A Metabolic Challenge on CD-ROM

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Abstract

We have introduced a novel approach to the learning of metabolism by undergraduate students of biochemistry by providing them, on CD-ROM, with an intellectual challenge relating to 'real world' metabolic problems.

The CD-ROM *Biochemistry - A Metabolic Challenge* is an integral component of our course curriculum but has been introduced with different emphasis into the different undergraduate Biochemistry courses. For science students, the programs are an adjunct to formal lectures and part of **problem-solving** sessions that are a component of the practical classes. For biomedical and medical students, who are high academic achievers, the CD-ROM is also used for **self-directed learning and case studies** whereby students are expected to take more responsibility for their own learning.

The **problem-solving** exercises, entitled *The Great Metabolic Race* and *The After Race Banquet*, explore the metabolic changes that occur to an athlete during a long distance race, and the subsequent recovery phase. The exercises are question/problem based and interactive, requiring students to analyse the questions, think logically and respond by integrating information drawn from a variety of sources. A set of thirteen self-paced, interactive tutorials covering the fundamentals of metabolism are linked to these exercises to act as one resource. While the answers to the questions do not appear in the tutorials, the information required to formulate the answers does. The CD-ROM is used for **self-directed learning** to help students visualize pathways and the relationship between them, and to integrate the knowledge they have acquired from various sources. It also contains case studies to teach students how these pathways are affected in specific clinical cases.

Surveys have shown that students respond particularly well to the participatory nature of this new resource and find the self-paced learning and testing very valuable. We also have preliminary indications that the use of these programs does translate into improved student comprehension as judged by examination performance.

Introduction

Biochemistry is a very broad and complex discipline, knowledge of which requires the ability to integrate a wide range of concepts. It is a challenge to teach students, especially in large classes, how to acquire this skill. This can be partly overcome using computer-aided programs which provide a highly flexible way to deliver difficult material and enable students to learn at their own pace, in their own time.

Most computer programs developed in the field of biochemistry to date are either aimed at school leavers, or cover a very specific topic (e.g. enzyme kinetics). The CD-ROM entitled *Biochemistry - A Metabolic Challenge* is more broad ranging and has been developed with the aim of teaching the principles of metabolism to a variety of university undergraduates including science, biomedical and medical students.

The package also forms the basis of a non-traditional and very flexible approach to the acquisition and development of learning skills; it is used as the focus for both ***problem-solving exercises*** and ***case study related self-directed learning***, as well as being a resource for information, revision and self-assessment. In a teaching sense, the package is utilised in different ways depending on the prior knowledge of the students, the objectives of the particular course and the size of the class.

Description of the CD-ROM

The CD-ROM contains two interactive self-paced exercises, *The Great Metabolic Race* and *The After Race Banquet* (Figure 1).

