

*Research article***Evolution in Health and Disease: The Role of Evolutionary Biology in the Medical Curriculum**

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*Date Received 13/05/2004      Date Accepted 10/09/2004*

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**Abstract**

*Recent work has emphasised the relevance of evolutionary processes to medical thinking and practice. However, medical curricular revisions, in reducing basic science content, have often excluded evolution. This study establishes the extent of inclusion of evolution in UK medical courses, reports on the level of medical student rejection of evolution, and on student reactions to a special study module (SSM) approach to evolution's relevance to medicine.*

*A questionnaire survey was sent to course directors of all UK medical schools on evolution in the curriculum. First year medical students completed a questionnaire on their acceptance or rejection of evolution. Students completing an SSM on Evolution in Health and Disease evaluated the course by questionnaire.*

*Only 37% of responding medical schools included evolution in the curriculum. 10% of medical students surveyed did not accept long-term evolution, though most rejectors accepted that natural selection works within species. Rejection of evolution was firmly linked to a religious belief in a creation account, not to any consideration of the evidence. Rejection influenced attitudes to the intergenerational equity issue of drug resistance evolution. Students taking the SSM on Evolution strongly appreciated its relevance to medicine.*

*It is recommended that evolutionary biologists should urgently work with medical schools to develop courses in evolutionary medicine that will help clinicians in training to appreciate the importance of evolutionary processes in medical practice.*

**Keywords:**

evolutionary medicine; Darwinian medicine; medical education; health; disease

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**Introduction**

*Tomorrow's Doctors* (General Medical Council, 1993) summarised the prolonged debate over the content of the undergraduate medical curriculum in the UK, quoting Thomas Huxley's complaint, as long ago as 1876, of "the burden we place on the medical student . . . a system of medical education that is actually calculated to obstruct the acquisition of sound knowledge and to heavily favour the crammer". Matters got worse, if anything, following the recognition of the need for the curriculum to include the basic sciences relevant to medicine: human biology, biochemistry, anatomy and physiology.

For the present paper, Huxley's more famous role, as "Darwin's bulldog", the tireless promoter of the theory of evolution by natural selection, is equally relevant, in a discussion of the role of evolutionary biology in the medical curriculum.

*Tomorrow's Doctors* recognised the need for medical practitioners to be able to keep up with the latest scientific advances and to maintain an open-minded enquiring attitude to their work. The report recommended that this could be best achieved by encouraging an active approach to learning and that it was time to abandon the notion that all medical students needed to master a vast common curriculum. The report's prescription was for the identification of a core of knowledge, skills and attitudes, combining basic science and clinical medicine. In addition, students should deepen their knowledge and understanding through a set of optional special study modules (SSMs), most of which should be in subjects related to medicine.

Many medical schools responded by carrying out thorough re-structuring and revision of the undergraduate curriculum. For example, at the University of Glasgow, the course was converted into three strands: a problem-based learning (PBL) core; vocational studies; and a range of optional SSMs. In the core, students examine fundamental cases, and explore underlying causes and possible solutions via these cases. The distinction between preclinical and clinical years is abandoned in this re-structured approach, which has much to commend it, but a possible criticism is that key aspects of underlying science may be completely omitted, because they do not relate easily to particular cases.

One such aspect may be evolutionary biology and its relationship to medicine. Three recent books by Nesse and Williams (1995), Stearns (1999) and Trevathan *et al*(1999) have emphasised the relevance of evolutionary biology to medicine. Nesse and Williams also emphasised the importance of a treatment of evolution in medical education. It was my impression, however, that the revised medical curriculum had paid little heed to Nesse & Williams's recommendation. Moreover, previous reports (Short, 1994; Downie and Barron, 2000) have shown that surprisingly large numbers of medical students do not accept the theory of evolution.

This paper reports on:

- A survey of the coverage of evolutionary biology in UK undergraduate medical curricula.
- A survey of medical students' attitudes to evolution.
- A special study module on Evolution in Health and Disease and student responses to it.

A short account of this work has appeared in the *Lancet* (Downie, 2004).

## **Methods**

### **Medical School Survey**

In November 2001, Heads of all 27 Medical Schools in Scotland, England, Wales and Northern Ireland were sent a covering letter drawing attention to Nesse and Williams's book and asking that the director of the undergraduate medical course complete a short questionnaire on the teaching of evolution within medical courses. Over the next few months, 18 replies were received of which two were from either a postgraduate-only school or a school whose curriculum was still under development. Appendix 1 gives the text of the questionnaire.

