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Virtual models for interactive e-learning in Medical Biochemistry

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Abstract

The aim is to produce a collection of own and free virtual models and useful links to Web-sites. Models found illustrate the structure, function and purification of deoxyribonucleic acids (DNA). Selected expensive, complex and dangerous experiments were modeled. Short videos and animations were created as illustrations of real processes. These virtual models cover the techniques for isolation of DNA from cells, the polymerase chain reaction and the steps for direct DNA sequencing. The virtual models and links are useful for self-work, traditional lecture-based and problem-based learning. They are appropriate for regular and distance e-learning in Medical Biochemistry.

Keywords: Medical Biochemistry; recombinant DNA techniques; virtual models.

1. Introduction

Virtual models for e-learning are defined by the European Commission as computer programs that simulate the action of real devices and systems and which, when used by students, help them to improve their theoretical knowledge and practical skills (E-learning Initiative: http://www.elearningeuropa.info/main/index.php?page=home). According to Craig, Sherman, & Will (2009), "virtual reality" is a computer simulation that creates an image of a world that appears to our senses in much the same way we perceive the real world, or "physical" reality. Virtual reality is a medium, by which people can share ideas and experiences. In Biochemistry the term *virtual model* usually includes animations, molecular visualizations and videos, representing real processes, experiments and phenomena. Especially appropriate is their use in representation of dangerous, complex and expensive experiments.

The aim is to create a collection of own and free virtual models as well as useful links to Web-sites with various virtual models for interactive e-learning in Medical Biochemistry in English and Bulgarian. These models better illustrate the theory on structure, functions, purification of deoxyribonucleic acids (DNA), and recombinant DNA techniques in the interactive Medical Biochemistry course (http://biochemistry.orbitel.bg/).

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2. Necessity of virtual models in teaching Medical Biochemistry

The students find difficulty in understanding the structure and function of deoxyribonucleic acids (DNA), as well as processes and mechanisms included in recombinant DNA techniques, since they are generally complex and abstract. Recombinant DNA techniques themselves are expensive and inaccessible for the mass of students.

The virtual models are part of the Medical Biochemistry course, which was designed to ensure implementation of flexible Web-based problem-solving oriented interactive e-learning in Medical Biochemistry. The flexibility is in terms of five sets of dimensions – time, content, entry requirements, instructional approach and resources, and delivery and logistics as proposed by Collis and Moonen (2001).

In Medical Biochemistry virtual models are used worldwide to help understanding and learning of complex molecular structures and visualization of expensive or dangerous experiments. Virtual models also help basic concept reinforcement. In particular, using virtual models of recombinant DNA techniques are very useful to review and reinforce the fundamentals of Biochemistry and Molecular Biology.

Creation of virtual models is in unison with the requirements of the World Global standards in Medical education (2003) for implementation of information and communication technologies (ICT) in teaching, learning and accessing information.

It is also important to point out that from financial point of view restricted budget justifies the use of models, created in prestigious universities with advanced educational centers.

Use of virtual models is important also because the present students at the universities belong to a new generation, born after 1981, the so named net-generation (Prensky, 2001) or digital natives (Koch, Grondal, & Schei, 2009). This generation is unique because they use computer and Internet technology since they were children and they were grown up with digital technologies. The virtual models are relevant to their style of thinking and perception.

Last but not least Bulgarian medical students do not know well English (only 10% speak fluent English). Therefore translation from English into Bulgarian is necessary to allow more effective and efficient use of the models.

3. Free online and offline virtual models and useful links to Web-sites

The following criteria were used for choosing animations from Internet sources: modern content, concise text, clear pronunciation (especially important for those whose mother language is not English), high quality of images, interactivity, different modes of performance, easy to run with at least one of the common browsers.

According to these criteria we have distinguished several important sites to recommend to our students. One of them is the site of McGrow-Hills Companies, Inc. (2009). It contains in chapter 14 the animations: “How nucleotides are added in DNA replication”, “Hershey and Chase Experiment”, “Meselson and Stahl Experiment”, and “Replication Fork”. Chapter 16 of the same site contains the animations: “Restriction nucleases”, Early Genetic Engineering Experiment”, “Restriction fragment Length Polymorphisms”, “Constructing vaccines”, “Southern Blot”, “cDNA”, “Steps in Cloning a Gene”, “Polymerase Chain Reaction”, and “Microarray”.

