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Using an Online Interactive Game to Enhance the Learning Outcomes for First Year Tertiary Students

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Academics acknowledge that students are often unable to link and extend first year, first semester foundation material throughout their undergraduate degree. The use of a pedagogically sound interactive digital game-based learning (DGBL) resource to engage first year biological science students in recalling, linking and applying foundation knowledge and increasing their learning outcomes has been explored. According to the current literature there exists no evidence that DGBL resources have previously been used to address this transfer and linking of knowledge and core skills. Results from our study of student perceptions and student learning outcomes suggest that our creatively designed resource has effectively targeted a mixed cohort of students to retain, link and extend foundation knowledge. Our study also indicates that DGBL resources have a valid role in enabling students, many of whom are classed as "digital natives", to demonstrate positive learning outcomes by successfully recalling and transferring unit content into new learning domains.

Keywords: Interactive Game; Learning Outcomes; Tertiary; Life Sciences; Creative Design

Introduction

Foundation knowledge is a major component of first year unit content at university level and is the platform for developing and expanding learning in successive units, particularly in specific, discipline based, professional degrees. Traditional presentation methods (i.e., lecture formats) are particularly disengaging for today's students, tending to produce "uninterested pragmatists who cram for tests, commit the material to short-term memory, and quickly forget it thereafter" (Foreman, 2003: p. 62). As a result, academics and educational developers have embraced technology to develop creative and complementary alternative learning resources to provide a blended learning approach. We have developed a web-based multi-player interactive game fulfilling the pedagogical criteria of DGBL. This resource enables students to recall foundation material from core units and to transfer and link knowledge and concepts, while engaging in a fun and stimulating learning environment. The purpose of this paper is to share the results from the use of a DGBL resource aimed at supporting the recall of foundation knowledge and the transfer of that knowledge to similar learning constructs. The effect of this creative resource on student learning outcomes is also explored.

Digital Game-Based Learning (DGBL)

DGBL is defined as "any marriage of educational content and computer games" (Prensky, 2001a: p. 145) and is an ideal platform to engage first year student learning. DGBL resources have been available for a number of years but have increased in complexity and diversity since Web 2.0 applications became available post year 2000 (Alexander, 2006; Cheung, Yip,

Townsend, & Scotch, 2008; Geith, 2008; Greenhow, Robelia, & Hughes, 2009; Jones, Ramanau, Cross, & Healing, 2009; Owston, 2009). There is also an increased expectation among the current student population for sophistication in DGBL which is based on their individual experiences of technology use.

The inclusion and alignment of both game taxonomy and learning taxonomy (Van Eck, 2006b) in a resource has a profound influence on successful engagement and learning outcome. Our DGBL resource has been constructed using a teaching methodology which includes a constructivist approach to knowledge transfer (Macaulay & Cree, 1999) and a spiral curriculum involving iterative processes of scaffolding (Kiili, 2007). In addition, one of the primary indications of successful game design is its ability to elicit emotional enjoyment in the player—i.e., if the game isn't fun, it won't be played or revisited (Prensky, 2001a; Sandford & Williamson, 2005). Humans who become overwhelmingly engaged in an activity are described as "in the zone", or experiencing "flow". Flow is a model of emotional experience which is so gratifying, that people are willing to do it for its own sake (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005). Our DGBL resource integrates the essential game design elements required to maintain such immersion whilst generating learning outcomes. It also includes essential elements designed by Pivec & Kearney (2007), such as persistent re-engagement, player control, scaffolding of abilities, different learning types (e.g., skills-based, knowledge-based, effective), cognitive challenge and reflection.

Immersing DGBL into the First Year Curriculum

"Digital natives" is a term which refers to the new generation of students, predicated around their exposure to, and use of,

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recent modern technologies (Prensky, 2001a; Van Eck, 2006b; Kennedy, Judd, Churchward, & Gray, 2008). First year cohorts contain a large number of "digital natives" who expect the incorporation of sophisticated digital technology as a component of their learning resources. An intrinsic shift in cerebral information processing mechanisms has occurred for "digital natives" (Prensky, 2005), compared with those adopting this technology later in life. Prensky (2005) suggests that "digital natives" brains respond in a different manner to education methodology and content by processing information at a different speed (twitch speed), and thus require information to be presented in a non-traditional manner to optimize learning. This is supported by some researchers (Van Eck, 2006a; Oblinger & Oblinger, 2005) and not by others (Kennedy, Judd, Churchward, & Gray, 2008). As a result of this, the needs of "digital natives" and other students must be considered by all staff involved in first year teaching and learning. Many staff are already engaging with digital teaching resources and a survey conducted in 2005 to explore educators' attitudes to digital games in the classroom showed that the majority of United Kingdom teachers were open-minded about their usefulness (Futurelab, 2006).