### **Medical Student Survey**

This survey involved an anonymous questionnaire completed by first year medical students at the University of Glasgow in a class right at the start of the core course in Term 1 of 2002 (having the survey completed during a class ensured a high return rate). The questionnaire form was headed "Evolution : fact, theory or belief?" and began with a preamble pointing out the different status of the theory of evolution among professional biologists (overwhelmingly accepted) and the general public (not so sure). It also reminded the students that the theory has two parts (a) that evolution has happened; (b) that natural selection is the main mechanism. The preamble emphasised that the questionnaire was mainly about the occurrence of evolution, not about how it may have happened.

The first question asked students to grade their previous exposure to evolutionary biology. The second asked whether or not they accepted that some kind of biological evolution, lasting millions of years, had occurred on earth. On the basis of this answer, students proceeded to either section A or section B, each of which contained five or six questions, three of which were identical in the two sections. The text of the questionnaire is given as Appendix 2.

To analyse the data, completed questionnaires were separated into acceptors and rejectors of evolution. All rejectors (the minority) were analysed in detail. For the much larger number of acceptors, a random sample was analysed (60 - a third of the total).

Since close to 90% of the whole class completed questionnaires and handed them in anonymously, there should be little prospect of bias in the sample, or incentive to make false responses.

### **Course evaluations: *SSM in Evolution in Health and Disease***

At the end of an SSM in Evolution in Health and Disease, which has run for 4 years (2000-2004) at the University of Glasgow, students were asked to complete an evaluation form. Some of the questions were for quality assurance purposes, but others asked the students to assess the value of the course as part of the medical curriculum. Data from these questions are presented here.

## Results

### **Medical School Survey**

The courses of all the medical schools surveyed had been revised, in different ways, as a result of the *Tomorrow's Doctors* recommendations.

Question 1 asked whether or not evolution is covered in the course. 63% (10) answered no, 37% (6) yes.

Question 2 asked whether the respondent was aware of any significant number of students not accepting the occurrence of biological evolution. 75% (12) answered no (with one noting that he had not tried to find out); 19% (3) felt that there would be a small number, one guessing that there could be 1-2 in a class of 280; only 6% (1), answered yes.

Question 3 asked whether the teaching of evolution in the course fell within the guidelines recommended in *Tomorrow's Doctors*. 50% (8) responded yes, though one felt that evolution should not be part of the core; 44% (7) responded no; one did not answer on the basis of being unclear about the context.

Where evolution was part of the course, what kind of coverage did it receive? 67% (4) taught evolution as an option, with about 10% of students taking it. The remainder (2) included some coverage of evolution in the core.

When evolution was not part of the course, possible reasons were given as options. 62% (8) ticked "in the most recent revision of our course we never considered inclusion of evolution". 23% (3) ticked "we consider evolution as of too little relevance to medicine for inclusion in a crowded curriculum". Options chosen by single respondents were: "omission of much fundamental science previously taught included evolution"; and, "only a minority of staff considered that evolution should be covered".

### **Medical Student Survey**

#### **Acceptors and rejectors**

In 2002, 10.8% of first year medical students (24 from a sample of 223 : 88% of the class) rejected the proposition that "some kind of biological evolution, lasting many millions of years, has occurred on earth". This was nearly identical to the 10.2% reported for 1999 by Downie and Barron (2000) and a little higher than their 9 year average for first year biology students (7.3%).

#### **Reasons for rejecting / accepting evolution**

Since it was possible that rejection of evolution was the result of too little exposure to the subject in prior education, students were asked to assess how much they had learnt about evolution before studying medicine. They responded on a five point scale (from very little to a lot) and also stated the context (e.g. A level Biology). Results are shown in Table 1. Although there was a clear difference in the level of prior knowledge claimed by evolution rejectors (mainly low) compared to acceptors (mainly medium or high),

background coursework was very similar: mainly A level Biology or Scottish Higher Biology. Rather more of the acceptors than rejectors had a previous degree in a biological science, but not usually one with a high evolution content.

