategic planning within knowledge-providing institutions of higher learning, and must evoke intensive, information technology-conscious schools/colleges, and faculty development. While applying the results of new technology in higher education does not necessarily mean a higher quality instruction, ignoring these opportunities will certainly put the students of such institutions in an unfavorable situation. Physiology education can benefit from the new technologies and approaches that would make learning more interactive and fun. Case-based learning, including the use of team-based learning, has been credited for improving learning in medical schools, and can certainly enhance learning in veterinary schools and colleges. The same can be said about peer instruction and the flipped classroom. In addition, the use of e-learning management systems would facilitate the process of learning by making the materials available for students before they come to class, and facilitate online interaction with their peers and with the instructor. Further, aligning and integrating the teaching of basic medical sciences and providing clinical correlations that encourage the application of physiological concepts to solve clinical cases would facilitate students' engagement and would improve their learning and competences.

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Competing interests

The authors declare that there are no significant personnel, professional or financial competing interest that might have influenced the presentation of the results of the study described in this manuscript.

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