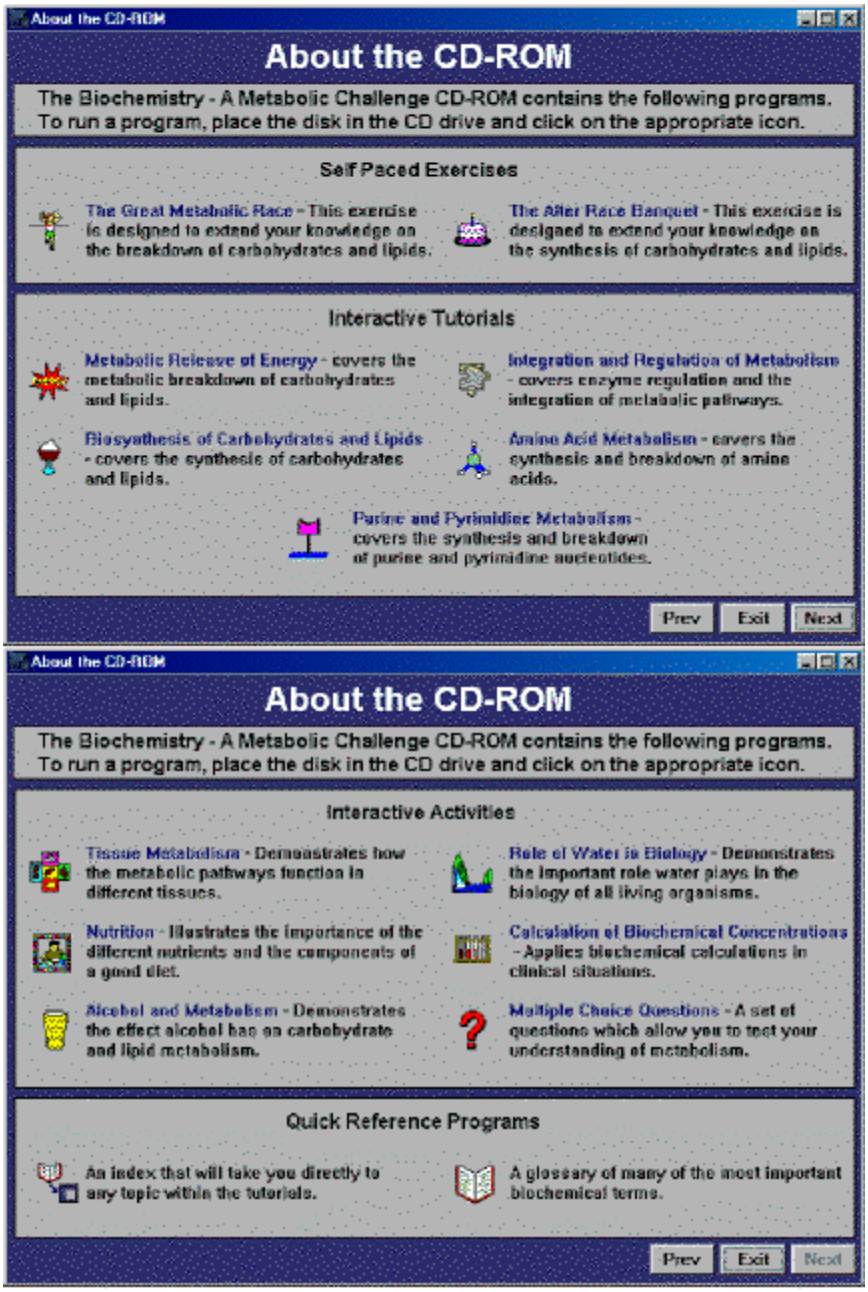

Figure 1. Content of the CD-ROM *Biochemistry - A Metabolic Challenge*

These exercises relate specifically to the catabolic metabolism associated with long distance running and the anabolic metabolism associated with the recovery phase. They test the students' ability to integrate and understand concepts and pathways that are often learned in isolation. The exercises involve true/false questions, multiple choice questions, 'click and drag' questions and answers and calculations, the results of which are scored by the computer.

A series of quite extensive self-paced interactive tutorials and activities on various aspects of metabolism accompany and are linked to these exercises (Figure 1). The tutorials use animated demonstrations, 'click and drag' reaction sequences, 'click and drag' question and answers and

multiple choice extension questions. The tutorials serve as an information resource and the information within them can be readily accessed through a comprehensive index of topics, even while undertaking the exercises.

Application of the CD-ROM to teaching/learning

The flexibility of the package is reflected in the ways in which it has been used, both within a structured teaching environment and by the students in their own time. Our experience relates to the teaching of three separate groups of undergraduate students, all doing biochemistry as a discrete discipline for the first time, namely science, biomedical and medical students. Our utilisation of the package has varied depending on the course being taught: the science students using a combination of formal lectures and **problem-solving exercises** while the biomedical and medical students use a more case related **self-directed learning** (SDL) approach with a lesser emphasis on formal lectures.

