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Effective teaching of science in an undergraduate course; knowledge, discipline and dedication yield scientists

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Abstract

Effective undergraduate teaching has always been a challenge. In 1987 Chickering & Gamson published the seven principles for good practice in undergraduate education, which was highly used and recommended by most practitioners, yet teaching basic science was still difficult. It is not easy to convey that in science negative results are as important as positive results. In fact, sometimes interpretation and troubleshooting are more important than the experiment itself. In order to make the students feel the importance of science and the importance of every experiment they are doing, the laboratory component of the course was designed as a small project through which they were taught important lessons. Every time an experiment failed, we (instructors) pointed out how it could serve the purpose of the project and how each result, whether positive or negative, leads us to another step and a better understanding of the project's goal. Other than the technical aspects of designing the course, we made sure that there's a strong bond between every student and us without compromising discipline, as it is the way to success and great achievements. Everyone had a talent and a skill that needed to be sculptured to unleash the great scientist –we believe- was in him or her. Our goal was to create an image and to set an example of how a scientist should be; manners, attitude, discipline and perseverance. By the end of the semester, the students were able to interpret, troubleshoot and report the results they collected throughout the whole semester in consolidated reports that mimicked published research papers. More importantly, they learned how to be scientists and they enjoyed learning science.
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Keywords: Effective teaching; undergraduate; developmental biology; differential expression; genotyping.

1. Introduction

It is always a challenge for instructors to provide high quality education, trigger students' enthusiasm and most challenging of all is to ensure qualified graduates. This concern was reduced when Chickering and Gamson published seven principles for good practice in undergraduate education in 1987 (Chickering and Gamson, 1987). The seven principles were based on researches and feedbacks from students and practitioners for many years. According to Chickering and Gamson, the way science is conducted is as important as what is taught. These seven principles are "The encouragement of contact between students and faculty, the Development of reciprocity and the cooperation among students, the encouragement of active learning, giving prompt feedback, emphasizing time on tasks, communicating high expectations, respecting diverse talents and ways of learning" (Chickering and Gamson,

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1987, Codde, 2006, Chickering and Stephen, 1996). Each practitioner applies these principles according to his or her own vision and manipulates them to obtain the maximum required benefits to the students (Chickering and Stephen, 1996). Although some teachers use some of the principles and concentrate on them, Chickering & Gamson recommend and believe that the use of the seven principles combined will provide a synergistic effect. Nowadays, the former principles are being enhanced by using the available upgraded technologies as telecommunications, videos and online conferences (Codde, 2006). Although Chickering & Gamson principles had provided a foundation for good educational practice in undergraduate teaching, yet it is still difficult to teach basic science. What is even harder is to develop scientists that have the ability to address key questions, interpret results, troubleshoot and make the best use of every result they get whether it was positive or negative. In scientific research, negative and positive results are two guides that lights the path of pursuing truth and conquering uncertainty. This was a very important message that needed to be conveyed to every student.

2. Scope of the study

In this article, we as instructors share our experience in designing, teaching, implementing teaching skills and of course learning from a developmental biology course intended for undergraduate course (Gurney, 2007). Our focus will be on the experimental part of the course. It will be narrated in details. Highlights will be made on the problems that were very prominent in specific sections and how they were dealt with. Finally, we'll provide the lessons learned and skills needed to overcome such problems.

3. Materials and methods

The plan for the laboratory activities throughout the semester is illustrated in figure-1. There was no laboratory manual for this course. So, the instructions for each laboratory period were made available for students one week in advance by posting them on the Blackboard system.

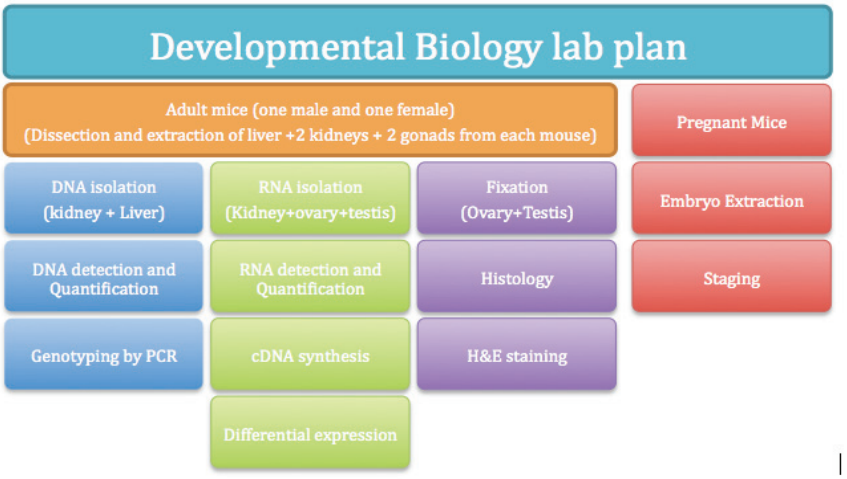


Figure1. Schematic presentation of the laboratory activities and experimental techniques.

3.1. Tissue Harvest

Each student was supplied with two mice; one male and one female. The mice were euthanized by CO_2 asphyxiation followed by cervical dislocation. Different tissues were extracted from the mice for DNA extraction,

RNA extraction and histological examination. Tissues designated for DNA extraction were stored at -20°C while those intended for RNA extraction were stored at -80°C. One gonad of each mouse was processed for histology (washed in 1X PBS and fixed in 4% paraformaldhyde).