One of the goals of DGBL is to allow students to enter the game environment at their own level of expertise, and provide the means (scaffolding) for them to develop mastery by linking and integrating the knowledge gained. Scaffolding, in pedagogical terms, refers to the different kinds and amounts of support that a learner receives during the process of acquiring knowledge, and allows learners to "perform activities that they were unable to perform without this support" (Merrienboer, Clark, & Croock, 2002: p. 54). The support, in the form of interventions, can be through the educators (e.g., teacher, tutor) or by other means such as assistance mechanisms built into digital learning resources (e.g., feedback, just-in-time help).

Digital games whose structures are competitive, utilize content information as currency (or a weapon) in gaming contexts, to motivate and encourage players to battle for intellectual supremacy (Herz, 2002). Motivation, when applied to learning systems, is defined as "the process by which we consciously or unconsciously allocate working memory resources" (Brooks & Shell, 2006: p. 17). Motivation leads to student engagement which is of paramount importance in any effective learning strategy.

The Game Project

There is a general assumption that skills and knowledge developed in first year will be transferable to other academic contexts and real life situations, but, students are often unable to identify these links and apply their skills and knowledge into new domains (Britton et al., 2005; Scott, 2005; Rebello et al., 2007). The transfer of core skills can occur under particular learning conditions supported and enhanced by curriculum design and specific pedagogical objectives (Justice, Rice, & Warry, 2009; Lobato, 2008). The game project involved the development and implementation of an online interactive game (Alien Tissue II) to enable students to link content between successive units in the first year of their degrees. The methodology of the online game allows for a structured progression by linking and extending foundation knowledge with the increasing complexity of the curriculum content. Currently there exists no literature on the use of DGBL resources to link and extend this foundation knowledge and/or to produce positive learning

outcomes.

Students studying Health Science based degrees (including Exercise Science, Biomedical Science, and Environmental Health) and, some Education and Science degrees, study a Cell Biology unit in semester one. This unit is a prerequisite for the semester two units, Anatomy & Physiology 1 and Microbiology and Health. The online game incorporates content from the above units in a tiered game system to engage students in both learning and retaining the unit material, and in recognizing and applying cross-unit content. The game is interspersed progressively with the introduction of new and more challenging concepts, thus allowing the combination of experiential and problem based learning methodology to create a balance between student boredom and student challenge, motivation and engagement. Alien Tissue II also includes a suite of single player games (Appendix 1) designed for students to use for quick revision.

The game is currently written using a combination of perl, html and java script and is compliant for students with disabilities who use Dragon or Jaws software for computer access. The content of each specific unit (i.e., Cell Biology, Anatomy & Physiology 1 and Microbiology & Health) is delivered in the game using multiple choice questions (MCQ). The MCQ's are written at differing orders of difficulty based around the domains of Bloom's taxonomy of learning (Bloom & Krathwohl, 1956). This taxonomy is a framework for organizing learning objectives related to curriculum development and assessment. The content of the MCQ's in the game varies from simple knowledge recall from the long term memory, to combinations of recall and/or application and/or analysis, evaluation and synthesis requiring both short and long term memory. Research suggests that the MCQ format, when written according to the higher levels of Bloom's taxonomy, offers comparable reliability and learning outcomes to the short answer format (Bacon, 2003; Selby, Blazey, & Quilter, 2008; Zheng, Lawhorn, Lumley, & Freeman, 2008).

Feedback is available for the majority of the questions in the game. The content of the foundation MCQ's is linked to similar, but more complex content areas throughout the first year units. This linking, forms part of the feedback as the student progresses through related curriculum content. The feedback is designed as a help system (scaffolding).and is provided after an answer to an individual question. A study by Sweetser and Dennis (2003) involving first year psychology students, demonstrated that computer games used as a learning resource are improved by the "addition of a help system that provides information to the user at the time that it is most required" (p. 49).