Students in all courses use the programs extensively for revision and self-assessment purposes.

Science students

Science students constitute a large group of approximately 250-300 students. They come from very diverse academic backgrounds and include students doing double degrees such as Arts/Science and Science/Law - some have had a lot of chemistry and biology, others very little. They also represent a broad range of academic abilities.

For these students, the lecture programme on metabolism spans a 13 weeks period and presents core information. The CD-ROM is often used within the lectures for illustrative purposes and for the animated demonstration of difficult concepts such as electron transport - see Figure 2.

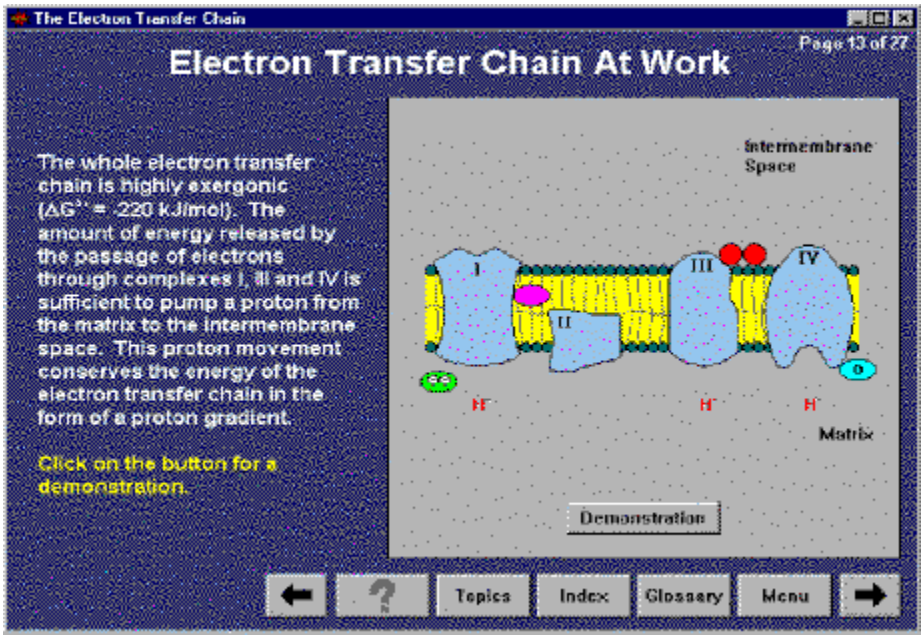

Figure 2. Demonstration of electron transport from *The Electron Transfer Chain* tutorial

The **problem-solving exercises**, which rely extensively on the use of the CD-ROM, are an adjunct to the formal programme of lectures and form an integral part of the practical course as outlined in Table 1.

Lectures on Carbohydrate Catabolism	3 hours
Problem-solving exercise: *The Great Metabolic Race*	4 hours minimum
Follow up tutorial on problem-solving exercise	1 hour

Table 1. A science student's typical weekly timetable

In the **problem-solving exercise** session mentioned in Table 1 students are required to work through the exercise *The Great Metabolic Race* (Figure 3). In this exercise the metabolic activity of a distance runner is monitored at various time intervals to give practical examples of how the body generates energy from the catabolism of various macromolecules.

Figure 3. A preparatory screen from *The Great Metabolic Race* exercise

Students learn to interpret a graph (Figure 4) illustrating the changing dependence on carbohydrates and fats as energy sources throughout the run and monitor their knowledge through a series of questions which are linked to the tutorials.