3.2. Genomic DNA extraction

DNA extraction was carried out using QIAamp DNA mini kit (Qiagen, Catalogue #: 51304) protocol. The mouse liver and one kidney were processed separately for DNA isolation. To ensure enriched DNA preparation DNase-inactivated RNase (100mg/ml) was added to digest RNA.

3.3. RNA extraction

One gonad (testis/ovary) of each mouse and one kidney were used as a source for RNA extraction. Tissues were incubated with TRIzol reagent (Invitrogen, Catalogue #: 15596-018) following manufacturer's protocol. The RNA pellet developed at the end of the procedure was resuspended in DEPC-treated water.

3.4. Analysis of nucleic acids (DNA and RNA)

DNA and RNA were detected using 1% native and denaturing agarose gel electrophoresis respectively. Students were provided with precast gels and not involved in the preparation of the denaturing gel to avoid inhalation of paraformaldhyde vapours. Nucleic acids quantification was carried out using the Shimadzu UV1800 spectrophotometer. Absorbance (A) was measured at two wavelengths (260 and 280). Good quality nucleic acids have A_{260}/A_{280} ratios between 1.8 and 2. The following formulas were used to obtain the concentration of nucleic acids: (1) The concentration of DNA = A_{260} x Dilution factor x 50. (2) The concentration of RNA = A_{260} x dilution factor x 40

3.5. cDNA synthesis

First strand cDNA was synthesized using the RevertAid first strand cDNA synthesis kit (Fermentas, Catalogue #: K1621). The reaction volume used was 25ul. 1ug of RNA was used as a template. Two negative control reactions were run for each sample; one received no reverse transcriptase while the other had no template. And an in-vitro synthesized *Gapdh* RNA was used as a positive control. The cDNA synthesis was performed in the thermal cycler (Veriti from Applied Biosystems).

3.6. PCR

PCR was used in two instances: genotyping and differential gene expression. For genotyping (sex determination), *Zfy* (zinc finger Y-chromosomal protein) primers were used to amplify DNA sequences present on the Y chromosome only. Another set of primers, *B-actin,* was used to amplify DNA sequences from both male and female DNA preparations. Amplification products using these primers, was used as a positive control for DNA presence. For differential gene expression, we used *Zp3* (Zona pellucida glycoprotein3), *Cobra1* (Cofactor of Brca1) primers and *Gapdh* (Glyceraldehyde-3-phosphate dehydrogenase) as an endogenous house-keeping gene and hence regarded as a positive control for RNA presence and successful cDNA synthesis. The sequence of all primers (5' to 3') used in PCR and RT-PCR methodologies is listed in table-1.

The PCR conditions were adopted from the cDNA synthesis kit (Fermentas, Cat.no : K1621). Annealing temperatures were adjusted for each primer as supplied by the manufacturer. Dream*Taq* polymerase (Fermentas, Cat.no: EP0702) was used to amplify the desired templates.

3.7. Embryo retrieval and staging

Pregnant female mice were purchased from Tudor Bilharz at 11 and 15 days post copulation (E11 & E15). Mice were euthanized as mentioned previously and the uteri were retrieved after dissection of the body cavity and transferred to a petridish containing PBS (Phosphate Buffered Saline) solution. Each female carried four to seven embryos, which were retrieved by teasing the decidua apart following the protocol of isolating post-implantation embryos as stated in "Manipulating the Mouse Embryo" (Nagy A, 2003). The retrieved embryos were washed with cold 1XPBS and viewed under microscope. Embryos were staged based on both fore- and hind limbs' degree of development. At E15 embryos were dissected and gonads were retrieved and visualized under microscope (morphological sex determination).

Table1. Primers used in PCR for genotyping and for differential expression after cDNA synthesis.

Primer	Sequence
Zfy	AAGATAAGCTTACATAATCAC
	CCTATGAAATCCTTTGCTGCA
B-actin	ACGCAGGATTTCCCTCTCAGC
	GGCCCAGAGCAAGAGAGGTAT
Gapdh	ACTCCACTCACGGCAAATTC
	TGTGAGGGAGATGCTCAGTG
Zp3	GACCATGGCGTCAAGCTATT
	GTCTGGACTTCTGCCTGGAG
Cobra1	ACCCCAACACACTTCCTGAG
	CTCTGCAGCTTGGGTAGGAC

3.8. Ovarian and testicular tissue staining with Hematoxylin and Eosin

The fixed ovaries and testis were sectioned and mounted on glass slides in the pathology laboratory at Al-Monofia Liver Institute. Students stained the slides with Hematoxylin and Eosin. The staining procedure included: deparaffinization & hydration of tissue sections followed by Hematoxylin, and Eosin staining before mounting sections into glycerol based medium. The *Deparaffinization and Tissue Sections Hydration* process involved introducing slides into xylene for 10 minutes followed by consecutive dipping in ethanol 100%, 95%, 80% and 70% for 5 minutes each. Then the slides were rinsed with tap water for 5 minutes. Slides were then dipped in Hematoxylin, which stains the nuclei of the cells, for 10 minutes. Excess stain is removed by dipping slides in 0.1% HCl, followed by one dip in 0.1% NH4OH to fix the blue color. The cytoplasm of the cells can be stained by processing the slides through Eosin followed by dehydration in ethanol (100%) + 0.1% acetic acid 5 times.Following that, the slides were soaked twice (5 dips each) in ethanol 100%, acetone 100%. Finally, tissue sections were cleared in xylene 100% jars twice (5 minutes each). A glycerol based mountant was added to each slide and covered by a cover-slip.