### Table 1

*Level of knowledge gained about evolution, before studying medicine. Students responded on a 5 point scale. In analysis, 1 - 2 combined = low; 3 = medium; 4 - 5 = high. Data given as percentages, with real numbers in brackets.*

<i>Group</i>	<i>Present</i>	<i>Half and half</i>	<i>Future</i>
Rejectors	46%(10.5)	50%(11.5)	4%(1)
<b>Acceptors</b>	37%(22)	49%(29)	14%(8)

Rejectors showed their reasons for rejecting evolution by ticking as many of a set of statements as they felt applied to them. Results are shown in Table 2a. The predominant reason given for rejection was acceptance of the literal truth of a religious creation account. Only two students wrote in "other" reasons: one was concerned by "gaps" in Darwin's theory; another could accept changes within species, but not the origin of new species.

Similarly, acceptors showed their reasons for accepting evolution - Table 2b. Very few took the "teacher knows best" option, and rather more favoured the lack of good alternatives than that the available evidence was clear. Those writing in other points gave varied responses : some noted that though they accepted that there is evidence, it is certainly not clear and unambiguous; others noted that they accepted evolution had a lot to do with the origin of species, but that some kind of supernatural being may also have had an influence, especially on human origins.

**Table 2**

*Reasons for rejecting or accepting evolution: percentage of students (number in brackets) choosing the various reasons. Percentages do not total 100 because students were asked to tick all the reasons that applied to them.*

<i>a) Reasons for rejecting evolution</i>	<i>Percentage (number)</i>	
The evidence for evolution is full of conflicts and contradictions	35%	(8)
I accept the literal truth of a religious creation account that excludes evolution	91%	(21)
I think that there are other good alternatives to evolution that explain the origin and distribution of species	4%	(1)
Other (please state)	9%	(2)
<i>b) Reasons for accepting evolution</i>		
The evidence for evolution is clear and unambiguous	45%	(27)
I tend to accept what my teachers say: they know the evidence much better than I do	7%	(4)
I do not think there are good alternatives to evolution that explain well the origin and distribution of species	57%	(34)
<b>Other (please state)</b>	10%	(6)

As a follow-up to the reasons for rejecting / accepting evolution, students were asked to state their religion (emphasising that they should write in "none" if they had no faith). Results are shown in Table 3. Amongst the rejectors, not a single student claimed to have no religion, whereas 39% of acceptors stated "none". However, having a religion clearly did not preclude acceptance of evolution.

**Table 3**

Proportions (% and numbers) of the different religions stated by evolution rejectors and acceptors. Catholics were the biggest single type of Christianity stated: data given separately as well as included in All Christianity.

Religion	Rejectors	Acceptors
All Christianity	96% (23)	56% (33)
Catholic	21% (5)	25% (15)
Islam	4% (1)	3% (2)
Judaism	0	2% (1)
<b>None</b>	0	39% (23)

### Microevolution and drug resistance

To probe into the implications of evolution rejection, students were asked questions about microevolution and the appearance of drug resistance amongst pathogenic micro-organisms.

First, evolution rejectors were asked whether they accepted that natural selection could operate within a species to adapt individuals to fine scale environmental change. Interestingly, 96% of the rejectors accepted this proposition, with only one dissenter. Next, the appearance of drug resistance in micro-organism populations, following the introduction of drugs, was explained as an example of natural selection, and students were asked to accept or reject the explanation. There was no difference between the two groups: 96% of evolution rejectors accepted the proposition, as did 97% of the acceptors. Finally, it was pointed out that drug resistance evolution posed a possible equity conflict between present and future generations i.e. heavy use of an effective drug today may make it useless in treating future patients. Students were asked whether their duty should be mostly to present or future patients. Results are shown in Table 4. Interestingly, the evolution acceptors were more prepared to consider a duty to future generations than the rejectors, a possible example of how evolution education could influence medical practice.

**Table 4**

Drug resistance evolution: responsibility to present and future patients. Students responded on a 5-point scale: 1-2 = mostly to the present; 3 = half and half; 4-5 = mostly to the future. Data given as percentages, with real numbers in brackets.

Group	Present	Half and half	Future
Rejectors	46%(10.5)	50%(11.5)	4%(1)
Acceptors	37%(22)	49%(29)	14%(8)

### Evolution and medicine

Students were asked to rate the relevance of evolutionary biology to an understanding of medicine. Results are shown in Table 5. Not surprisingly, evolution rejectors saw little relevance in evolution as contributing to medical understanding. However, it is interesting that the evolution acceptors not only

accepted that evolution occurs, but a high proportion saw it as relevant to an understanding of medicine.