The game is designed to reward students for demonstrating and applying knowledge. The rewards increase in value according to the difficulty, application and linking of the conceptual knowledge which is required to correctly answer individual questions. There is a reward system for certainty of using a correct answer and the rewards are embedded in specific scenarios—Appendix 2 for an example of a student playing Alien Tissue II. In Cell Biology and Anatomy & Physiology 1, the scenario involves the prevention of mutation in cell lines. In Microbiology & Health, the scenario is thwarting an invasion by an alien microbe. The rewards include ATP (a form of energy currency), immune cells, enzyme levels and mutation resistance. These rewards increase the strength of the player against attack from another player, which is one of the interactive components of the game.

Method

Questionnaire

A hard copy anonymous questionnaire, containing both closed and open-ended questions, was used to survey the use of the game by students enrolled in Anatomy & Physiology 1. Of the 25 questions in the questionnaire, the results of nine closed and two open-ended questions are presented and discussed. Ethics approval for this questionnaire was granted by the Tasmanian Health and Medical Human Research Ethics Committee (application number HOO10216).

Introduction of the Game to the Students

Students in Anatomy & Physiology 1 were introduced to the game in dedicated computer laboratory sessions in the second week of semester two. All students had completed a Cell Biology unit at UTas in semester one of the first year of their undergraduate degree.

Study Sample Demographics and Data Collection

First year students enrolled in Anatomy & Physiology 1 on the Launceston campus of the University of Tasmania (UTas) were asked to complete a questionnaire during tutorial time in the thirteenth week of semester two. The cohort comprised 311 students (154 males, 157 females) enrolled in the first year of a UTas undergraduate degree in the Faculty of Health Science, Faculty of Education, Faculty of Business or Faculty of Science, Engineering and Technology. Students gave their informed consent and all responses were anonymous. The students were a varied cohort, representing ten different degree courses. The cohort comprised a mixture of Grade 12 school leavers, mature aged students and students from interstate and overseas. The overseas students comprised approx. 7.5% of the cohort. The age range was 18 to 64 years with an average age of 22 years. Only 18% of the cohort were 25 years of age or older.

The questions were designed to obtain a variety of information: general demographic data; general computer use; frequency of game access; opinion regarding the use of a digital game as a learning tool; perceptions of knowledge recall from Cell Biology; and perception of transfer of learning across three core first year modules, Cell Biology, Anatomy & Physiology 1, and Microbiology & Health. The eleven specific questions used to gather responses for this study are displayed in **Table 1**.

Students' perceptions of knowledge recall and transfer of learning were obtained via guided, closed questions within the questionnaire (**Table 1**). Transfer of learning was not quantitatively measured because controversy remains regarding the methodology used to gather such information, and in fact, about what parameters are actually being measured (Barnett & Ceci, 2002; De Corte, 2007; Lobato, 2006; Rebello et al., 2007).

Results and Discussion

Results from this study were evaluated using a qualitative research methodology including descriptive statistics and phenomenology. Data regarding gender and degree were collated according to commonality of response and presented as rudimentary summations about the sample cohort and their respective responses. Some of the interpretations are subjective in nature, particularly those based around the open-ended questions. Whilst phenomenology usually relies on in-depth interns

Table 1.

Questions analyzed in this study[a].

Question 1	What degree are you currently enrolled in? E3J M3G M3H M3L M3P M3Q M3R Other
Question 2	Are you male or female? Male Female
Question 4	Did you revisit the game? If so, how many times? No 1 - 2 3 - 5 >5
Question 7	Did you enjoy playing the game? Yes No Unsure
Question 13	Do you think that the online game has helped you to recall cell biology knowledge? Yes No Unsure
Question 14	Now that you have played the game, can you see content links between cell biology and anatomy and physiology and/or microbiology? Yes No Unsure
Question 17	Did you enjoy the interactive aspects of the game (i.e., infect option, message function)? Yes No
Question 20	What did you like most about the game?
Question 21	What did you like least about the game?
Question 22	Do you find the game an effective tool for revision purposes? Yes No Unsure
Question 24	Do you enjoy playing computer games outside university study? Yes No

Note: [a]The full questionnaire comprised 25 questions.

(Hansen, 2006). This study evaluated results from 161 respondents. The overall mean age of the total cohort (311 students) was 22 years. This suggests that the game effectively targeted the "digital natives" (Van Eck, 2006c) within our student cohort.

