ASTROBIOLOGY
Volume 9, Number 8, 2009

DOI: 10.1089/ast.2009.0348

Education Article

Survey on Astrobiology Research and Teaching Activities Within the United Kingdom

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Abstract

While astrobiology is apparently growing steadily around the world, in terms of the number of researchers drawn into this interdisciplinary area and teaching courses provided for new students, there have been very few studies conducted to chart this expansion quantitatively. To address this deficiency, the Astrobiology Society of Britain (ASB) conducted a questionnaire survey of universities and research institutions nationwide to ascertain the current extent of astrobiology research and teaching in the UK. The aim was to provide compiled statistics and an information resource for those who seek research groups or courses of study, and to facilitate new interdisciplinary collaborations. The report here summarizes details gathered on 33 UK research groups, which involved 286 researchers (from undergraduate project students to faculty members). The survey indicates that around 880 students are taking university-level courses, with significant elements of astrobiology included, every year in the UK. Data are also presented on the composition of astrobiology students by their original academic field, which show a significant dominance of physics and astronomy students. This survey represents the first published systematic national assessment of astrobiological academic activity and indicates that this emerging field has already achieved a strong degree of penetration into the UK academic community. Key Words: Research—Teaching—United Kingdom—Astrobiology Society of Britain (ASB). Astrobiology 9, 717–730.

Introduction and Background

Addressing the question of the possibility of life existing beyond Earth requires the synergy of many disciplines, including biology, chemistry, geology, planetary science, and astronomy. This combined field of research has come to be termed *astrobiology*. As well as being inherently multidisciplinary, the emerging science of astrobiology has already become a truly international endeavor. For example, attendees and co-authors of both oral and poster papers presented at AbSciCon 2008, a biennial US astrobiology conference that held its fifth meeting in 2008, constituted representatives from 33 countries: Argentina, Australia, Austria, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Hungary, Iceland, India, Republic of Ireland, Israel, Italy, Japan, Republic of Korea, Mexico, Netherlands, New Zealand, Norway, Russia, South Africa, Spain, Sweden, Switzerland, Taiwan, Trinidad and Tobago, United Kingdom, and the United States (abstracts given in *Astrobiology* volume 8, number 2, 2008).

There is additionally the sense that astrobiology is currently enjoying something of a Golden Age in that it has become rapidly more generally accepted by the scientific community and benefits from extensive media coverage and public interest. Two new dedicated astrobiology journals have been started in the last eight years, *Astrobiology* (founded in 2001 by Mary Ann Liebert, Inc., USA) and the *International Journal of Astrobiology* (founded in 2002 by Cambridge University Press, UK). There are also other long-standing journals, such as *Origins of Life and Evolution of Biospheres* (started in 1968 and published by Springer), which address specific issues that relate to the origin of life, a key issue for astrobiology.

Astrobiology in the USA

The United States unarguably has the strongest national astrobiological effort. Unlike other national programs, a significant proportion of US astrobiology is overseen and funded by a central organization, the NASA Astrobiological Institute (NAI; http://astrobiology.nasa.gov/nai). Other funding streams for astrobiology within the US include research institutions themselves; the NASA program in exobiology; evolutionary biology, planetary exploration, and

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instrument development; as well as the National Science Foundation, which supports projects of astrobiological relevance. However, while the NAI is by no means the sole funding or coordinating agency for astrobiology in the US, it is the only organization to have reviewed and assessed the range of astrobiology research on a national level.

The NAI was founded in 1997 with several key stated goals, which include promoting the formation of interdisciplinary teams and managing research efforts nationwide to build a coherent astrobiology community, training the next generation of astrobiology researchers, and supporting education and outreach activities to enable public access to NASA-supported astrobiology research (Committee on the Review of the NAI, 2008). The NAI currently consists of 16 research teams, or "nodes," that involve approximately 600 investigators distributed across roughly 150 institutions, all administered by a director based at NASA Ames Research Center (Committee on the Review of the NAI, 2008). The NAI has been assessed twice. First, in 2001, the Space Studies Board and the Board on Life Sciences undertook a study to assess NASA's astrobiology program (Committee on the Origins and Evolution of Life, 2003). While favorable, the review concluded that insufficient time had yet passed to assess whether the contributions of the individual NAI nodes were greater than the sum of their parts and, thus, whether the NAI's funding structure produced net benefit. It was recommended that a comprehensive review of the scientific and educational output of the NAI be conducted after the institute had been in operation for 10 years. As a consequence, the Space Studies Board of the National Research Council conducted a decadal review in 2007, in which the progress made by the NAI (Committee on the Review of the NAI, 2008) was evaluated. The NAI was assessed on its success in each of its stated goals and was overall found to have broadly succeeded in fulfilling its original mandate.

In addition, the US astrobiology community has published roadmaps that help cast their activities into an overall shape (Des Marais *et al.,* 2003, 2008).