**Table 5**

*Relevance of evolutionary biology to medicine. Students responded on a 5-point scale: 1-2 = low; 3=medium; 4-5 = high. Data given as percentages, with real numbers in brackets.*

Group	Low	Medium	High
Rejectors	83%(19)	13%(3)	4%(1)
Acceptors	20%(12)	45%(27)	35%(21)

### **Special Study Module: Evolution in Health and Disease**

At the University of Glasgow, an SSM in Evolution in Health and Disease is offered as an option to third year medical students and has so far been taken by 13, 17, 20 and 22 students in successive years, building to about 9% of the class. The course lasts 5 weeks and includes seminars, discussions and student assignments (an oral presentation and a written assignment, chosen from a wide range of topics). The main features of the course are given in Appendix 3.

In the end of course evaluation, students were asked how suitable the course is as a medical SSM. Over the four years, over 90% regarded the course as very suitable and interesting, with only a few regarding it as merely OK, and no-one rating it as unsuitable. Several wrote that the course was thought-provoking and more relevant to medicine than anticipated, though a few others felt that it would have marginal relevance to their future work. In the two most recent years, students were asked to rate the importance of a course like Evolution in Health and Disease as part of the medical course. 10% (4) rated it as of low importance, 60% (24) rated it as important or very important, with 30% (12) being in between. This suggests that students who had completed the course appreciated the importance of evolution in medicine more than the general population of evolution acceptors as shown in Table 5.

### **Discussion**

Nesse and Williams (1995) subtitled their book "the new science of Darwinian medicine". It was a conscious attempt to integrate evolutionary biology and medicine. Williams was impressed by Ewald's (1980) work on the effects of evolutionary processes on our treatments of infectious diseases; Nesse was hopeful that evolutionary biology could provide a theoretical foundation for understanding human behavioural disorders. They made a strong recommendation that evolution should be a key theme in medical education: *"when evolution is included, it will give students not only a new perspective on disease, but also an integrating framework on which to hang a million otherwise arbitrary facts. Darwinian medicine could bring intellectual coherence to the chaotic enterprise of medical education"* (p.245). This statement is a conscious echo of Dobzhansky's (1973) famous article "Nothing in biology makes sense except in the light of evolution".

Some medical educators will think that evolution was previously taught as part of basic biology in pre-clinical medicine, and was removed along with anything

else that was not directly relevant to medical practice. As Nesse and Williams (1995) point out (p.241), it has taken biologists some time to address the evolution of disease processes and how the body reacts to them: in older curricula, evolution was taught as part of pure biology, not for its relevance to medicine.

Since Nesse and Williams, two further books by Stearns (1999) and Trevathan *et al.* (1999), both multi-author works, have addressed the topic of evolutionary medicine, though neither paid significant attention to education. However, Day's preface to Trevathan *et al.* concludes: "the doctors of the future will find it necessary to take account of the biological imperatives that Darwin revealed if they are to have any real understanding of their trade as it will be practised in the new millennium".

In the light of these comments, the results of the medical schools survey reported here are worrying. Rather few include evolutionary biology at all, and when included, usually only as an option. Lee's (1995) enthusiastic *Lancet* review of Nesse & Williams noted "what is surprising is the lack of serious and purposeful discussion, teaching and research of this subject in medicine". For any clinician who doubts the importance of evolutionary processes in medical practice, Palumbi's (2001) review of the speed of evolution of antibiotic resistance, and its costs to the US economy, is salutary reading: he also makes proposals on how an understanding of evolutionary processes can help us modify treatment practice so as to avoid the rapid obsolescence of drugs.

