MacCycle: an extensible multimedia for teaching the physiology and histology of the menstrual cycle

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Introduction

The development of MacCycle, a multimedia visual database of the female menstrual cycle, stemmed from two related events. First, the School of Biological and Medical Sciences at St Andrews University began to make contingency plans to update a computer classroom which had been used to teach physiology for about five years. Second, staff retirements were about to change the profile of the School's teaching coverage in the key area of preclinical medicine. We anticipated that the introduction of a more flexible delivery system for the histology course might go some way to offsetting potential staff shortages.

These factors led us to examine the feasibility of adapting parts of our histology course to a computer-based system. The major constraint was that software would have to be delivered on student workstations which, while low-cost, would be able to provide acceptable image quality.

At St Andrews, histology is taught to 90 science students and 200 preclinical medical students, though at any one time the numbers in the practical classes are approximately 50. In thinking about introducing a computer-based teaching system for histology instruction, four important technical and strategic criteria emerged as being central to the success of our project. Any solution we adopted would have to be:

(1) an integral and compulsory component of the course;
(2) capable of coping with 100 students per week;
(3) part of a general purpose solution to other computing requirements of the School;
(4) able to provide good image quality at an affordable price.

We were already aware of the existence of other computer-based teaching programs for histology and pathology, particularly laser disc-based systems[1,2]. While these had some features that impressed us, laser disc technology requires dedicated hardware, it is rather inflexible and is

This article is reprinted from the forthcoming volume, *Technology and Teaching*, edited by Les Lloyd and published by Information Today.

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also expensive to implement for teaching large numbers of students. More importantly, the not invented here syndrome all too readily afflicts academics asked to develop a course using someone else's material. A software-based, digital image storage and display system offered a less expensive and more flexible solution to our specific problems (Hanka *et al.*, 1991).

After evaluating a number of hardware configurations during the summer of 1991, we selected the Apple Macintosh LC 6/80 (6Mb RAM, 80Mb hard disk) running System 7 as our basic student workstation. For display, we chose the Apple 12in. color monitor (512 × 384 pixels) with 512K expansion VRAM (video RAM) added to each machine. This gave 16-bit color capability with images displayed from a palette of 32,000 colors.

Although the pixel resolution of the 12in. Macintosh screen seemed relatively low, in practice the ability to display images at 16-bit color depth proved to be a crucial factor in successfully displaying high quality histological images, and we reached the conclusion that, for the type of images we used, increased color resolution could be offset by lower spatial resolution. By October 1991, we had completed the installation of a teaching laboratory of 30 Macintosh LC computers connected by an AppleTalk network to a LaserWriter IIg for printing and to a Webster Multigate for access to the University ethernet network. The laboratory is equipped with HyperCard 2.1, QuickTime 1.6 and standard productivity software (word processor, spreadsheet, graphing and statistics package, etc.). We are now in the process of upgrading the computer laboratory and even the current UK entry level Macintosh (LC 475) will offer a significant improvement in performance over our original hardware choice.

Teaching background and aims

Histology is taught as an integral component of our preclinical human function course and consists of 35 lectures followed by 32 hours of practicals. The range of subjects covered includes all the major body systems (respiratory, cardiovascular, reproductive and nervous system, etc.). The students examine a collection of approximately 100 microscope slides which are fully described in a weighty course booklet. Although sections are demonstrated on large color television monitors via a video camera linked to a teaching microscope, students sometimes experience difficulties both with microscope technique and the individual identification of relevant structures. We hoped to overcome these and other difficulties by using computer-based technology to:

- integrate the teaching of physiology and histology by emphasizing the structural and functional relationships of cells and tissues in the body systems;
- introduce a wider range of human material than would have been previously used in our histology classes e.g. endoscopic and other medical imaging techniques;
- enhance the student's opportunity to see and understand the relevant microscopic detail, first by eliminating the frustration and limitations of the student microscope and second by making available explanatory diagrams.

At the start of term in January 1992 we committed ourselves to replacing a timetabled practical unit on reproductive physiology with a computer-based histology unit (MacCycle). This gave us approximately eight weeks to develop our first histology program for student use.

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The complexity of the interactions between the four major female reproductive hormones and the cyclical changes in the structure of the ovary and uterus meant that this topic was well suited to the integrated approach which we felt was important to student understanding of dynamic biological processes. Conventional treatment of the subject in lectures, laboratories and textbooks often fails to convey the very dynamic nature of the menstrual cycle and we felt confident that the subject material would lend itself to the approach we envisioned. Three other important factors influenced decisions on program content and timing of introduction:

(1) Students would already have had 30 hours of scheduled computer practicals. These practicals not only familiarized students

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with general purpose software packages, but also included a number of physiological simulations implemented in HyperCard. Students already had adequate skills to cope with instantiation of the computer-based histology practicals (mouse technique, file handling, etc.).