Astrobiology worldwide

Many countries also have national groupings that support astrobiology. The situation in the UK is discussed in detail below, but here we note that societies and organizations also exist in countries such as Australia, China, France, Israel, Mexico, Norway, Spain, Sweden, and Russia, as well as societies with worldwide membership, such as the International Astrobiology Society. There are also international groupings, such as the International Astronomical Union commission 51 (dedicated to astrobiology), the European Astrobiology Network Association (EANA), and the Federation of Astrobiology Organizations (which aims to provide an international umbrella for national or regional societies). Clearly, there is a growing worldwide interest in the field of astrobiology. Many of these bodies provide a forum not just for promoting research but also for the development of the field in all levels of education and in engaging the general public with the topic.

Astrobiology in the UK

As with astrobiology worldwide, it is apparent that the discipline is growing rapidly within the UK, in terms of the committed research effort as well as astrobiology education and public outreach activity. Investigators within the various disciplines that contribute to the study of astrobiology are meeting with increasing regularity to discuss methodologies and results that reach beyond the traditional discipline boundaries at conference sessions, workshops, and symposia convened by dedicated organizations such as the Royal Society, the Royal Astronomical Society, the Geological Society, and the Society for General Microbiology. The UK astrobiology community as a whole is unified regularly by the Astrobiology Society of Britain (ASB; www.astrobiologysociety.org), which holds biennial conferences (Cambridge 2003, Canterbury 2006, Cardiff 2008), and by other similar meetings such as the recent Habitability in our Galaxy workshop 2008 at the Royal Observatory Edinburgh, Scotland (www.roe.ac.uk/roe/workshop/2008). These ASB and Royal Observatory Edinburgh meetings have not only had sessions on the primary academic research results but also presentations on astrobiology education at university undergraduate or school level and presentations for public outreach. Furthermore, the UK astrobiology effort is connected to the wider European community through the EANA (http://www.astrobiologia.pl/eana/) and its annual workshops.

This increasing level of activity is reflected in changes inside British universities. Interdisciplinary departments are being founded with research into the origins or distribution of life in the universe among their stated goals, and new lecture courses that explicitly treat astrobiology are appearing on both undergraduate and postgraduate programs. In addition to local initiatives, nationally organized courses are also appearing. For example, in 2007 the Science and Technology Facilities Council, STFC, created the first of a biennial week-long astrobiology summer school for postgraduate students (in the UK, government money for publicly funded research is channeled through independent bodies such as the STFC, which are known generically as research councils; they in turn distribute money to the academic community via peer-reviewed grants on agreed objectives). This inaugural summer school was hosted by the Open University (www.open.ac.uk/astrobiology/school) and was attended by 16 new astrobiology students. A second STFC astrobiology postgraduate summer school will take place in 2009 at the University of Kent and is intended to attract 30 students. Also, as part of the drive in astrobiology education and public engagement, members of the UK community have published a number of recent astrobiology textbooks and popular science books, many of which are recommended on course reading lists (see Table 1).

United Kingdom academics also actively promote their science through radio programs and television documentaries. In 2003, Professor Monica Grady (Open University) was selected to deliver the Royal Institution Christmas Lectures, an annual series of five lectures performed to a live audience of 400 children, which is televised nationally. This series, titled "Voyage in Space and Time," included a final hour-long lecture on astrobiology and the potential of life beyond Earth.

Astrobiology research has had a long history in the UK, with the current period of growth starting in the late 1990s. In 1996 and again in 1998, one-day meetings on astrobiology were held at the Royal Society in London. The second of these meetings was attended by about 50 scientists. One

Table 1. Examples of Astrobiology Popular Science Books and Textbooks Published by UK Academics since 2000

Author(s)	*Title*	*Publisher*	*Year*
Cockell, C.S.	*Impossible Extinction: Natural Catastrophes and the Supremacy of the Microbial World*	Cambridge University Press	2003
Cockell, C.S.	*Biological Processes Associated with Impact Events*	Springer	2005
Cockell, C.S.	*An Introduction to the Earth-Life System*	Cambridge University Press	2008
Cohen, J. and Stewart, I.	*What Does a Martian Look Like? The Science of Extraterrestrial Life*	J. Wiley and Sons	2002
Dartnell, L.	*Life in the Universe: A Beginner's Guide*	OneWorld Publications	2007
Gilmour, I. and Sephton, M.A.	*An Introduction to Astrobiology*	Cambridge University Press	2004
Grady, M.	*Astrobiology*	Smithsonian Books	2001
Jones, B.W.	*Life in the Solar System and Beyond*	Springer	2004
Jones, B.W.	*The Search for Life Continued: Planets Around Other Stars*	Praxis	2008
Shaw, A.W.	*Astrochemistry: From Astronomy to Astrobiology*	Wiley-Blackwell	2006

outcome of this meeting was a report on UK capabilities in the field, which was published in 1999 by the British National Space Centre (BNSC) (Cowan *et al.*, 1999). This BNSC report contains a list of researchers in the field and undergraduate course modules known to the authors at that time to include aspects of astrobiology, but it did not involve a systematic survey. Another outcome of the 1998 meeting was the creation of an *ad hoc* pressure group that, in 2003, developed into the Astrobiology Society of Britain. Since that time, there has been great growth across the UK in the many different fields that constitute astrobiology. However, this growth has been difficult to track, and the community is believed to be largely unaware of the full extent of astrobiology research and teaching now active throughout the UK. Part of this is undoubtedly because the UK has no central astrobiology organization similar to the NAI in the US, so compiling such important information is particularly difficult (the STFC, for example, while very supportive of UK astrobiology and indeed offering as one of its nine main science questions, "Are we alone?" is historically predominantly aimed at the physics- and astronomy-based communities).