How best can evolutionary or Darwinian medicine be incorporated into the curriculum? In my view, the core of the medical curriculum should have some introduction to evolution's role in shaping our anatomy, physiology and behaviour, and to key evolutionary concepts such as natural selection and trade-offs. Such an introduction could establish the legitimacy of evolutionary biology in medicine and act as a 'taster' for students who wished to learn more, in the form of a Special Study Module (SSM). As MacNaughton (1997) emphasised, SSMs give an un-missable opportunity for imaginative innovation in the medical curriculum. A review of progress since the first edition of *Tomorrow's Doctors* (Christopher *et al.*, 2002) noted that many medical schools have introduced an enterprising range of SSMs, but that others have been more restrictive. The second edition of *Tomorrow's Doctors* (General Medical Council, 2002) emphasised the importance of student-selected course components, and under the scientific basis of medical practice, stated that graduates should have an understanding of the natural history of human diseases, including the genetic and environmental factors that determine disease and response to treatment. In my view, this understanding will be seriously incomplete without coverage of evolution. The class survey results from Glasgow's SSM in Evolution in Health and Disease show that the students fully appreciate the relevance of the subject to medicine.

A possible problem for the integration of evolutionary biology into medical education is the attitude of some students. The survey reported here, added to Downie and Barron's (2000) results, suggest that around 10% of medical

students reject the basic idea of long term biological evolution. This is fewer than the 27% of Australian medical students reported by Short (1994) and no doubt many fewer than in the USA, where surveys show that 45% of the general public reject evolution (Scott and Branch, 2003), but it is many more than the 1-2 from a class of 280 guessed by one UK medical school director in this study. The students surveyed here may be different from elsewhere in the UK, but there is no evidence for this.

As in Downie and Barron's (2000) survey, the principle factor in evolution rejection was the acceptance of the literal truth of a religious creation account that excludes evolution. Although evolution rejectors felt that they were more poorly informed about evolution than acceptors, this was not supported by their previous biological education, which was very similar in the two groups. The worrying conclusion, then, is that a significant group of our cleverest students, undertaking education and training in a highly evidence-based discipline, are prepared to reject an important part of modern science on the basis of an inculcated belief, rather than a consideration of the evidence.

However, the situation may not be so bad in terms of the practical implementation of evolution in medical education. Follow up questions made clear that what creationist students objected to was long-term evolution and the origin of humans from animal ancestors: they were willing to accept that natural selection worked within species to allow adaptation to environmental change. Erecting such a dichotomy irritates evolutionary biologists, but may allow large-scale evolution rejectors to investigate and understand the interactions between humans and diseases in evolutionary terms, and the medical consequences of selection on our own species.

However, large-scale evolution rejection does colour students' attitudes on the relevance of evolutionary processes to medicine. Rejectors rated relevance much lower than acceptors and in their responses to the question on treatment regimes, were much more likely to favour their duty to present over future patients than were the evolution acceptors. This indicates that attitudes to evolution can have an influence on medical practice.

## **Conclusion**

Evolution is a foundation of modern biology and therefore a unifying principle in biological science courses. However, recent revisions of medical courses have largely deleted a treatment of evolution, just at the time when the direct relevance of evolutionary thinking to disease processes and medical practice has begun to be appreciated. Given the lack of evolutionary expertise in most medical departments (see Lee, 1995; also note the lack of clinical contributors to the multi-author volumes edited by Stearns, 1999 and Trevathan *et al.*, 1999), it is likely that a proper coverage of evolution and its relationship to health and disease will only enter modern medical courses if evolutionary biologists make the effort to advocate it. This advocacy should be aimed at introducing a short treatment of evolutionary biology and its relevance to medicine to the core of the course, with more detail kept to an optional special study module. This twin strategy should help significant numbers of future

clinicians to appreciate the importance of evolution in medicine, and to work with biologists to increase our understanding.

### Acknowledgements

I wish to thank all those who kindly completed questionnaires: first year medical students, third year students in the SSM on Evolution; and medical course directors around the UK. I also thank several colleagues for commenting on a draft of this manuscript and for contributing to the design and delivery of the evolution SSM.

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## Appendix 1:

### Medical School Questionnaire

#### SECTION A

1. Is evolution covered in your medical course?  
If your response is NO, proceed to Section B.  
If your response is YES, proceed to questions 2-6.
2. Please tick the kind of coverage of evolution that your course includes (tick as many as apply).
  - a) A course on evolution as a fundamental part of biological science
  - b) A course on the relevance of evolution to modern medicine
  - c) Evolution is taught as part of the core of our course
  - d) Evolution is available as an option in our course
3. Where evolution is taught as an option, approximately what proportion of your students choose to take it?
4. Are you aware of any significant number of your students not accepting the occurrence of biological evolution?
5. Do you regard the teaching of evolution in your course as falling within the guidelines recommended in "*Tomorrow's Doctors*"?
6. Please provide here any further comments you would like to make on the teaching of evolution in medical courses.

