This study investigated the use of multimedia materials to enhance student learning in a large, introductory biology course. Two sections of this course were taught by the same instructor in the same semester. In one section, video podcasts or “vodcasts” were created which combined custom animation and video segments with music and faculty voiceover, and which were designed to address those topics known to be difficult for biology students. In the other section, “class captures” were produced for each class session which combined the output of the classroom’s digital projector with a recording of the instructor’s voice. Both types of multimedia were made available to students online through the Blackboard-Vista course management system.

Student reception of the custom vodcasts was more enthusiastic than reception of the class captures. Additionally, after controlling for potential confounding variables including students’ overall GPA, major, sex, ethnic background, high school rank, year in school, composite ACT scores, and initial level of evolution knowledge, it was found that students who used the custom vodcasts achieved significantly higher scores (9.4%, or 2/3 of a standard deviation) on an end-of-term test of evolution knowledge than students who used the class captures.
captures. Students in the two sections of the class achieved statistically equivalent final grades in the course, however. It is argued that vodcasts are a more effective way of utilizing multimedia in large classes than class captures due to their targeting of known student problems in the course material and to their better implementation of established principles for the design of effective multimedia resources.

INTRODUCTION

Recent years have seen a substantial increase in the use of Web-delivered multimedia materials in post-secondary education, in part as a result of the proliferation of high-bandwidth internet connections and of the popularity of media-capable portable devices such as the netbook and the smartphone. Research on the use of such materials has lagged behind, and while some high-quality studies of the use of online technology in education have emerged, many investigations are limited to reporting variables such as student satisfaction and perceptions of impact on the learning process (Bernard et al., 2004; Means, Toyama, Murphy, Bakia, & Jones, 2009; Zhao, Lei, Yan, Lai, & Tan, 2005).

The current study seeks to contribute to the body of high-quality inquiry into the nature and effects of educational technology used at the post-secondary level. Specifically, this investigation focuses on the impact on student learning of two promising and popular ways of using multimedia materials in conjunction with a large lecture class, namely video podcasts or “vodcasts”, and class capture technology.

Online multimedia materials have the potential to be particularly beneficial for students in large classes (Carbone, 1999; Cuseo, 2007; Wulff, 1987). These materials can provide pedagogically constructive opportunities that are otherwise hard to achieve, such as active engagement with class material and student control over the learning experience.

Further, a long tradition in educational theory and research supports the use of multimedia in learning activities. Standard information-processing models of the mind (Atkinson & Shiffrin, 1968; R. Gagne, 1985) hold that there are three main memory registers: sensory memory, short-term or working memory, and long-term memory. Because working memory is severely limited in capacity and duration (Miller, 1956), it can become overloaded during learning activities, resulting in the diminished learning outcomes described in research on cognitive load (Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Sweller, 1988).

However, working memory is commonly thought to contain separate processing systems for verbal/auditory information and for visual/imagistic information (Miller, 1956; Ashcraft, 1989; Mayer & Moreno, 1998), which
means that one way to reduce cognitive load is through the dual coding of information. The use of the separate yet interdependent visual and verbal channels of working memory increases the amount of memory that is effectively available, thus enhancing both the encoding and storage of information into long-term memory and its retrieval from that system (Clark & Paivio 1991; Paivio 1971, 1986; Zhu 2006). A substantial body of research conducted over nearly five decades supports this hypothesis, particularly the work of Sweller and colleagues (e.g. Chandler & Sweller 1991; Sweller 1988) and Mayer and colleagues (e.g. Mayer 2001).

Both vodcasts and class captures combine visual and auditory information into a single multimedia package that can be delivered over the Web, but there are important differences between them. Vodcasts are custom-designed and –produced materials that combine video, audio, still images, and animation into an interactive module intended to supplement content delivered in class meetings. Class captures, by contrast, are recordings of the video and audio content of class meetings and do not supplement course content so much as repeat it, providing students the opportunity for review.

Another difference lies in the fact that vodcasts are typically more time-consuming and more expensive to produce, at least for individual instructors. Class captures are typically easier for instructors to set up, produce, and deliver, since these functions are usually handled by technical staff who install and configure the capture package provided by a commercial vendor (e.g., Apreso, Tegrity, or Camtasia).