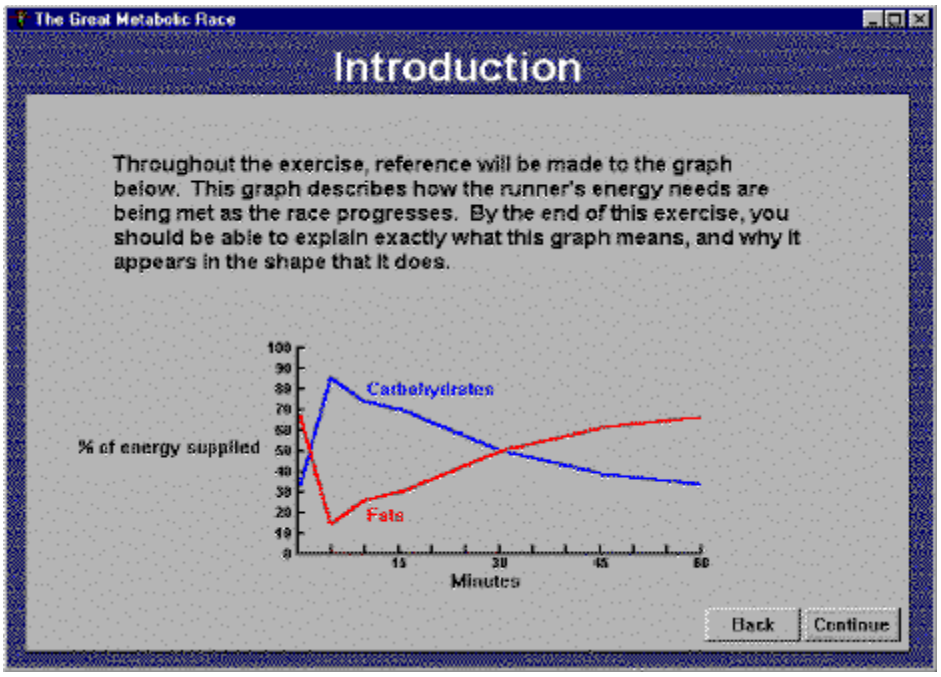

Figure 4. Time course of carbohydrate and fat utilisation in *The Great Metabolic Race*

Student performance in this exercise is scored by the computer and provides useful information about their level of understanding.

In one such question screen, for example (Figure 5(a)), a student who is unsure about the pathways used by the muscle to produce acetyl-CoA for energy generation can obtain assistance from the tutorials using the Index link as shown in Figure 5(b). In this example, the student can click on 'Muscle' in the Index, followed by 'Pathways Utilised by' to find the required information as shown in Figure 5(c). In this manner, students must think logically about how to find the information rather than being led directly to it using hyperlinks.