4. Designing the course

One of the main objectives of the developmental biology course offered in undergraduate programs of biology is to teach students the importance of basic scientific research. The course was divided into two main parts, 39 hours devoted to lectures, 8 hours of which were dedicated to "Journal Club". Through these sessions, students were

assigned a scientific research paper to present. Students actively learned how to identify a hypothesis in question, what experiments were proposed to answer the question and how the results obtained can be analyzed.

Moreover, they were asked to propose an alternative experiment to answer for the hypothesis and their recommendation for future work to complete this hypothesis. The laboratory part of the course was composed of 36 hours. It was designed as a comprehensive and small project during which students will learn how to interpret their results and how to formulate a conclusion based on these results. We made sure that the students appreciated the significance of the actual results whether being positive or negative, and that negative results are not of less value than positive ones. This allowed them to address the reasons and causes that may have contributed to the false negative result and hence troubleshoot their methodology.

The laboratory project was designed to use different developmental stages and to retrieve mouse tissues from which histological sections were obtained. In addition to that were very prominent in specific sections and how they were dealt with. Finally, we'll provide the lessons learned and skills needed to overcome such problems

5. Results and discussion

5.1. First day at the lab isn't an excuse to be messy!

The project students are working on depended mainly on analyzing and testing morphological, cellular, and genetic differences between males and females. Moreover, the students were supposed to analyze the different expression profiles between organs of the same sex. In order to be fully aware of how experiments are run, students were asked to start their project from scratch. So, the first step was to dissect mice and isolate different organs to be used later for preparing tissue sections as well as DNA and RNA extraction. Each student was supplied with two sacrificed mice (male + female). The liver and one kidney were retrieved from each mouse for DNA extraction while the other kidney and one gonad were carefully handled and directly stored at -80□ for RNA extraction. One gonad from each mouse was fixed and sent for sectioning. The dissection of the mice gave the students real anatomical experience and it was fun for everyone. However, this fun resulted in a lot of movement and noise. It was time for stressing upon the uncompromised rule of the laboratory: *order*.

5.2. DNA extraction, quantification and determination of its integrity and purity

Part of the liver or kidney isolated from both mice was used for DNA extraction. The DNA extraction procedure, obtained from the manufacturer's protocols, depended on using a filter to isolate DNA from other cell contents. Other cellular structures were removed by using Proteinase K and other propriety buffers. RNase was added to digest any remnant RNA molecules that might yield false positive DNA content. Students were encouraged to work in groups and to keep order throughout the lab period. All reagents were supplied to each working station/group in order to avoid chaos. We kept in mind the possibility that when any mistake happens in a working station, the whole group will be affected. So it was very important to have a *back-up plan.* By initially distributing extra reagents and having a reserve, we guaranteed the quick restoration of any lost material. To examine the overall quality and integrity of the DNA preparation students assessed an aliquot of the preparation by agarose gel electrophoresis. This procedure can be also considered semi-quantitative if another intact DNA sample with known concentration is run on the same gel and at the same time. More accurately, the concentration of the extracted DNA was determined spectrophotometrically to evaluate the extraction procedure and to optimize conditions for further experiments. This offered us a chance to stress upon the importance and value of *time***.** Gel electrophoresis required casting of gels to which DNA samples will be applied and subjected to an electric. A genomic DNA running under the influence of a current with 100Volts, as a potential difference, consumes 30 minutes before being detectable. This was considered enough time for preparing the dilution of DNA needed for quantification. The absorbance at 260nm was used to

determine the DNA concentration while that at 280nm was used to determine protein contamination. A_{260}/A_{280} ratios of 1.8-2.0 were considered good and reliable. Table2 is a sample of spectrophotometer absorbance readings.

Table-2: Absorbance of DNA at two different wavelengths (260 nm and 280 nm) and the ratio between the two measurements.

	A260	A280	A260/A280
Sample 1	0.250	0.132	1.908
Sample 2	0.132	0.066	2

This instance illustrated that *time management* is very crucial to fit the designed experiments in the number of lab sessions dedicated for this course. More importantly, it helped us teach undergraduates that time is precious and should be utilized carefully.