Given the differences between these two popular ways of creating, using, and delivering multimedia materials, this study sought to answer the following research questions:

1. Are class captures or vodcasts better at promoting student learning in large-format introductory biology classes?

2. What are students’ preferences regarding class captures and vodcasts?

**Methods, Participants, and Data**

**Methods:** This study used a pre- and post-test non-equivalent groups design involving students in two sections of an introductory-level biology course at the University of Minnesota, titled The Biology and Evolution of Sex. In spring 2009 one section of Biology 1001 (the experimental or vodcast section) had access to vodcasts designed to help them learn course material by addressing known student misconceptions in biology, while students in the other section (the control or class capture section) had access to class captures. The sections were taught by the same professor who held constant as many factors as possible between the two sections of the course,
so that the sections used the same syllabus, textbooks, course materials, and learning activities.

The 11 vodcasts used in this study were created using Macromedia’s Flash development platform and Apple’s Final Cut Pro video editing software. The vodcasts combined custom animation and video segments with music and faculty voiceover in multimedia packages three to ten minutes in length. The content of the vodcasts was selected to address topic areas in biology which have historically presented difficulties for introductory students, particularly with respect to evolutionary theory. These problematic areas included questions such as whether individuals or species evolve; whether evolution is goal-oriented; what ‘fitness’ means in an evolutionary sense; the idea that evolution is something that happens in response to need; and the thought that evolution is a random process. Vodcast topics included biodiversity, immunology, mutation, and gender determination. (The vodcasts themselves can be viewed at http://www.youtube.com/user/bio11003#p/u.)

The 20 class captures used in this study were produced using Camtasia Relay technology which combines the output of the classroom’s digital projector with a recording of the instructor’s voice into a single Quicktime movie file. The vodcast and class capture files were distributed to students in the two sections by means of separate, password-protected websites on the University of Minnesota’s Blackboard-Vista course management system.

Participants: The participants in this study were self-enrolled students in a live, for-credit course. The research began with 150 students in the experimental section of the course and 156 students in the control section. However, after examining the data files, participants who did not fit the study’s parameters (for instance, who did not complete the course, or did not fill out either the pre-class or the post-class survey) were removed from the pool. Students who reported nonuse of the multimedia resources, either vodcasts or class captures, were also excluded from the analysis. Finally, the records of five high-aptitude students were removed who were taking the course pass-fail and who exerted only just enough effort to pass. This process left N=83 participants, 48 in the experimental section and 35 in the control section.

Because the participants were not randomly selected from the larger population, there were worries about external validity, or about whether the results of this study can be generalized to the population of students at large public universities in the United States. To help to establish generalizability, demographic and other information about study participants was collected from the University’s Office of Institutional Research and from in-class surveys. These data included students’ GPA, major, sex, ethnic background, high school rank, year in school, and ACT scores. Parametric tests revealed
Vodcasts and Captures: Using Multimedia to Improve Student Learning

no significant differences between students in the study and other students at the University of Minnesota on any of these variables.

Random assignment of participants to treatment and control groups was not possible in this study, which raises questions about internal validity, or about whether there were differences between the treatment and control groups which could confound the link between the dependent and independent variables. However, there are reasons to think that there were minimal confounds in this study. To begin with, Biology 1001 is a course that fulfills a requirement for many students, so that a wide range of students have a strong incentive to take the course. Further, information about which section would have access to which technological resources was not available during the registration period. These facts mean that students probably did not choose one section of Biology 1001 rather than another for reasons having to do with the variables of interest in this study.

Further, parametric tests were used to determine comparability of the treatment and control groups on the available exogenous variables. These included aptitude variables (composite ACT score, GPA, high school rank) and demographic variables (ethnicity, college of enrollment, sex, year in school). As the data in the tables below show, no significant differences were found between the two groups.

**Table 1**
Comparison of control and treatment groups on aptitude variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite ACT</td>
<td>Control</td>
<td>155</td>
<td>21.30</td>
<td>10.48</td>
<td>.596</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td>21.93</td>
<td>9.99</td>
<td></td>
</tr>
<tr>
<td>Cumulative GPA</td>
<td>Control</td>
<td>156</td>
<td>3.16</td>
<td>0.52</td>
<td>.970</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td>3.16</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>High school rank</td>
<td>Control</td>
<td>155</td>
<td>82.48</td>
<td>12.29</td>
<td>.352</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td>81.04</td>
<td>15.02</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2**
Comparison of control and treatment groups on demographic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Chi-square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnicity</td>
<td>Control</td>
<td>156</td>
<td>9.72</td>
<td>.205</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College of enrollment</td>
<td>Control</td>
<td>156</td>
<td>5.35</td>
<td>.500</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>Control</td>
<td>156</td>
<td>2.28</td>
<td>.131</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year in school</td>
<td>Control</td>
<td>156</td>
<td>2.65</td>
<td>.617</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data: The main independent variable of interest in this study was student use of different types of multimedia technology, either vodcasts or class captures. Data on student use of media were gathered through an end-of-term student survey and indicated that a large majority of students in both sections used the media resources available to them (70.1% in the vodcast section and 75.0% in the class capture section).