#### SECTION B

7. Your course may not include evolution for a number of possible reasons. Please tick any that apply in your case:
  - a) In the most recent revision of our course, we never considered inclusion of evolution.
  - b) We consider evolution as of too little relevance to medicine for inclusion in a crowded curriculum.
  - c) Our response to *Tomorrow's Doctors* omitted a considerable amount of fundamental science, and our previous coverage of evolution was one of the topics to be left out.
  - d) Some of our staff consider that evolution should be covered, but they are a minority.
  - e) Other reason(s) - please state
8. Are you aware of any significant number of your students not accepting the occurrence of biological evolution?
9. Would you regard the teaching of evolution as falling within the guidelines recommended in *Tomorrow's Doctors*?
10. Please provide here any further comments you would like to make on the teaching of evolution in medical course.

## Appendix 2

### Evolution: fact, theory or belief?

#### QUESTIONNAIRE

Please take a few minutes to read and complete this short questionnaire.

Introduction: For most professional biologists, the evidence for the occurrence of evolution is overwhelming. But how evolution happens, and is happening, is a matter of considerable debate. Hundreds of scientific papers each year are concerned with this question - though most agree that Darwin's explanation of evolution by natural selection is of central importance.

However the general public is not so sure: the "average person" would have a very hazy idea of how good the evidence for evolution is, and what natural selection as a process is. This, of course, is not too different from the situation concerning most scientific ideas, where the general public tends to be poorly informed.

Biology students are in status half-way between the two: not quite professional biologists, but better informed on biological matters than the general public. Medical students are in a similar position, with much of what you learn being based on biological research findings as applied to the human body and diseases.

In this questionnaire, we are interested in your beliefs about evolution, and what influences those beliefs.

N.B. 1) This questionnaire is about the *occurrence* of evolution, not about how it may have happened.

2) If you wish to make any comments on the questionnaire, write them below, or contact Dr J R Downie, Graham Kerr Building. (J.R.Downie@bio.gla.ac.uk).

#### **Evolution questionnaire**

R1 Grade how much you have learnt about evolution before studying medicine (from 1 = very little to 5 = a lot)

Circle            1            2            3            4            5

Also, state the context of that learning (e.g. Higher or A Level Biology)

Context:

R2 Do you accept that some kind of biological evolution, lasting many millions of years, has occurred on earth?

Circle            YES    NO

If your answer to R2 is NO, go to Section A;      If your answer to R2 is YES, go to Section B

### **Section A**

R3 You may have several possible reasons for rejecting evolution as a mechanism for producing the existing variety of living things. Please **tick** those that apply to you.

\_\_\_\_\_ a) The evidence for evolution is full of conflicts and contradictions.

\_\_\_\_\_ b) I accept the literal truth of a religious creation account that excludes evolution.

\_\_\_\_\_ c) I think there are other good alternatives to evolution that explain the origin and distribution of species.

\_\_\_\_\_ d) Other reasons - (please state)

R4 Please state your religion; if you have none, please state 'none', rather than leaving this blank.

R5 You may reject the idea that species can change from one kind to another, yet, accept that natural selection can operate within a species to adapt to fine scale environmental change.

Do you accept that natural selection of this kind occurs?

**Circle** -    YES            NO

R6 Give your rating of the relevance of evolutionary biology to an understanding of medicine from

1 = very little to 5 = very high, by circling the appropriate number.

1      2      3      4      5

R7 In your view should evolution be included in a medical course?

**Circle**    YES            NO

R8 It has been a common finding that following the introduction of a drug to treat a disease caused by a micro-organism (such as bacteria, or the malaria parasite), the micro-organisms become increasingly resistant to the drug. Evolutionary biologists claim this is an example of natural selection: that the presence of the drug in the micro-organism's environment selects for resistant variants.

a) Do you accept this explanation?      **Circle** -    YES            NO

b) In the case of such drugs, there is a possible conflict of interest between present and future patients i.e. heavy use of the drug now may make it useless in treating future patients.