Student Feedback on the Game

One of the aspects of this study was to determine if the students themselves could identify whether or not the game assisted them with foundation knowledge recall and making links between unit material and concepts. Results of the closed questions (questions 13 & 14) revealed that a majority (77%) of the respondents recognized that the game had improved their ability to recall foundation knowledge and to use it in a related context. The directed nature of the questions did not seem to influence the students' responses because answers to the open-ended question about what respondents most liked about the game (question 20), supported their answers to questions 13 and 14. For example, one respondent agreed the game had helped with recall and making the links between units and commented the game was "More than just regurgitating information". Another respondent on the other hand, thought the game helped make the links between units but didn't help with content recall. These answers corresponded with his opinion that the game "helps relate cell bio to anat & physic". A small number of respondents (n = 9) thought the game was useful for Cell Biology content recall but were either unsure if it helped make content links, or thought that it didn't. These respondents

all commented that the game either helped with revision or to recall Cell Biology content.

Impact on Student Learning Outcomes

At present, the conventional measure of transfer of learning, is the students' ability to be successful in their assessments and ultimately to graduate from university. The result of this study suggests that the DGBL increases knowledge recall and transfer of learning in Anatomy & Physiology 1. Student learning outcomes were enhanced in the unit when the DGBL was available as a learning resource, as shown by end of semester examination results. The average theory exam result was 52.3% when the resource was available, compared to 48.3% in the year prior to its implementation. It was also noted that an average theory exam result of above 50% was recorded for this unit when the DGBL was available. This had not been observed in previous years. The theory exam contains both MCQ and Short Answer questions (SA). In comparing MCQ and SA sections; there was an improvement in the MCQ section compared to the SA section of the theory exam. When the DGBL was available, students averaged 62.8% in the MCQ section compared to 57.7% in the previous year. However, only a slight improvement was observed in the SA section (48.2% with the DGBL, compared to 46.9% without the DGBL). As the DGBL is MCQ based, it is apparent that it assists knowledge recall in this form of summative examination and one respondent stated that they liked the game because it "was handy for revising for multiple choice questions".

These increases in students' examination scores also need to be considered in the context of this specific student cohort and any other pedagogical methodologies and platforms changed within the unit, such as the incorporation of Peer Assisted Study Sessions (PASS), which were also introduced into Anatomy & Physiology 1. Further analysis of the student cohort performance still needs to be compared across all first year units to determine if there are other factors involved in the improvement of their learning outcomes.

One of the aspects of this study was to determine if the students themselves could identify whether or not the game assisted them with foundation knowledge recall and making links between unit material and concepts. 75% of respondents found that the game helped them recall cell biology knowledge whilst 70% agreed that it enabled them to identify content links between related units of study. This was also supported by the students' responses to the open-ended questions about what they most liked about the game. For example, one respondent liked the game because the "game helped me to recall things done in past units and link them to the present ones". Similarly another respondent found that the game "… reinforced material learnt". Furthermore, questionnaire responses indicated that the resource did have a positive impact on student learning as one respondent liked the game because it "helped work out what I did and didn't know", while another respondent stated that "it helped to recall info and enforce (sic) confidence in knowledge of material". Similarly, another respondent found the game to be "a different/motivating way of learning and with the implementation of the hint-help—I learnt a lot". These responses indicated that the DGBL has a positive impact on student learning.

Whether or not respondents played other computer games did not seem to influence their enjoyment of this game. In fact,

89% of respondents indicated that they enjoyed the game even though only 49% enjoyed playing computer games outside of their university studies. Respondents liked the game because it was "fun and interactive" and "it was a fun way of learning". One respondent also stated that "it provided learning in an enjoyable environment, learning by playing a game". The game also incorporated some interactive components to engage students and 81% of respondents enjoyed the interactiveness of the game. This seemed to be reflected by the gender of the individual as male respondents were fairly consistent about liking the game and enjoying playing other computer games. The female respondents however, admitted to enjoying the game to a greater degree than would be expected, considering the very small proportion who normally played other computer games. Female players typically liked the game because "it was fun and educational at the same time". They were able to "gain knowledge in an enjoyable way" and "being able to infect other players and build resistance" was also favored by some of the female players.

These results suggest the format of the game was such that it not only maintained the interest of habitual computer game users (mainly male in this instance) and engaged student learning but, it also succeeded in capturing the interest of those students (mainly female in this study) less inclined to engage in game playing. Gender is an issue in DGBL, as to whether digital games are a "boy toy" or, indeed, if females will use them to the same degree (Prensky, 2001b). In addressing the issue of whether males and females may prefer differently styled games, it is suggested that whilst some females might prefer "interaction" rather than "action", that fundamentally, "an exciting game is an exciting game", and gender is not an issue if the games are engaging and enjoyable (Prensky, 2001b). Paraskeva, Mysirlaki and Papagianni (2010), in discussing the development of educational multi-layer online games, states that "females enjoy games with characteristics which they consider to be fun, such as games played against the computer, puzzles and quiz games" (p. 500).