(2) We anticipated that the development process would require considerable input not only from a software developer but also from a domain expert. Most staff in the School had no software development skills and we therefore relied on the expertise of a visiting research fellow (NSP) who had been involved in the development of educational software for several years. The domain expert had only limited computer skills at the beginning of the project but was enthusiastic about the concept.

(3) Technological advances in digital image handling and storage (QuickTime) on personal computers had made feasible our idea of storing an extensive visual database of images on each workstation.

The QuickTime system extension and its associated image compression and decompression capabilities (codecs) permits the efficient storage and display of still and moving images. QuickTime is best understood as a storage technology for a collection of time-based data. The data file is called a "movie" because it is typically used to store a series of still images (frames) with an optional audio channel. The file may be incorporated into many different applications and played in a number of ways, including forward and reverse motion sequences, stop action and random access of individual frames or segments.

QuickTime provides a software-based solution for displaying digital video and sound on any color-capable Macintosh (PowerMac, Quadra II series, or LC models) with 4Mb of RAM and System 6.0.7 or later. The QuickTime codecs compress the large data files that are normally needed to store complex visual images in digital form and automatically decompress them only when they are being viewed on screen. A typical, full screen, 24-bit color image can be compressed and stored as a 35kb file. When the compressed image is recalled, there is no apparent loss in the quality of the color or spatial resolution. In our work, we used the video, animation and photo Joint Photographic Experts Group (JPEG) compressors to store and display short movies, diagrams, and high resolution 24-bit color pictures. Apple's PICT Compressor is a software implementation of the JPEG standard and can be used to open and compress any PICT file. JPEG can achieve compression ratios of between 10:1 and 50:1 depending on image complexity and degree of compression chosen. Thus with QuickTime, not only were we able to think in terms of creating a database containing many tens of images, but we were also able to modify the content of the image library as and when needed.

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We chose to implement MacCycle in HyperCard (as opposed to other authoring languages such as Guide or Authorware) for four reasons:

(1) it was well suited to rapid prototyping, having facilities for both navigation and computation;
(2) it came free with all Macintosh computers and thus avoided licensing problems[3] (Hanka *et al.*, 1991);
(3) Version 2.1 was fully QuickTime compatible;
(4) it was capable of displaying 24-bit color images in separate windows.

Image capture

Four image capture technologies were used during the development of the program (Whiten *et al.*, 1992):

(1) A VideoLogic DVA-4000 full motion digital video adapter was used to capture and display live video images on a standard Macintosh 13in. color monitor. The DVA-4000 board can accept input from analog sources (e.g. video tape and video cameras) in a number of different video input formats including composite video (PAL or NTSC), RGB and S-Video. The analog images are dynamically resizeable and single frames can be saved as 24-bit PICT files.

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(2) VideoSpigot boards (SuperMac Technology) were used to capture still and moving digital video images from composite video sources. The VideoSpigot displays the incoming signal in a live window and can store both sound and video data directly to RAM memory or disk at up to 24-bit color depth. The VideoSpigot can also be used for making QuickTime movies directly.
(3) A 24-bit color flatbed scanner (LaCie SilverScanner) was used for the digitization of drawings and photographic prints. We normally scanned at 72 dots per inch (maximum screen resolution) to minimize file size.
(4) A Microtek ScanMaker 1850s was used to scan 35mm photographic slides. Slides were scanned at 1,850 dots per inch and 24-bit color depth, then scaled to produce the appropriate screen-sized image.

Both the flatbed and slide scanner have software plug-ins for Adobe Photoshop, which also provides JPEG compression. The images were archived at 24-bit color depth on a 128 megabyte 3.5in. rewritable optical floppy drive and cataloged using FileMaker Pro.

Design and creation of MacCycle

The menstrual cycle is usually described as a series of phases based on hormonal and structural changes. In the MacCycle stack, individual cards were used to give details of different phases. The title of the card appeared in the upper left-hand corner. Some significant days, such as the day of ovulation (day 14), required an individual card, whereas other phases could be described as a group of days (days 18-24). Pictures were attached to the cards to illustrate significant structural and hormonal changes. As the students used MacCycle they were able to call up illustrations using the Figures pop-up menu.

Most of the histological sections in the image database were captured using the Microtek slide scanner from 35mm slides taken with a Nikon 35mm camera attached to an Olympus BH2 microscope. Some sections were digitized using the DVA-4000 board with an S-video signal input from a Sony 3 chip video camera (DXC 325p) attached to the Olympus BH2 microscope. Subjects too large for microscopy were photographed with a macro camera (Leitz Dialux 20), then printed (5 × 7 inches) and scanned with the flatbed scanner. The images were edited (color balance adjustment, cropping, rotation, etc.) with Photoshop and compressed at medium quality.

Initial prototypes of MacCycle had up to three fixed windows on each card (to show the endometrium, the follicle and the hormone levels). However, this approach was abandoned because of the size restrictions imposed by the screen. The final card design had a fixed, scrollable field set aside for text but the visual images were displayed in freely movable windows.

Students were therefore able to choose which images to view on screen, where the image would be located and, in most cases, what size of image was displayed. When using MacCycle, we found that the students appreciated the freedom to control the screen configuration.