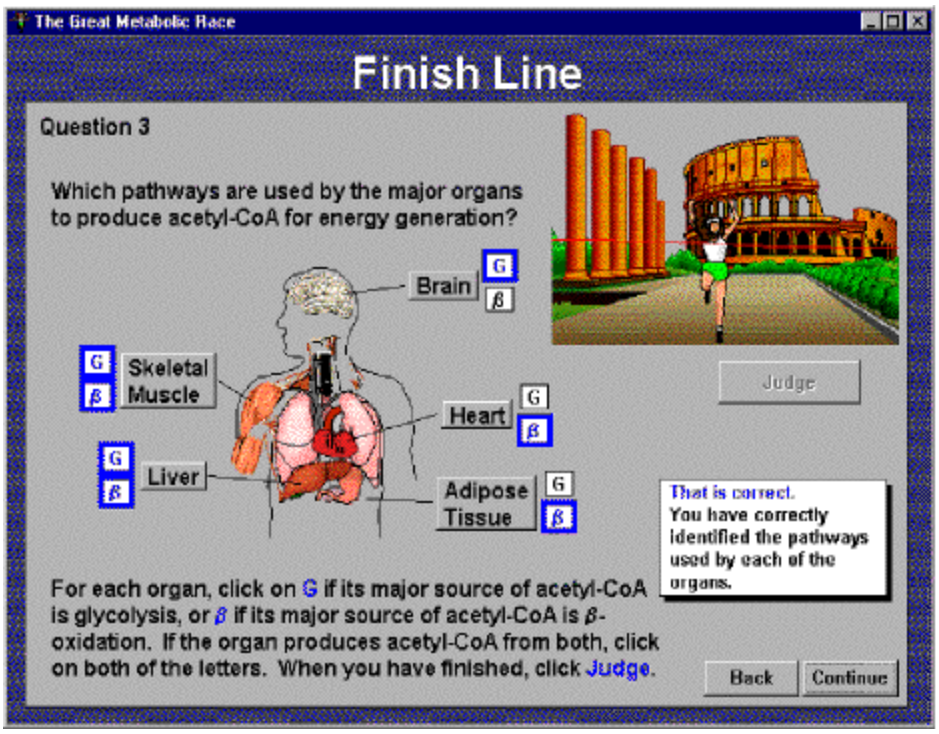

Figure 5(a). A question screen from *The Great Metabolic Race* exercise

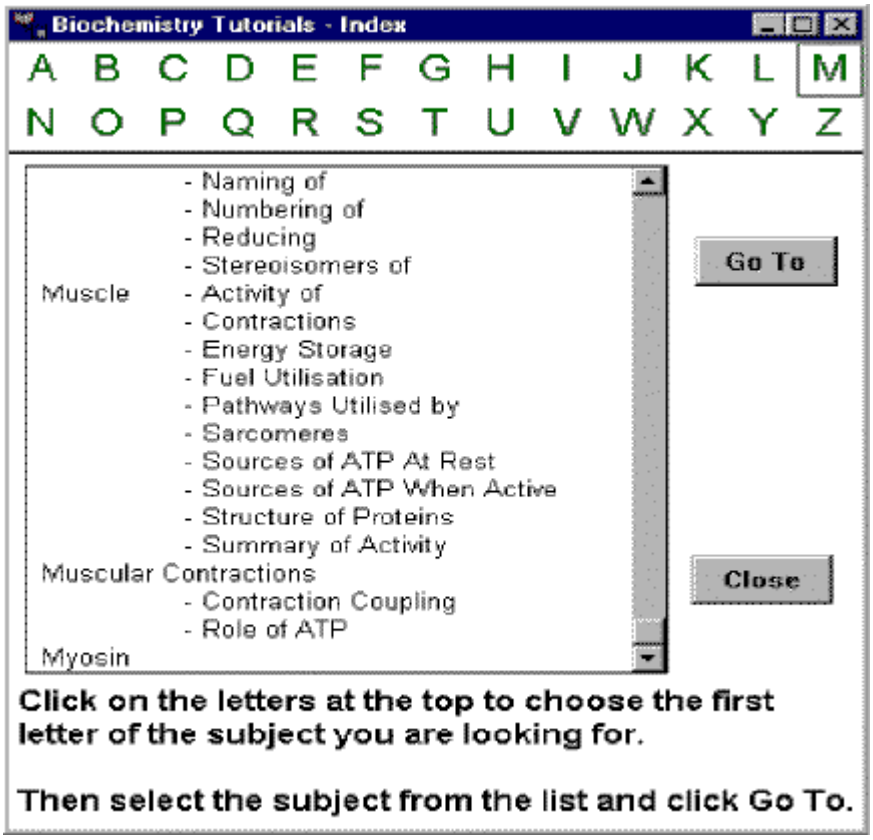

Figure 5(b). The Index linking the exercises and tutorials

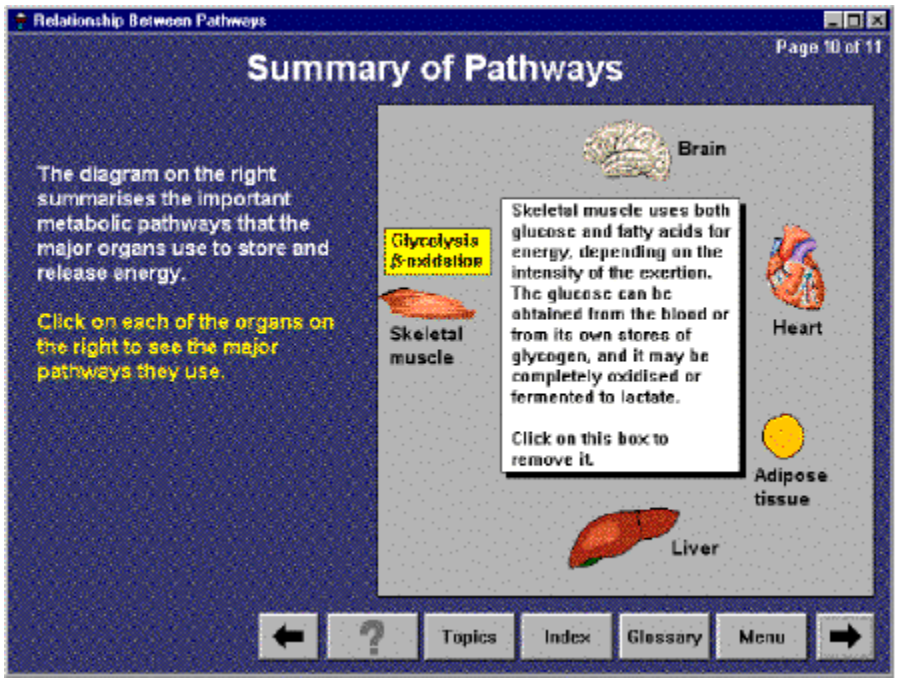

Figure 5(c). Interactive information screen (from the *Relationship between Pathways* tutorial)

On completion of the exercise, students are asked to write an essay of approximately 1000 words to consolidate what they have learned. The essays are discussed in a small group setting with the tutors once they have been corrected.

Biomedical and medical students

Biomedical and medical students constitute two separate groups each of approximately 160-200 students. They tend to be less diverse in their background and generally have a good grounding in chemistry or biology or both. Course entry requirements dictate that they are high academic achievers and generally very highly motivated. The depth of knowledge required in biochemistry is not as great for the medical students as for the science or biomedical students and the emphasis is somewhat more clinical. The course component on metabolism is taught over a period of 10 weeks for medical students and 14 weeks (spread over two years) for biomedical students.

In order to stimulate and challenge these students we have adopted a much more self-directed learning approach whereby students are expected to analyse problems, locate relevant source material and develop habits of independent study. As indicated in Table 2, there is a reduced core of basic lectures, supplemented with SDL tasks that are largely case study based.

Case studies are conducted in small tutorial groups (approximately 10 students) which meet for approximately 3-4 hours (Table 2). Students are expected to prepare for the tutorial in their own time and are responsible for the running of the tutorial. The tutors act merely as facilitators.

Lectures on Carbohydrate Catabolism	2 hours
Self-Directed Learning: "Tissue Metabolism- How do skeletal muscles convert energy stored into mechanical movement?"	1 hour minimum
Case-study: 'Alcohol Metabolism'	3-4 hours
Follow up tutorial on SDL	1 hour

Table 2. A medical student's typical weekly timetable

Students experience great difficulties in integrating concepts taught at different stages of the course, generally by different lecturers. SDL using computer programs and case studies are excellent tools to help overcome these difficulties.

In the **SDL** example used here, students are asked to look at the metabolism of macromolecules by skeletal muscles in various energy states and to correlate the events occurring in the muscles with those in other tissues/organs. Students can test their progress by using multiple choice questions that accompany most screens.

During a **case study** on 'Alcohol Metabolism', students extend their knowledge on 'Tissue Metabolism' by looking at the effects of alcohol on the general pathways. Case studies are held as paper exercises but accompanying computer programs again facilitate the students' task in visualizing and integrating pathways.