5.3. Sex determination using PCR; focusing isn't an option.

To experimentally differentiate between male and female DNA samples, students were asked to amplify the gene *Zfy* located on the Y-chromosome of the male using specific primers that will only anneal to the target DNA of the *Zfy* gene. Aliquots of DNA preparations (from male and female mice) were separated into fresh tubes and given a number before passing them to students. Consequently, students ran the PCR genotyping reaction on both samples without knowing the gender of the mouse from which the samples were obtained. *B-actin* primers were used to amplify a segment of the gene from both samples and the amplification was regarded as a positive control for the presence of DNA and for the accuracy of the procedure. Thus, male samples were supposed to generate an amplicon (give true positive result) with both *Zfy and B-actin,* while female samples would be amplified only with the *B-actin* set of primers. In order to rule out the possibility of negative results due to low DNA yield (poor extraction in the previous lab session) we supplied the students with DNA samples with confirmed quality and quantity. Since every student was preparing six reactions, it was important to prepare a master mix. The mix contained all reagents needed for amplifications and the *Taq* polymerase enzyme but not the primers. The master mix was then divided into two equal aliquots in separate tubes. Each tube received one set of primers (*Zfy or B-actin*). Students then carefully distributed the master mix into three PCR tubes. During the lab exercise, students were continuously asked about the rationale behind every special setting or preparation. Figure 2 shows a sample of true positive and negative results.

PCR is a very powerful and indicative technique yet it is sensitive to the slightest changes. Some students did not get any results (even in positive controls). That day the procedures and precautions spoke for themselves about *focusing and organization.* It was necessary to repeat the lab activities to let everyone master this crucial technique. The lab was repeated and the number of samples and different primers were distributed among the students of the same group. Each working station was divided into two groups of two students. And each group within a working station handled the same samples but different set of primers. Basically every two students were responsible for preparing three PCR tubes; depending on the primers two tubes were intended to test the presence of *B-actin* products or to determine which of the two DNA preparations was contributed by the male mice (*Zfy* gene), while the last one was projected to examine the absence/presence of any cross contamination that may have taken place during the procedure by using water instead of DNA in the PCR reaction. The lab was successful in the second time. Reasons for this success might be less tension, more experience and definitely more focusing since everyone knew the consequences of not paying full attention (Rutherford and Ahlgren, 1991). It may also be attributed to the fact

that each student handled fewer samples in the second time (Rutherford and Ahlgren, 1991). Of course the students learned through this session the importance of *perseverance and insistence.*

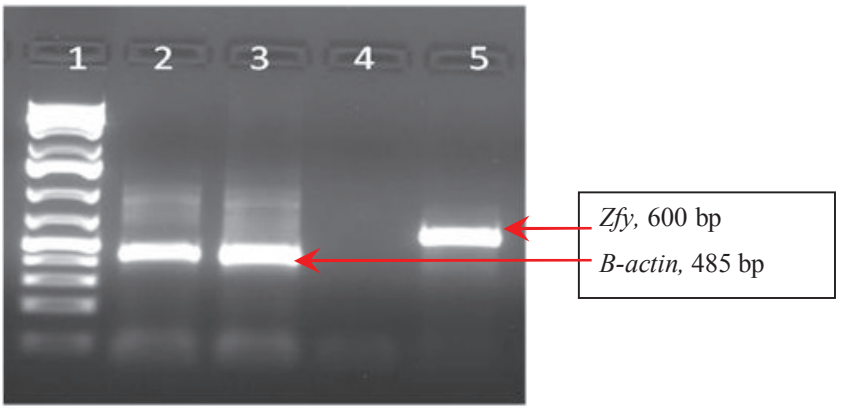


Figure 2: PCR analysis of DNA extracted from mouse kidney samples. From left to right: Lane1 is a 1Kb ladder. Lanes 2 & 3 represent amplification products using *B-actin* primers *(485bp)* in female and male samples respectively. Lane 4 does not show any band indicating absence of *Zfy* expression in female mice. Lane 5 shows a band of nearly 600bp corresponding to that of *Zfy.*

5.4. RNA extraction and differential expression require neat conditions and careful handling

No one can deny that RNA extraction is a challenge for many researchers. It's strange how an extra hydroxyl group can yield RNA very prone to degradation by nucleases when compared to DNA. RNA extraction was carried on different tissues (kidney, testis and ovary). The goal behind extracting RNA was to allow students to appreciate the different contents of transcriptomes of different tissues. This diversity among transcriptomes that are later translated to proteins lead to the development of different tissues. For example, there are certain genes such as those responsible for making the zona pellucida of the egg required for the function of the ovary would be detectable in the expression profile of ovaries but not testes or kidneys. RNA extraction was carried out using TRIzol which is used mainly to destroy all nucleases and to maintain an acidic pH that yields RNA separable in an aqueous medium without co-separation of DNA. Special precautions were made very clear to students when using TRIzol and chloroform because of their hazardous nature. Other experiments needed for detection like preparing paraformaldhyde treated agarose gels for running denaturing gel electrophoresis were only demonstrated and precast gels were supplied for the students' experiments. This step was important to detect the integrity of RNA extracted and to evaluate the possibility of using it in cDNA synthesis. Figure 3 shows an RNA sample with acceptable integrity.

The most challenging aspects of this lab session were handling tissues before adding TRIzol, phase separation and delicate handling of the RNA pellet after precipitation. Synthesizing cDNA was considered an important step. This was to ensure their complete understanding of the "Central dogma" and how exactly are proteins formed. For the abovementioned reasons the two-step rather than one-step RT-PCR was carried out. In addition to these reasons, a 2 steps-procedure would eventually render troubleshooting easier. Using different primers to amplify sets of genes, a profile for each type of tissue reflected their differentiation along a specific lineage and showed how each organ is unique and miraculous. Figure 4 shows a result of differential expression test.