One dependent variable was student knowledge of basic concepts in introductory biology, which was measured using standardized College of Biology instruments and expressed in course final grades (excluding the laboratory portion of the grade). Biology knowledge was also measured by means of a series of evolution knowledge questions delivered to students at the beginning and at the end of the semester (see Appendix I). The other dependent variable was student reception of the multimedia resources available to them, measured at the end of the term by means of a student survey and two student focus groups.

Dependent variable data were examined to determine whether they met the assumptions of parametric statistical tests, particularly normality and homoscedasticity, and they were found to satisfy these assumptions (see Table 3).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Levene's test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final grade</td>
<td>Control</td>
<td>-.634</td>
<td>.262</td>
<td>0.065 (sig = .800)</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>-.138</td>
<td>-.642</td>
<td></td>
</tr>
<tr>
<td>Evolution knowledge test</td>
<td>Control</td>
<td>-.026</td>
<td>-.800</td>
<td>1.203 (sig = .275)</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>-.206</td>
<td>-.667</td>
<td></td>
</tr>
</tbody>
</table>

Data on several possible moderator variables were collected and included in the data analysis due to their possible association with academic performance and/or with student use of or attitudes toward educational technology. These variables included two measures of academic aptitude, namely composite ACT score and cumulative GPA (see ACT, 1998; ACT, 2007); certain demographic variables, namely sex and academic level (see Smith, Salaway, & Borreson Caruso, 2009; Walker & Jorn, 2009); and the degree of students’ use of the multimedia resources.

Data were also obtained from the pre-class test of evolution knowledge and two-sample t-tests were used to determine whether students in the two sections differed significantly in their initial levels of understanding of the basic concepts of evolutionary theory. No significant differences were found (see Table 4).
Table 4
Comparison of control and treatment groups on pre-class evolution knowledge

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-class evolution knowledge</td>
<td>Control</td>
<td>58</td>
<td>.560</td>
<td>.216</td>
<td>.867</td>
</tr>
<tr>
<td></td>
<td>Treatment</td>
<td>69</td>
<td>.554</td>
<td>.234</td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

**Student learning:** Two multivariate ordinary least squares (OLS) regression models were constructed and used to predict students’ performance on the two measures of learning in this study, namely final grades and evolution knowledge.

In the regression analyses, casewise diagnostics were generated and examined to locate outliers in the data set, defined as cases with standardized residuals greater than 3.3. This procedure revealed no outliers for either dependent variable. Variance inflation factor (VIF) statistics were also generated to check for multicollinearity among the predictor variables. In no case was the VIF statistic greater than 1.299, far from the common cut-off of 4, so multicollinearity did not appear to be a problem in the data set.

**Final grades:** The model that predicted student final grades was highly significant (p ≤ .001) and accounts for a considerable amount of the variation in final grades with an $r^2$ value of .672, adjusted $r^2 = .636$. The covariate, ACT score, was significantly related to final grade ($t = 4.840$, p = .001), as were GPA ($t = 5.420$, p ≤ .001) and sex ($t = 3.312$, p = .002). Degree of media use was not significant, however, nor was the main treatment of interest, section.

Given the results displayed below, we can conclude that for each unit increase in a student’s ACT score, we can expect a .01 point increase in that student’s final grade. Similarly, for each unit increase in a student’s GPA, we can expect a .094 point increase in that student’s final grade. The coefficients for the sex predictor variable indicate that on average, male students had final grades .045 points higher than female students.  

Putting these points in standardized terms, for each standard deviation increase in a student’s ACT score, we expect a .397 standard deviation increase in that student’s final grade. Similarly, for each standard deviation increase in a student’s GPA, we expect a .449 standard deviation increase in that student’s final grade, and male students had final grades that were an average of .247 standard deviations higher than female students.