The Companion Website of Cooper, & Hausman (2009) contains animations with sound, opened with Internet Explorer. The titles are: “Avery, MacLeod, & McCarty”,”Bacterial Transformation”, “The Central Dogma”, “DNA Mutations”, “HIV Reproduction”, “Restriction Endonucleases”, “Recombinant DNA Molecules”, “Sequencing a DNA Strand”, “Polymerase Chain Reaction”, “Nucleic Acid Hybridization”, “Southern Blotting”, “Monoclonal Antibodies”. The site of Howard-Hughes Medical Institute (2009) contains also very useful animations: “DNA replication (schematic)”, “DNA replication (basic detail)”, “DNA replication (advanced detail)”, “DNA transcription (basic detail)”, “DNA transcription (advanced detail)”, “Translation (basic detail)”, “Translation (advanced detail)”,”DNA packaging”, “Binding blocks of DNA”, “Chargaff’s ratio”, “Coding sequences in DNA”, “Damage to DNA leads to mutation”, “Genetic engineering”, “Human chromosomes”, “Human genome sequencing”, “Paired DNA strands”, “Polimerase chain reaction”, “Sanger method of DNA sequencing”, “Shotgun sequencing”, “Sickle cell anemia”, “Triplet code”, “Watson constructing base pair models”.

The CDs, accompanying prestigious textbooks (Lieberman, & Marks, 2005; Lodish et all, 2008) are also useful.

Using these resources, students see how science, people, ethics and history are interrelated and thus Medical Biochemistry becomes much more interesting, exciting and relevant to research and clinical practice.

4. Modeling of recombinant DNA techniques

Biochemistry understanding, similar to Chemistry understanding, relies on making sense of the invisible and untouchable (Barak, & Hussein-Farraj, 2009) and requires the ability to navigate properly between four levels of understanding: macroscopic, microscopic, symbolic and process levels (Dori, Barak & Adir, 2003). However, research has shown that many students find it difficult to properly link between the different levels of understanding (Dori & Barak, 2001). These difficulties, combined with difficulties in understanding the spatial structures of molecules, obstruct students' ability to solve questions and problems. Barak, & Hussein-Farraj (2009) reported that visual models help students to reach higher level of conceptual understanding and navigation between different levels when using computerized molecular models. Their research showed statistically significant difference between pre- and post-scores for students who studied biochemistry via computerized molecular models either by hands-on manipulation or teacher's demonstration.

To ensure good students' knowledge of laboratory techniques, it is appropriate to use video. Video films show real experiments in authentic environment. Video is one of the most widely used instructional formats (Geber, 1989), due to common availability of recorders and to the instructional medium attributes of television and computers. Three primary forms of video are in wide use in education and training: linear, interactive and distance (Smith, & Ragan, 1999). The laboratory recombinant DNA techniques are expensive and inaccessible for most of the students and for that reason we used video films. We consider video or movies as virtual models because they simulate environment that is distinct from their physical reality – the events occur on the monitor and students or instructors may interact with them whenever, wherever, and however. We have designed these models as interactive form of video because thus users can stop, go back and forward, watch again, and choose specific video fragments. This is not the highest level of interactivity but allows the user to interact with the video.

The movies prepared cover recombinant DNA laboratory techniques and are shown in Table 1:

4.1. Phases of video production

The process of video production consists of three phases – preproduction, production and postproduction.

One particular preproduction technique that is unique to video (and related media such as film) is the use of storyboard script. Video consists of a linear sequence of visuals with an accompanying linear sequence of audio. We have made storyboard script for each video film in the form of a table. The left part of the storyboard script contains sequence of schematic pictures and description of shots. The narrator text, which accompanies it, is situated to the right. The function of the storyboard script is related to the structure of the video itself. The storyboard describes the content and sequence of shots thus representing the instructional concept.

Table 1. Virtual models

Video films	Fragments	Note
1. Isolation of DNA from blood	1.1. Lysis; 1.2. Magnetic separation; 1.3. Washing	With animation Using magnetic separation module
2. Spectrophotometric analysis of DNA, isolated from blood	2.1. Pipetting the sample on the detection surface; 2.2. Measurement	Using nanospectrophotometer
3. Amplification of DNA – Polymerase Chain Reaction (PCR)	3.1. PCR mix preparation; 3.2. PCR apparatus	
4. Electrophoresis of DNA, obtained during PCR	4.1. Preparation of gel; 4.2. Dispending of DNA into gel; 4.3. Electrophoresis; 4.4. Result	Using agarose
5. Direct DNA sequencing	5.1. Washing with ExoSAP;	With animation embedded in video