Patience, carefulness, thoughtfulness and dedication to an experiment with such a delicate content and goal were among the important messages sent to the students. We encouraged students to stick to the procedures to get good RNA yield, a result most researchers *awareness* spread among the students about the delicacy needed in this section helped a lot in avoiding any sort of injuries and false negative results (Stipek, 1996).

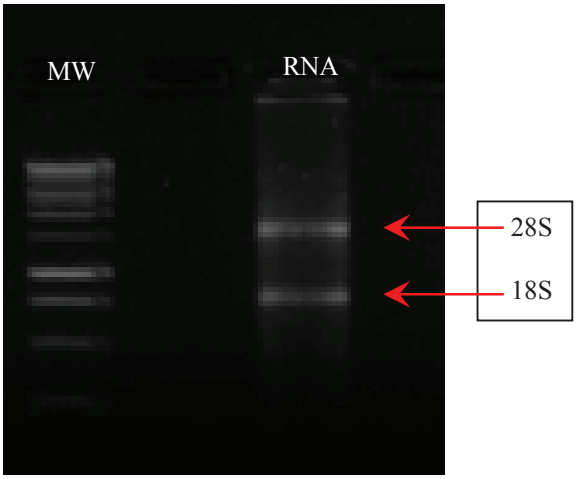


Figure 3: Separation of total RNA on denaturing agarose gel. Intact total RNA is separated into two bands when run on denaturing agarose gel corresponding to rRNA species. The upper band refers to the 28S rRNA and the lower to the 18S rRNA. Integrity is reflected by the fact that 28S band is nearly double the intensity of the 18S band.

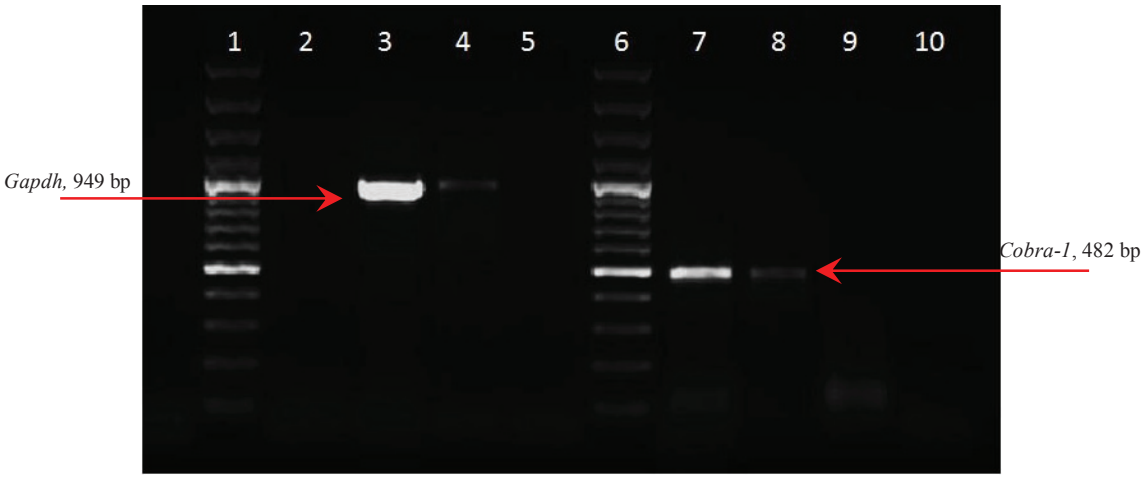


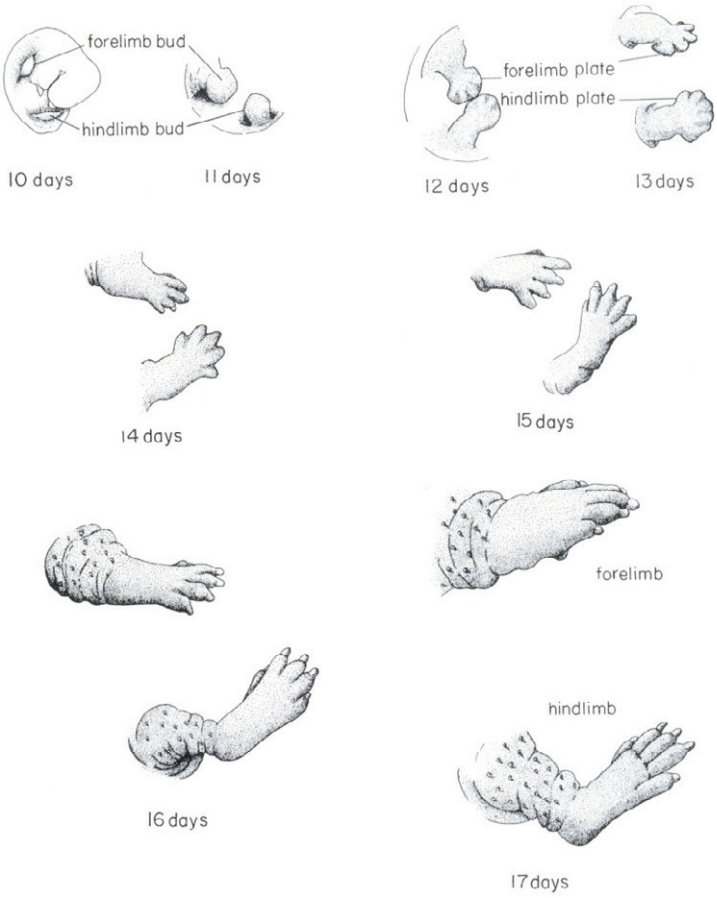
Figure 4: Differential gene expression. Agarose gel electrophoresis representing the expression of certain genes in different mouse tissues; from left to right lane 1 is 100 bp ladder while lanes 2-5 represent amplification products using Gapdh primers. Lanes 2 and 5 represent the negative control cDNA (no reverse transcriptase enzyme) of the ovarian and kidney RNA respectively. Lanes 3 and 4 represent the ovarian and kidney cDNA Gapdh products respectively. Lanes 6-10: 100 bp ladder (lane6), Cobra-1 products in ovarisn (lane7), and kidney (lane8) cDNA. Lanes 9 and 10 represent the negative control cDNA of the ovarian (lane9), and kidney (lane10) RNA respectively.