Summary of Findings and Future Directions

The outcomes which support student use of a game format include emotional engagement, motivation, challenge and a feedback scaffolding system. The results of this study, contribute significantly to the body of literature about the use of digital game resources for transfer and application of foundation knowledge, particularly at the level of the first year tertiary experience. The game has succeeded in engaging and motivating both "digital natives" and those new to game technology, enabling them to acquire and transfer knowledge with positive learning outcomes. We acknowledge that this study worked within a relatively defined cohort of students in terms of social and academic environment. Future studies encompassing a more diverse student sample should support and strengthen the validity of these findings and permit extrapolation to a wider cohort.

Currently the game supports teaching and learning in three first year units (Cell Biology, Anatomy, & Physiology 1, Microbiology) which are common to a number of Health Science undergraduate degrees. Development of the game to include support for three additional units is currently underway, with funding being sought to develop this. It is envisaged that ultimately the game will be developed sequentially to include

modules which support and link second and third year under-graduate units, particularly in the Faculties of Health Science and Education. The resource also has the potential to be expanded into a generic game based tool for interdisciplinary use across faculties. However, Van Eck (2006c: p. 18), cautions against arguing that "all games are good for all learners and for all learning outcomes". He emphasizes that research is needed into understanding "why DGBL is engaging and effective" and the importance of taking a realistic direction for "when, with whom, and under what conditions", digital games can be successfully incorporated into "the learning process to maximize learning potential". In addition, Krotoski (2005) believes that whilst today's students are accepting digital games as a powerful learning tool, it may be a challenge to convince the educators who do not yet embrace this technology.

Conclusion

Ultimately, the progressive transfer of foundation knowledge between units, and its application in more complex contexts, is the aim of all higher education institutions. Based on the results of our study which used a DGBL resource in first year units, there are indications of positive learning outcomes in students' recall, application and transfer of knowledge. A digital game based resource, which is creatively designed to engage and motivate students whilst simultaneously increasing their learning outcomes, is a valid and valuable tool in the portfolio of teaching and learning resources, particularly at the first year level.

Acknowledgements

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Appendix 1. Screen Capture of Alien Tissue II and Single Player Games Available at biosciencelink.com
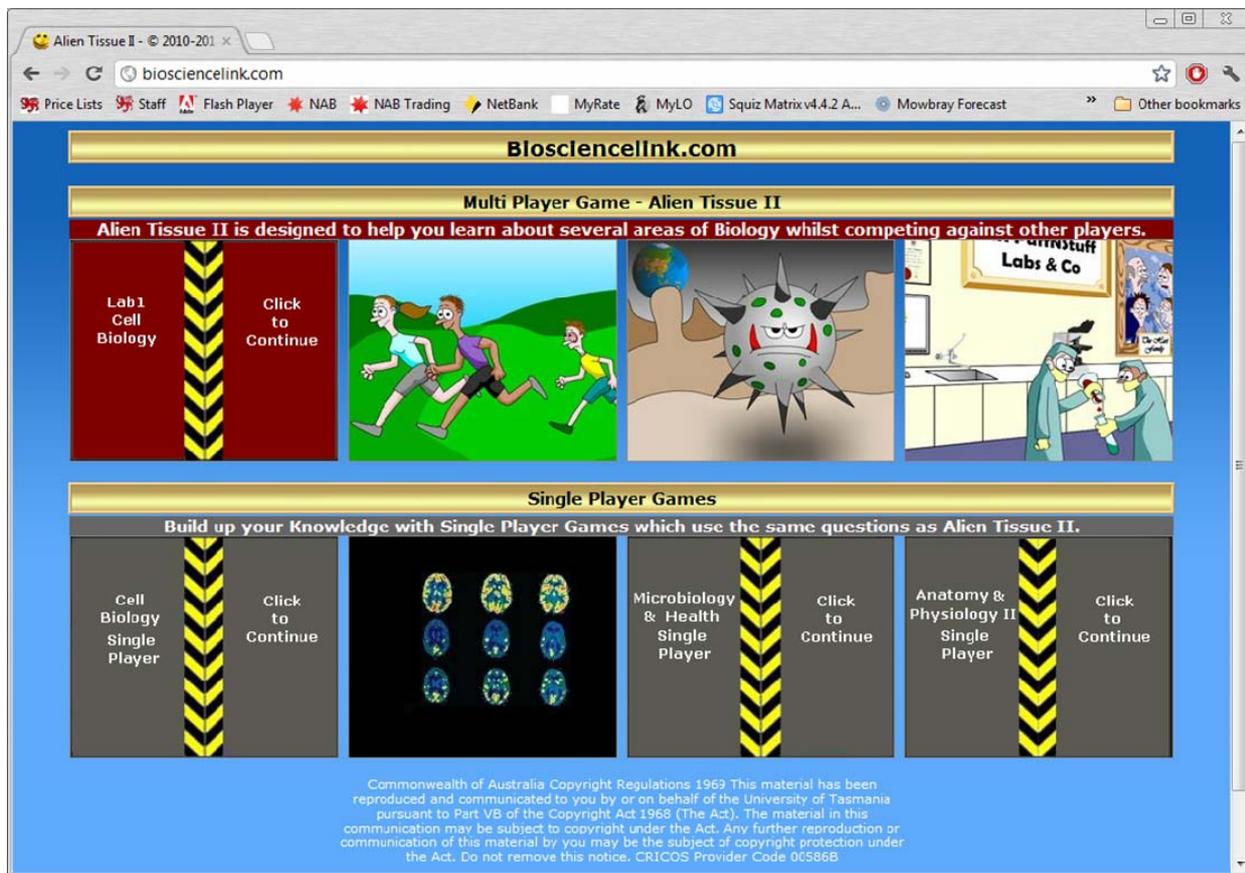
Appendix 2: Example of a Student (Username: Golgi) Playing Alien Tissue II