In treating patients, assess whether your duty is mostly to present patients (= 1) or to the future (= 5)

**Circle**            1            2            3            4            5

c) Comment briefly on the reasons for your choice -

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### **Section B**

R9 You may have several possible reasons for accepting evolution as the mechanism for producing the existing variety of living things. Please tick those that apply to you.

\_\_\_\_\_ a) The evidence for evolution is clear and unambiguous

\_\_\_\_\_ b) I tend to accept what my teachers say; they know the evidence much better than I do

\_\_\_\_\_ c) I do not think there are any good alternatives to evolution that explain well the origin and distribution of species

\_\_\_\_\_ d) Other reasons (please state)

R10 Some opponents of evolution act out of religious belief. Please state your religion, if you have one. If none, please state 'none' rather than leaving this response blank.

R11 Give your rating of the relevance of evolutionary biology to an understanding of medicine from

1 = very little to 5 = very high, by circling the appropriate number.

**Circle**            1            2            3            4            5

R12 In your view should evolution be included in a medical course?

**Circle**            1            2            3            4            5

R13 It has been a common finding that following the introduction of a drug to treat a disease caused by a micro-organism (such as bacteria, or the malaria parasite), the micro-organisms become increasingly resistant to the drug. Evolutionary biologists claim this is an example of natural selection: that the presence of the drug in the micro-organism's environment selects for resistant variants.

a) Do you accept this explanation?      **Circle** -      YES      NO

b) In the case of such drugs, there is a possible conflict of interest between present and future patients i.e. heavy use of the drug now may make it useless in treating future patients.

In treating patients, assess whether your duty is mostly to present patients (= 1) or to the future (= 5)

**Circle**              1              2              3              4              5

c) Comment briefly on the reasons for your choice -

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### Appendix 3

- Special Study Module: Evolution in Health and Disease course content.
- Aims: to outline the theory of evolution and discuss its relevance to human health and disease; to develop an appreciation of evolution's keystone role in modern biology and its consequent relevance to many concepts in medicine.
- Outline: The theory of evolution is the keystone of modern biology, and biology is the scientific foundation of modern medicine. It is strange, therefore, that medical courses pay so little heed to evolutionary biology. This module outlines the main concepts of the theory of evolution, discusses the evolution of the human species and the nature of the dynamic interactions with our environment, including the organisms which can cause disease. In the light of the well-known example of the evolution of antibiotic resistance, the course discusses what impact an evolutionary perspective could have on the design and delivery of a health service.
- Seminars: eleven three-hour sessions on –
  1. Evolution: origins of the theory, and basic principles.
  2. Human evolution: origins, diversification, colonisation of the world: how we define species.
  3. Evolution of ageing.
  4. Repair systems: from molecules to organs.
  5. The human skeleton: evolutionary origins and associated problems.
  6. Understanding human physiology - an evolutionary perspective.
  7. Coping with diseases: evolution of the immune system.
  8. Multifactorial inheritance: the role of genes in disease.
  9. The arms race - counter evolution of the immune system and pathogens.
  10. Human nutrition - the ancestral human diet. Why are we so fat?
  11. Evidence for evolution and natural selection in human beings.
- Discussions: three two-hour sessions on -
  1. The perfectability of man.
  2. The impact of evolutionary biology on medicine.
  3. Malaria eradication: evolution and ecology.
- Assignment: each student to deliver an oral presentation and complete a 2500 word written assignment on two topics from the following list -
  1. The puzzle of hypertension in African-Americans.
  2. Evolutionary origins of alcoholism.
  3. The costs of immunity.
  4. Evolutionary loss of hair by humans.

5. Evolutionary significance of the human diet.
6. The evolution of female reproductive cancers.
7. The evolution of disease.
8. Symmetry as a sign of good genes.
9. The origin of AIDS.
10. Evolution of the menopause.
11. Evolution of homosexuality.
12. Evolution of menstruation.
13. The many causes of diabetes.
14. Does selection maintain disease - causing recessive mutations in humans?
15. Is morning sickness adaptive?
16. Biodiversity and human health.
17. Is rape adaptive?
18. What is the adaptive value of human emotion?
19. The evolutionary significance of aggression in human societies.
20. Sexual selection and the evolution of modern man.
21. Limits on human locomotor performance.
22. Evolution and ecology of influenza.
23. The significance of cannibalism in human societies.
24. The evolution of morality.
25. What is Darwinian agriculture?