5.5. Embryos Retrieval and Staging

Retrieving embryos from the uteri of a pregnant female mouse is a tedious yet an elegant procedure. The same settings and preparations made for mice dissection were followed. Each two students were provided with a female pregnant mouse. This lab was repeated twice so that students would be able to retrieve embryos at two different stages (10.5 and 14 days of pregnancy). Some of the female mice were not pregnant yet the majority of students were able to retrieve embryos since the female mouse carries around 4-7 embryos. Students successfully staged

embryos by carefully observing limb development and referring to the index that has been handed to them as part of the lab activities instructions. The development of appendages of mouse embryo is illustrated in figure 5.A. Two different stages of embryo development (embryo age) are shown in figures 5.B and C.

A)



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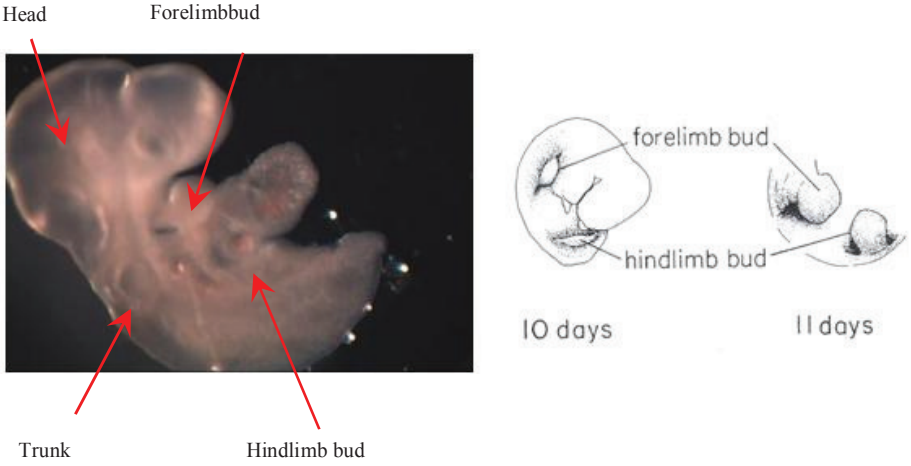
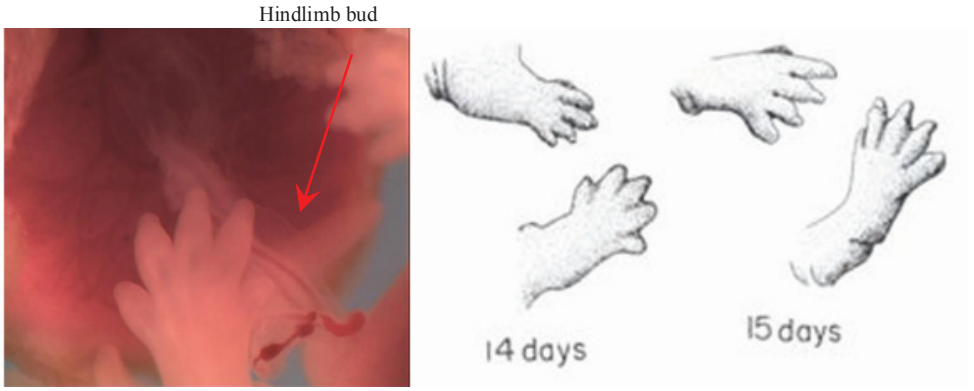


C)



D)