Golgi logs onto game—selects Anatomy and Physiology **1** *Lab*

Status: 120 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 11

Click on Earn Credits, Quiz Credits
Click on New Question:

Q. 5) Which anatomical plane divides the body into equal left and right halves?

a) transverse
b) oblique
c) frontal
d) parasagittal
e) median

Click on answer e)
Click on Certainty: High

Correct.

Feedback: This plan is also referred to as the mid-sagittal plane.

12 ATP earned.

Bank ATP

Status: 132 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 11

Click on Next Question

Q. 39) Which of the following cell organelles would be most important to epithelial cells whose primary function is secretion?

a) Lysosomes
b) Peroxisomes
c) Golgi apparatus
d) Cilia
e) Desmosomes

Click on answer c)
Click on Certainty: Medium

Correct.

Feedback: Golgi apparatus package and process molecules into vesicles for export from the cell.

Links to the following Cell Biology Lab Questions:

CBQ 11) A hormone secreting cell would be expected to have a large number of:

Answer—Golgi apparatus and secretory vesicles distributed throughout its cytoplasm

CBQ 39) The functions of the Golgi apparatus include:

Answer—synthesis, storage, alteration and packaging

CBQ 118) Human pancreatic cells that are active in peptide hormone secretion would contain many:

Answer—Golgi bodies

9 ATP earned.

Bank ATP

Status: 141 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 11

Click on Next Question

Q.152) The thick myofilaments in skeletal muscle are composed of the protein:

a) myosin
b) keratin
c) actin
d) troponin
e) tropomyosin

Click on answer c)
Click on Certainty: Medium

Incorrect. Correct answer is a)

Feedback: The myosin (thick) and actin (thin) myofilaments in individual sarcomeres enable a skeletal muscle to contract.

Links to the following Cell Biology Lab Question:

CBQ 8) Actin and myosin in muscle cells are best classified as:

Answer—movement proteins

-9 ATP earned.

Bank ATP.

Status: 132 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 11

Click on Earn Credits
Click on Infect Credits
Select player to infect: Zeppity

Report: You Lost
The results of your attack on Zeppity in Lab 2
Your attack strength was 54 units
Zeppity had a strength of 92 units
ATP lost: 34 ATP
Immune cells lost: 1
Immune cells destroyed: 1
Status: 98 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 10

Click on Updates
Select Immune cells: 1
(costs 50 ATP)

Status: 48 ATP, Enzyme Levels: Average, Mutation resistance: Low, Immune cells: 11

Click on Exit

Select Exit Game and Logout