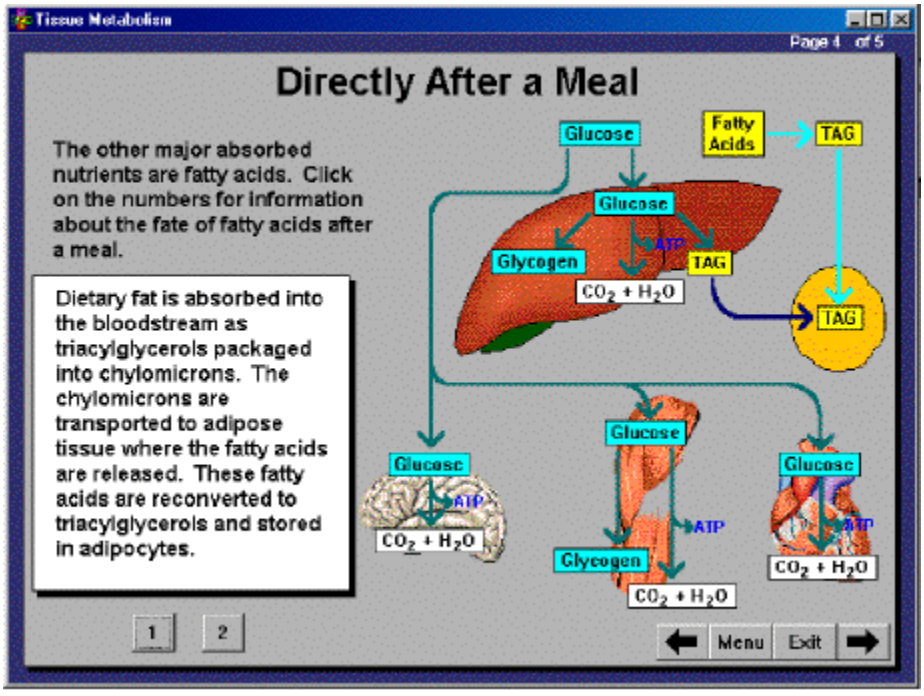

Figure 6. Integration of tissue metabolism

As hinted at in Figure 7(a), the NADH/NAD+ ratio is sensitive to alcohol and students need to explore why this is so, and identify which of the pathways will be affected by changes in this ratio. One example of a relevant pathway is given in Figure 7(b). Only then can the student begin to deduce the impact of excess alcohol on the liver.