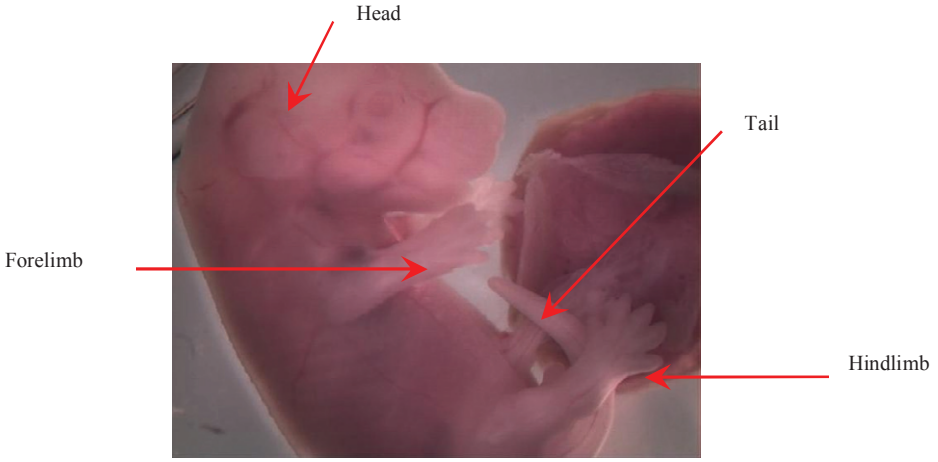


Figure 5: Development of appendages of mouse embryos used as a staging parameter for embryonic age. A) Diagrammatic presentation showing the different stages of embryos development (Roberts Rugh, 1990). B, C, and D photos for a 10.5 days embryo (B) attached to it is the alternative diagrammatic presentation, an embryo at 14.5 days (C) attached to it is the alternative diagrammatic presentation. D) A photo representing a mouse embryo at 14.5 days of embryonic age.

5.6. Ovarian and testicular tissue staining with Hematoxylin and Eosin

Due to proper *coordination, organization and good preparation,* the staining exercises were run smoothly. The lab was designed so that every two students work together on the same station. Each group handled 2 slides: one for an ovarian section and the other for a testicular section. Each station was organized into three staining phases as mentioned in the materials and methods. The coplin jars needed for each phase were labeled, and filled with the required staining solution. At the end of each phase the students removed the coplin jars, discarded the solution in the appropriate waste tank and placed the empty jars in a bucket filled with water to which a detergent has been added. This organized practice facilitated the staining process and minimized confusion between phases. Samples of the stained ovarian and testicular sections are presented in figure 6.

5.7. Reporting, presenting, troubleshooting and analyzing raw data

As easy as this section may seem to instructors, it's the most worrisome of all. It's at this stage that professors reap what they have sown during the whole course. Because it's the time to guide not teach, to show the path not walk it along and to wait for a piece of paper that somehow reflects what students have learned during four months.

This section also differs in that we were not there to observe mistakes or to straighten wrong ways. Of course, we were open to any consultation of any kind but it was the time for the students' *creativity and innovation* to shine**.** We

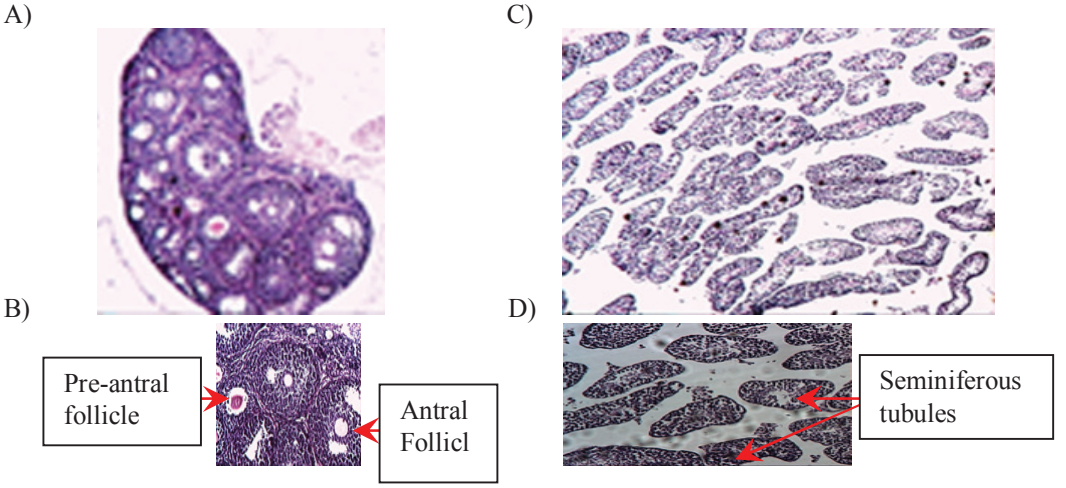


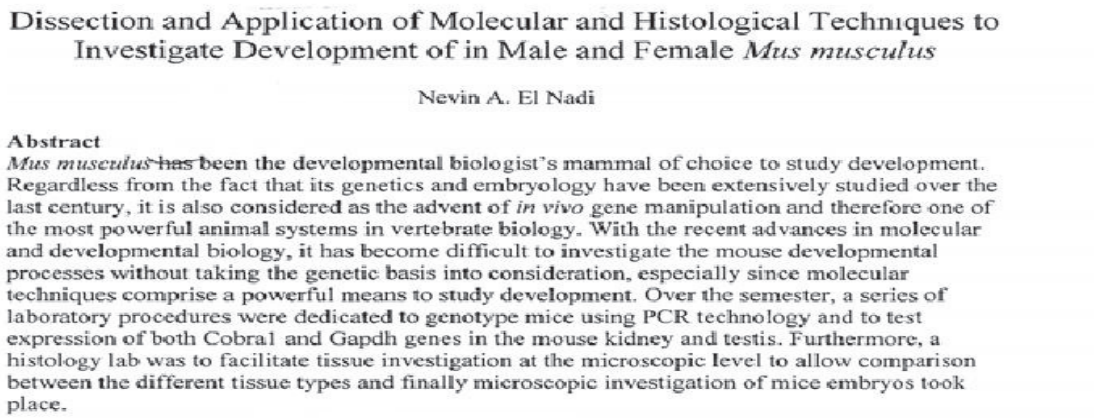
Figure 6: Histology of adult mouse gonad. Ovarian and testicular cross sections stained with Hematoxylin and Eosin.
A) Ovaries were dissected from adult females representing follicles at different stages of development. B) At a higher magnification growing oocytes within follicles at different stages of folliculogenesis (pre-antral and antral follicles). C) Testes were dissected from adult males representing active spermatogensis within seminiferous tubules. D) At higher magnification different seminiferous tubules are illustrated.