'…A movie, showing the actual moment of ovulation, was created by frame-grabbing key frames from a videotape recording and linking the frames using the PICTtoMovie application…'

Four types of image could be viewed and selected from the Figures pop-up menu:
(1) Color photomicrographs were obtained by the image capture techniques described above.
(2) Line diagrams highlighted the key structural elements in the photomicrographs. These diagrams were originally drawn by hand, scanned and colored using the paint tools available in Photoshop. Labels were subsequently added in Canvas 3.0.
(3) Graphs showed the changes in blood hormone concentrations through the cycle.
(4) Movies showed the cyclical changes in the endometrium, follicle and hormone levels (endometrium movie, etc.). The individual frames for the endometrium and follicle movies were drawn by hand, scanned and saved as PICT files. The hormone data movie were created from a series of histograms generated by DeltaGraph Professional. These series of PICT files were assembled into movies by using either Apple's PICTtoMovie application or Adobe

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Premiere. A movie, showing the actual moment of ovulation, was created by frame-grabbing key frames from a videotape recording and linking the frames using the PICTtoMovie application. Though these movies firmly belonged in the flick-book school of animation, they provided convincing evidence of the dynamic nature and integration of the physiological and histological changes which occur during the different phases of the menstrual cycle.

Authoring of MacCycle

MacCycle is a HyperCard stack with an index facility which allows rapid navigation through the different phases of the menstrual cycle (Whiten *et al*., 1993). The MacCycle stack also includes integral editing tools which make simple the assembly of the text with relevant illustrations. To create MacCycle, the domain expert typed text directly into the scrollable field on the card, where it was automatically saved. Appropriate images were selected from the database to illustrate the text and these were attached to the card. Attaching the pictures to the cards was achieved by using the Add Open Figures option from the File menu. Titles of the selected illustrations then appeared in the Figures pop-up menu. The list of figures appearing in this menu was therefore unique to each card and easily modifiable.

Student use

After an introductory lecture on gametogenesis, the students used the MacCycle database to investigate the menstrual cycle. They were able to read a short, explanatory text and examine digitized images of histological specimens, graphs and movies. Since the number of images which can be displayed at any one time is limited only by computer memory, the student could, for example, view on one screen, text, dynamic changes in hormone levels and the related structural changes in both the ovary and the uterus.

For assessment purposes, students submitted an "electronic multimedia essay" in which they synthesized structural and hormonal information by defining significant phases of the menstrual cycle. Using the MacCycle editing tools and instructions for editing, students composed their essays within the program, creating their own multimedia by illustrating important points with graphs and images drawn from the database. On average the essays took around two hours to write and the total time spent in the computer laboratory studying MacCycle was between four and five hours.

Student evaluation

Students enjoyed the innovative approach to the practical teaching of histology and they appreciated the opportunity to view a great variety of images. They also found animations a valuable aid to understanding dynamic biological systems and consequently had a better understanding of the integration of physiological and structural changes than had been achieved by previous methods of teaching the subject.

'…One interesting development we had not anticipated was that, after using MacCycle, students would look at histology sections under the microscope…'

Results of student evaluations from three classes, each of 100 medical students, show average scores in the top 20 percent for enjoyment, ease of use and acceptance of new technology. One interesting development we had not anticipated was that, after using MacCycle, students would look at histology sections under the microscope. A number expressed the view that, after having studied the computer images, they had gained the necessary confidence to be able to identify the key structures in the normal histological sections. We are conscious of the "novelty effect" that the introduction of new teaching technology has and think students would enjoy a mix of technologies with some practicals being taught in the traditional way and some on computer.

Conclusion

QuickTime image compression makes image-intensive projects, such as MacCycle, feasible on inexpensive student workstations. MacCycle

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provides a wide selection of materials which enhances the students' opportunity to see important histological details. It is also a rich computer database (not a page-turning tutorial) containing both histological and physiological information and thus can be used to set open-ended research problems which the students can complete within the same environment in which they view the material. We found that students enjoyed the materials and appreciated seeing a greater variety of images than are normally available for viewing in a traditional microscopy classroom setting. Animations were also a valuable aid for illustrating dynamic changes in biological systems. Having assessed the essays, we felt that the students who had used MacCycle had a clearer understanding both of the dynamics of the changes and also the integration of physiological and structural events than had been achieved by previous methods of teaching this subject. Our experience has led us to believe that it is possible for university staff with little or no prior experience of computers to use, with a minimum of outside expertise or assistance, the MacCycle HyperCard authoring shell in order to construct practical multimedia for teaching.

Notes

1. The UK Path disk is available from Cambridge Multimedia Systems, Burwell, Cambridge, UK.
2. Keyboard Pathology is available from Keyboard Publishing, 484 Norristown Road, Blue Bell, Pennsylvania 19422, USA.
3. Version 2.2 of HyperCard, which has recently been released, allows developers to create stand-alone applications, thus avoiding the need for licensing agreements, etc.

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