5.2. PCR with dideoxynucleoside triphosphates (ddNTP); 5.3. Capillary electrophoresis; 5.4. Result

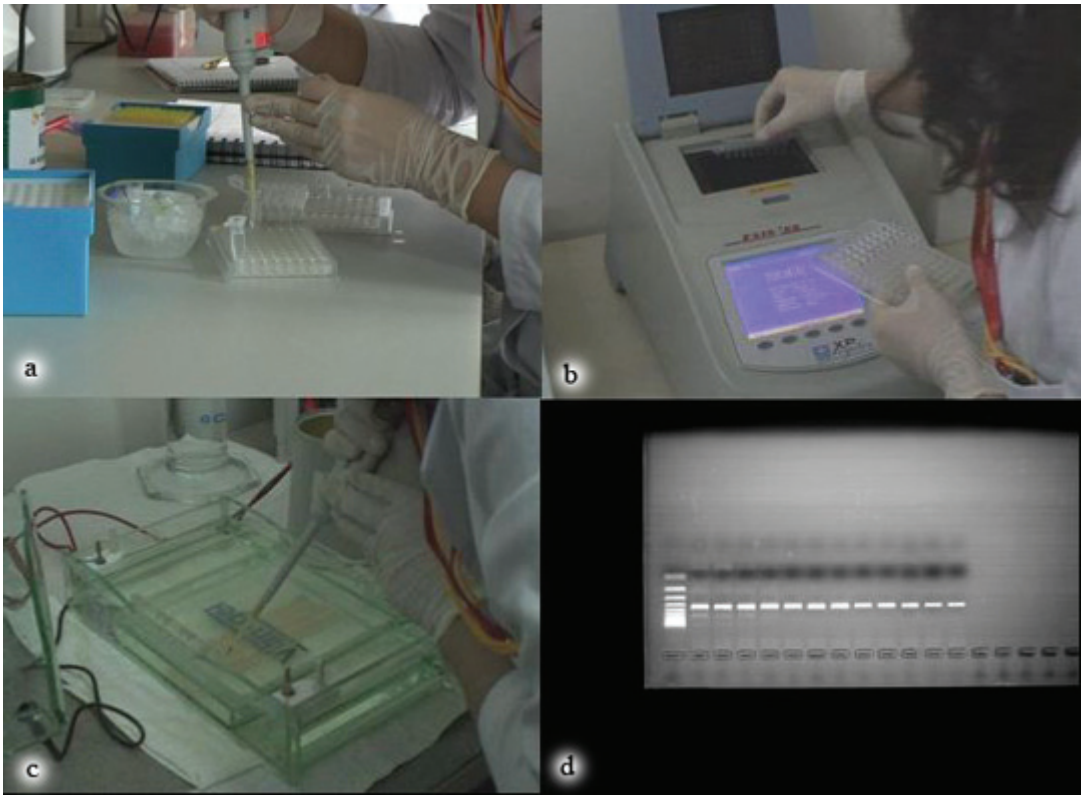

Figure 1. Examples of the videos: a – PCR mix preparation; b – PCR apparatus; c – Dispensing of DNA into gel; d – Electrophoresis result

Production included video recording in compliance with the storyboard script. Video films were created using video camera Sony HDV model HVR-A1E – professional. Specific lighting was used – warm and cool, operating at 500 and 1000 W depending on specific procedures.

Postproduction activities include editing and distribution. We used postproduction editing to assemble segments in order to make necessary adjustments to the audio. Video editing was done through SONY Vegas™Pro 9 – video editing software. The narrator voice, which was recorded separately, was edited in parallel with video editing. Some examples of the video are shown in Fig. 1. Distribution included straightforward process of preparing DVDs, multiplying them and giving to the students. DVD menu allows not just playing a whole movie but selecting and watching different fragments of each film. This interactive interface is better than linear representing of video which may be boring for students.

4.2. Animations

An animation was created using Blender, the free open source 3D content creation suite. The first step is the modelling process. In our case in the animation "Capillary electrophoresis" we have modelled the capillary and the oligonucleotides differing in length. Then the objects created are set in motion: as a result oligonucleotides are moving and arranging according to their length along the capillary. The last nucleotide in every oligonucleotide chain is marked in colour, which signifies the site of radio-labeling. The colour is different for each of the four nucleotides – dideoxyadenosine monophosphate (A), dideoxycytidine monophosphate (C), dideoxyguanosine monophosphate (G), and dideoxythimidin monophosphate (T). The ladder-like array represents from bottom to top

all of the successively longer fragments of the DNA strand. One can determine the sequence of nucleotides from the unlabeled end toward the labelled end (coloured) by reading up the capillary, what is shown in this animation.

Animations are embedded in video films and clarify the processes at micro level.

5. Potentiality of virtual models in Medical Biochemistry education

Teacher can demonstrate virtual models created during traditional lecture in order to present laboratory recombinant DNA techniques. Virtual models can be useful as visual aids during the lecture in creation of problem situation as well as like evidence at the end of the problem situation.

Students can manipulate virtual models at the time when they learn individually, preparing for seminars. It is particularly important for students when they study by hands-on manipulation. If there are questions attached to virtual models, students have to think about them. Students can share their answers with other students and with instructor during the seminar. Implementation and evaluation of virtual models created is our forthcoming work.

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