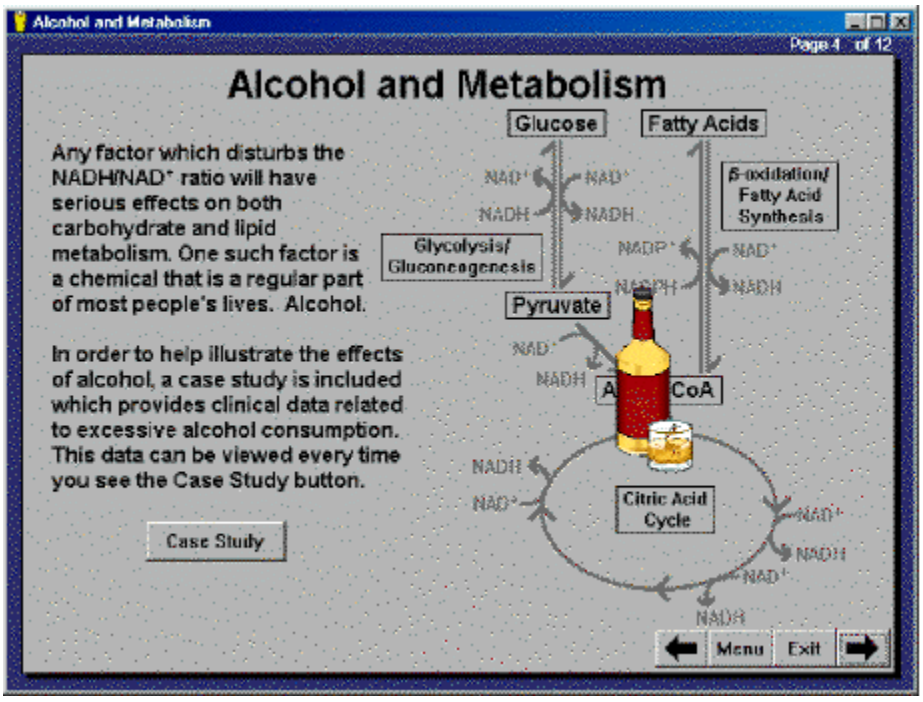

Figure 7(a). NADH/NAD+ sensitive pathways (from the case study on Alcohol Metabolism)

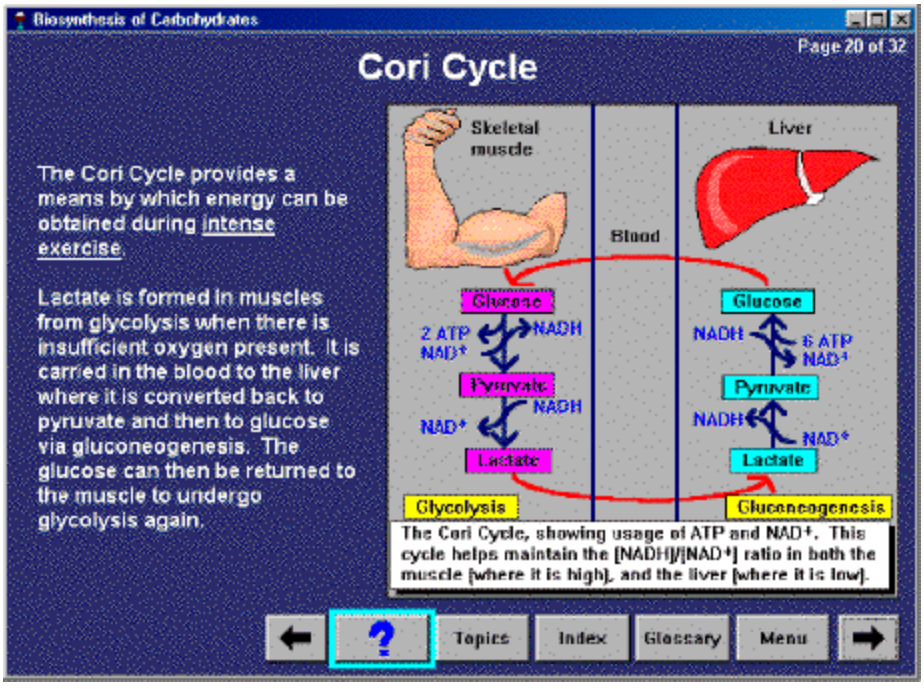

Figure 7(b). One of the pathways which can be affected by over-consumption of alcohol (from the tutorial *Biosynthesis of Carbohydrates*)

Evaluation of the CD-ROM's educational value

Response to surveys conducted with science students (250), biomedical (150) and medical students (160) indicated that 90% of students gave a score of 4/5 or above in terms of improving their understanding of the subject. The same percentage of students preferred this **Problem-Based Learning** approach to the more traditional didactic teaching. Although not all programs on the CD-ROM were part of a compulsory exercise, the survey showed that over 50% of the students had worked through all of these exercises.

It is felt that students' performance in essay writing has improved since the introduction of the CD-ROM into the biochemistry course and continuous feedback from the students has indicated how much more enjoyable and rewarding the learning of biochemistry has become.

A recent survey conducted with medical students who participated in the **Self-Directed Learning** sessions indicated that this mode of learning is preferable even though it is considerably more time consuming for students. SDL is also more time consuming for staff as followup tutorials are conducted in small groups requiring several staff members to be conversant with the topics.

Demonstrations of the exercises are accessible at
http://www.med.monash.edu.au/biochem/cdrom/metab.htm

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