---

1. Evolution pre-class knowledge and final grade were measured on a 0-1 scale; GPA was measured on a 0-4 scale; and in the sex predictor variable, male = 1 and female = 0.
Table 5
OLS Regression of Practice Exam on Final Grades and on Evolution Knowledge

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Final grades</th>
<th>Model 2: Evolution knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section (vodcasts vs. class captures)</td>
<td>0.008 (0.013)</td>
<td>0.094** (0.033)</td>
</tr>
<tr>
<td>ACT</td>
<td>0.010*** (0.002)</td>
<td>0.010 (0.005)</td>
</tr>
<tr>
<td>GPA</td>
<td>0.094*** (0.017)</td>
<td>0.057 (0.042)</td>
</tr>
<tr>
<td>Sex</td>
<td>0.045** (0.014)</td>
<td>0.060 (0.033)</td>
</tr>
<tr>
<td>Year in school</td>
<td>-0.003 (0.007)</td>
<td>0.010 (0.018)</td>
</tr>
<tr>
<td>Degree of use</td>
<td>0.005 (0.006)</td>
<td>-0.003 (0.015)</td>
</tr>
<tr>
<td>Pre-class evolution grade</td>
<td>0.059 (0.030)</td>
<td>N/A</td>
</tr>
<tr>
<td>N</td>
<td>71</td>
<td>71</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.636</td>
<td>0.193</td>
</tr>
<tr>
<td>F Test</td>
<td>18.735***</td>
<td>3.829**</td>
</tr>
</tbody>
</table>

NOTE: Cell entries are unstandardized OLS coefficients with standard errors in parentheses. *p < .05, **p < .01, ***p < .001

**Evolution knowledge:** In this model, evolution pre-class scores were not used as a predictor due to the likelihood of their being correlated with the evolution post-class scores and thus biasing estimates of model parameters. For predicting student knowledge of evolution, the model was significant (p = .002) and accounts for a moderate amount of the variation in evolution knowledge scores with an $r^2$ value of .261, adjusted $r^2 = .193$. The main treatment of interest, section, was significantly related to student evolution knowledge ($t = 2.871$, $p = .006$), but the predictors GPA, ACT score, and degree of media use were not.

Given the results displayed above, we can conclude that for each unit increase in a student’s section, we can expect a .094 point increase in that student’s evolution knowledge at the end of the semester. Because the control section of the class was coded as a 0 and the treatment section as a 1, this means that students in the treatment section ended the class with substantially greater evolution knowledge than students in the control section. Putting the point in standardized terms, for each standard deviation increase in a student’s section, we expect an increase of .309 standard deviations in that student’s evolution knowledge.
In a separate analysis, in order to check whether the treatment of interest, section, had different effects at different levels of other predictor variables, interaction terms were coded as the cross-product of the standardized independents and added in a separate block to both of the regression models. This was done for GPA, ACT, and sex, resulting in three interaction terms for each of the two models. None of these interaction terms was significantly related to the dependent variables.

**Student reception of media resources:** With respect to student reception, the student survey indicated that the vodcasts were used significantly more often by students than class captures were; that students used the vodcasts out of curiosity more often than they did the class captures; and that class captures were used just before exams more often the vodcasts, which were used at a wide variety of times during the semester.

Data from the student focus groups were consistent with the results of the survey and deepened understanding of student reception of the media assets on a number of points. For instance, students appeared far more interested in and excited by the vodcasts than by the class captures. There was a strong consensus in the vodcast focus group that the informality and humor of the vodcasts made them enjoyable to use, encouraged students to use all of the vodcasts, and focused attention on them. Some students explicitly pointed to the vodcasts’ combination of visual with auditory presentations of material, indicating that this multimedia approach helped them to grasp the concepts contained in the presentation.

**DISCUSSION**

The analyses performed in this study indicate that use of the vodcasts improved student performance compared to class captures when performance is measured by an evolution knowledge test but not when the measure is course grades. To provide some context for the effect of the vodcasts on evolution knowledge, it is worth noting that evolution knowledge scores were measured on a 0-1 scale, and that actual student scores ranged from 0.4 to 1 with a mean of .738 and a standard deviation of .153. The average effect size of .094 therefore seems to be a moderate to large effect, equivalent to 9.4% on a 100-point scale, or 15.7% of the actual range of evolution knowledge scores. Since none of the interaction terms in the model was significant, we can conclude that the effects of vodcast use on evolution knowledge were the same between men and women, and the same at different levels of academic ability as measured by ACT score and GPA.