made sure that we encourage them to be creative and innovative scientists throughout the semester by continuous discussions and brainstorming (Balaraman et al, 1995). Reporting experiments and results can be a very tricky part of research. It's not the kind or quality of one's work only that people benefit from. It's more importantly the way this data is presented and interpreted. Gathering information, clustering data and reaching reasonable explanations were the kind of fruits we were looking for in the garden we've been taking care of during that spring. Troubleshooting was the most important skill needed before developing the ability to present their creativity. Students were asked to meticulously screen their procedures and look for theories and explanations for their false negative results. Moreover, they were asked to include their own way of reasoning, to think out of the box to deal with the problem and eventually propose a way to get the experiment running. Interestingly, we found out that every student had his or her unique conclusion that differed from the others. However, the main picture and the lessons that we intended to teach them were prominent among all conclusions and interpretations. In figure7 we present an abstract written by one of the students that show a great deal of creativity.

At the end, it was very rewarding to receive such innovative consolidated reports that reflect thorough understanding of the course content and a deep way of thinking, or what teaching philosophers refer to as *critical thinking and spirit* **(**Tyler, 2006). Their interpretation also showed that they took into consideration the smallest details. Our lesson and most important experience were proving that *hard work always pays off.*

5.8. Overcoming obstacles in the lab and asking for help

Every lab has its limitations. It requires a smart management in order to reach one's goal by overcoming obstacles. In the course design, some experiments needed the presence of some special tissue-sectioning equipment. Here we point out the importance of communicating with other labs to reach our ultimate goal of teaching science effectively. We contacted a pathology lab and reached an agreement to have the pathology lab embed and section mouse gonads that have been fixed by students enrolled in the course.



Dissection and Application of Molecular and Histological Techniques to Investigate Development of in Male and Female *Mus musculus*

Nevin A. El Nadi

Abstract

Mus musculus has been the developmental biologist's mammal of choice to study development. Regardless from the fact that its genetics and embryology have been extensively studied over the last century, it is also considered as the advent of *in vivo* gene manipulation and therefore one of the most powerful animal systems in vertebrate biology. With the recent advances in molecular and developmental biology, it has become difficult to investigate the mouse developmental processes without taking the genetic basis into consideration, especially since molecular techniques comprise a powerful means to study development. Over the semester, a series of laboratory procedures were dedicated to genotype mice using PCR technology and to test expression of both Cobra1 and Gapdh genes in the mouse kidney and testis. Furthermore, a histology lab was to facilitate tissue investigation at the microscopic level to allow comparison between the different tissue types and finally microscopic investigation of mice embryos took place.

Figure 7: A sample of a student abstract: shows a great deal of understanding and creativity.

6. Conclusion

It takes more than just good teaching materials to create a scientist. It requires good course planning, dynamic professors and assistants, open-minded students and discipline to sculpture the young scientist inside each student. The design of the laboratory part of the Developmental Biology course allowed the students to read experiments, interpret results, and get exposed to some experiments that sent both direct and indirect messages. The direct message was the scientific one, questioning a hypothesis, designing and running experiments, troubleshooting, reporting either positive or negative results and eventually analyzing them; whereas the indirect message emphasized morals, skills, behaviour and perseverance. Although such qualities couldn't have been taught directly, they were accentuated in our interactions/dealings with students throughout the semester for they are instrumental in raising scientists, who respect science grounds and who can use his/her knowledge to benefit mankind. By the end of the semester, students were able to use the raw data they had collected during the semester to hand in a consolidated report that mimicked research papers. They also acquired habits and attitudes that wouldn't only improve the scientist in them but also help them become successful individuals in any life aspect.

7. Recommendations

Any project has a set of goals and a plan to accomplish them. It's very important to design the course in a very flexible manner to accommodate any emergencies or unexpected events. Back-up plans should always be considered to avoid stalling the plan. Further strategies can be used to ensure the interaction of students. In one of her articles, Julia Ray states different strategies intended for use with younger students that can yet be used with undergraduates successfully (Ray JR, 2004). An example of these strategies is the 3-2-1 method. This summarization method should be applied –at the end of every lab- by asking the students to write down: 3 things they think they learned, 2 things they need to read more about and 1 thing they need to learn and experiment more on. The most important thing to keep in mind for any instructor who seeks effectiveness in teaching is to keep her/his office door open and to establish a friendly relationship with students. As Leblanc (1998) gracefully describes good teaching as follows: "*At the end of the day, good teaching is about having fun, experiencing pleasure and intrinsic rewards ... like locking eyes with a student in the back row and seeing the synapses and neurons connecting, thoughts being formed, the person becoming better, and a smile cracking across a face as learning all of a sudden happens.*"

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