The difference in findings between the two dependent variables raises two related questions. First, why did the vodcast students outperform the class capture students on the evolution knowledge measure? And second, why was this difference not apparent using the course grades measure?
One possible answer to the first question is that the vodcast students outperformed the class capture students on the evolution knowledge test because of the proximal nature of that test to the vodcasts themselves. The vodcasts and the test were not explicitly designed to dovetail with one another, but perhaps the content of the evolution knowledge test is closer to the subjects addressed by the vodcasts than to the content of the class captures. If so, it would be no surprise that having access to the vodcasts improved student performance.

The evolution knowledge test is certainly conceptually close to the content of the vodcasts, but it is also very close to the content of the class captures. In the course under study, evolution is the guiding concept underlying the introductory biology curriculum, providing structure and shape to the entire course. Many of the class sessions – replicated in the class captures – focused explicitly on the central concepts of evolutionary theory, so it is difficult to see why the evolution knowledge test is conceptually more aligned with one of these two forms of multimedia than it is with the other.

Several other explanations suggest themselves as answers to the first question. To begin with, students in the focus groups consistently expressed impatience with the length of the class captures and reported fast-forwarding through the presentations to locate the areas with which they believed they were having difficulty.

This points to a difference in how the vodcasts and the class captures were targeted. The vodcasts were created in order to address areas of the introductory biology curriculum known to experienced faculty members to cause difficulty for students. The class captures, as used by students, targeted areas with which students believed they needed assistance. It may be, then, that students are sometimes simply mistaken about where they need help. A deeply ingrained misconception may not be recognized as such by the person who holds it (Pronin & Kugler 2007).

Second, survey and focus group data clearly indicate greater student enthusiasm for vodcasts than for class captures. A strongly positive reception of this sort can help to focus student attention and effort on learning activities and materials and thus benefit learning, and several students in the vodcast focus group reported explicitly that this was the case. Some of this enthusiasm may result from the novelty of vodcasts, however, and might fade if this sort of multimedia asset becomes more common in higher education.

Finally, a review of the literature on multimedia learning yields a number of principles for the design of effective learning activities that involve different media (Moreno & Mayer, 2000; Clark, R.C., 2002). These principles guided the construction of the vodcasts in the current study, and while many of these principles are instantiated in both the vodcasts and the class captures, several are arguably present only in the vodcasts and may help to ex-
plain the superior performance of the vodcast group on the evolution knowledge measure.

For instance, both vodcasts and class captures employ auditory and visual media, allow users to control the pacing of the presentations, and largely avoid the inclusion of irrelevant material. But the information provided in the vodcasts helps students by being presented in the form of brief, informal summaries rather than lengthy explanations, an effect reported by Moreno and Mayer (2000). The vodcasts take advantage of the “signaling effect” noted by Mautone and Mayer (2001), which aids student learning from combined narration and animation by including signals in the narration that serve as guides to how the material is organized. And the vodcasts benefit from the “personalization effect” discovered by Mayer and Moreno (2000a), which shows that conversational narration assists students’ learning compared to formal-style narration.

If the above explanations for the improved performance of students in the vodcast group are correct, why was there no difference between the sections on the final grade measure? Here, the relatively proximal nature of the evolution knowledge measure may be important. Final grades in the class reflect understanding of the central concepts of evolution, but they are based on a broad spectrum of other content as well. It may simply be that this other content causes sufficient statistical noise to prevent the effects of the vodcasts from appearing when the measure is course grades.

CONCLUSION

This study has reached a number of conclusions that will be of interest to post-secondary educators, multimedia designers, and administrators in colleges and in technology support units.

To begin with, multimedia resources involving a video component are likely to be enthusiastically received by university students, most of whom will not encounter serious difficulties with accessing, downloading, and playing multimedia files. Audio-only resources will probably be much less popular. If those resources are custom vodcasts that use personalized, informal narratives in the explanations of material, they are likely to be more avidly received and used than audiovisual class captures.

Further, students who use custom vodcasts are likely to outperform students who use class captures on measures of learning that are moderately proximal to the conceptual content of the media resources. The mechanisms underlying this phenomenon may include the deliberate targeting of the vodcasts to address known student misconceptions and the vodcasts’ more complete instantiation of established principles for the design of effective multimedia resources.
It should be noted, however, that the production of the custom vodcasts used in this study was a lengthy process involving a team that included the course instructor, a multimedia developer, an undergraduate student, and an educational researcher. Given these costs, if a class capture system exists on campus, it may be reasonable for instructors with limited resources to utilize this system for their students instead of trying to produce their own, customized multimedia objects.

The research presented here is limited in a number of ways. For one thing, the instruments used to measure the phenomena under study, while based on long instructor experience, were not subjected to formal reliability and validity testing and may therefore be sources of error or bias. In addition, the overall design of this study was not fully experimental. This means that, although efforts were made to improve the study’s internal and external validity, it was not possible to exclude the influence of all possible confounds. The use of an experimental design or the incorporation of propensity scores in future research would alleviate some of these concerns. The study does benefit, however, from the fact that it took place in a live, authentic educational setting rather than in a laboratory, which means its conclusions may be more representative of the results actual instructors would see if they integrate multimedia elements into their own teaching.

References


**Appendix: Evolution Knowledge Questions**

28. Which of the following support the theory of evolution?

A. artificial selection (also known as selective breeding), an analogue of natural selection

B. comparative biochemistry, where similarities and differences of DNA among species can be quantified

C. vestigial structures that serve no apparent purpose

D. comparative embryology, where the evolutionary history of similar structures can often be traced

E. all of the above provide evidence to support the theory of evolution
29. Resistance to a wide variety of insecticides has recently evolved in many species of insects. Why?
A. mutations are on the rise
B. humans are altering the environments of these organisms, and the organisms are evolving by natural selection
C. no new species are evolving, just resistant strains or varieties. This is not evolution by natural selection
D. humans have better health practices, so these organisms are trying to keep up
E. insects are smarter than humans

30. Which of the following is the most fit in an evolutionary sense?
A. a lion who is successful at capturing prey but has no cubs
B. a lion who has many cubs, eight of which live to adulthood
C. a lion who overcomes a disease and lives to have three cubs
D. a lion who cares for his cubs, two of who live to adulthood
E. a lion who has a harem of many lionesses and one cub

31. How might a biologist explain why a species of birds has evolved a larger beak size?
A. large beak size occurred as a result of mutation in each member of the population
B. the ancestors of this bird species encountered a tree with larger than average sized seeds. They needed to develop larger beaks in order to eat the larger seeds, and over time, they adapted to meet this need
C. some members of the ancestral population had larger beaks than others. If larger beak size was advantageous, they would be more likely to survive and reproduce. As such, large beaked birds increased in frequency relative to small beaked birds
D. the ancestors of this bird species encountered a tree with larger than average sized seeds. They discovered that by stretching their beaks, the beaks would get longer, and this increase was passed on to their offspring. Over time, the bird beaks became larger
E. none of the above

32. Which of the following statements about natural selection is true?
A. natural selection causes variation to arise within a population
B. natural selection leads to increase likelihood of survival for certain individuals based on variation. The variation comes from outside the population
C. all individuals within a population have an equal chance of survival and reproduction. Survival is based on choice
D. natural selection results in those individuals within a population who are best-adapted surviving and producing more offspring
E. natural selection leads to extinction

33. All organisms share the same genetic code. This commonality is evidence that
A. evolution is occurring now
B. convergent evolution has occurred
C. evolution occurs gradually
D. all organisms are descended from a common ancestor
E. life began millions of years ago
34. Which of the following statements regarding evolution by natural selection is FALSE?
A. natural selection acts on individuals
B. natural selection is a random process
C. very small selective advantages can produce large effects through time
D. natural selection can result in the elimination of certain alleles from a population's gene pool
E. mutations are important as the ultimate source of genetic variability upon which natural selection can act

35. A change in the genetic makeup of a population of organisms through time is
A. adaptive radiation
B. biological evolution
C. LaMarckian evolution
D. natural selection
E. genetic recombination

36. Which of the following is the ultimate source of new variation in natural populations?
A. recombination
B. mutation
C. hybridization
D. gene flow
E. natural selection

37. Which of the following best describes the relationship between evolution and natural selection?
A. natural selection is one mechanism that can result in the process of evolution
B. natural selection produces small-scale changes in populations, while evolution produces large-scale ones
C. natural selection is a random process, while evolution proceeds toward a specific goal
D. natural selection is differential survival of populations or groups, resulting in the evolution of individual organisms
E. they are equivalent terms describing the same process