Astrobiology Society of Britain

The ASB is a professional body founded in March 2003. It serves the astrobiology community by fostering interdisciplinary connections between its diverse members to ensure that astrobiology research in the UK remains vigorous, progressive, and successful. The ASB seeks to encourage new students and researchers into the field and support them throughout their career. It also endeavors to increase the general public's understanding and appreciation of astrobiology research. The Committee of the ASB is composed of active established astrobiology researchers (*i.e.*, faculty-level staff) and education leaders, as well as a significant component of Ph.D. students and early career–stage researchers who represent the interests of the next generation of astrobiology researchers. The ASB website provides regular news updates and announcements, as well as a popular book section that features reviews of new astrobiology books as they are published. The ASB website received an average of 4,300 hits each month during 2007, which rose to 11,500 hits each month in 2008. This popular website will also be used to help distribute the results of this survey and provide a freely downloadable report on the national resources for astrobiology teaching and research.

As part of its remit to encourage and support astrobiology, the ASB recently undertook a survey into the magnitude of astrobiology research and teaching within the UK. The purposes of the survey, and this paper publishing the results, are three-fold:

(1) To provide an information source on the prevalence and diversity of research groups now conducting work on astrobiology. This will allow researchers to identify other groups of interest, which will facilitate new interdisciplinary collaborations and increase the cohesion of the UK astrobiology community.
(2) To compile statistics on the current state of UK astrobiology to provide a comparator for other similar national surveys globally and for future UK studies, and thus enable international comparisons and charting of the growth of the field. It will also allow a measure of the growth of the field in the UK since the late 1990s, when the BNSC report was published (Cowan *et al.*, 1999).
(3) To provide a resource for students who wish to find an undergraduate or postgraduate course in astrobiology, as well as graduates who seek the research department or institution best suited for pursuing their astrobiology interests in a Ph.D.

This is believed to be the first such systematic survey to be conducted on the current state of astrobiology research and teaching at a national level.

Methods

The survey was conducted between May 2007 and October 2008 through the distribution of a questionnaire. To gather meaningful representative results, this survey questionnaire needed to reach a major proportion of the appropriate astrobiology-related community. However, the concerning incompleteness of knowledge regarding the current extent of astrobiology research and teaching within the UK was the very issue this survey was designed to address.

Great effort was therefore expended in ensuring that the survey reached as wide a range as possible of relevant researchers and institutions in the UK.

The survey was sent to all members listed with the ASB, the UK Planetary Forum (a society encouraging research into planetary science in the UK, see http://www.ukplanetaryforum.org), and the AstroSurf network (a network of surface scientists researching in astrochemistry). The survey was also forwarded to UK authors of papers published in the *International Journal of Astrobiology* and the journal *Astrobiology* over the previous two years, and to UK authors of oral presentations and posters delivered at several domestic and international meetings (including EANA 2006, AbSciCon 2006, and Bioastronomy 2007). Announcements with regard to the survey were also made at the EANA 2007 meeting. Those involved in applications for an Aurora Fellowship, an astrobiology-targeted post-doctoral fellowship scheme operated annually by the STFC since 2006, were contacted as well. Furthermore, the journal *Astrobiology* kindly agreed to send the survey to its entire UK-based e-mail distribution list in September 2007. In addition to these efforts to target specific researchers directly, the questionnaire and cover letter were e-mailed to administrators of university science departments and institutes and made available for download from the ASB website.

Furthermore, it was requested of all those researchers contacted that they forward the survey to colleagues or acquaintances potentially engaged in astrobiology. The hope was that the survey would percolate throughout the contact network of the greater research community and reach people engaged in astrobiology research and teaching who were unknown to the ASB.

Over the entire period, a total of around 360 individuals were contacted directly by the surveyor (L. Dartnell), and an unknown number of others would have received notification through the various untargeted distribution methods and announcements. Due to this untargeted distribution effort, it is impossible to know the total number of individuals reached by the survey or the method that was most successful in eliciting responses. Every effort was made to contact all relevant individuals and thus collate truly comprehensive information on astrobiology research and teaching within the UK. If any astrobiology research or teaching activity, or avenue by which to reach potential respondents, has been overlooked here, we invite readers to contact the surveyor (L. Dartnell) to notify of the correction. In several cases, survey respondents were re-contacted by the author to verify certain details.

Content of the questionnaire

Although the data collection period of this particular survey has now drawn to a close, a copy of the distributed questionnaire can be downloaded for reference from the ASB website (www.astrobiologysociety.org/Docs/ASBquestionnaire.pdf, correct on May 2009).

For this particular questionnaire, *astrobiology* was taken "to include, but not be limited to, fields in astronomy and astrophysics such as stellar evolution and exoplanet detection and characterization; planetary sciences such as planetary formation and evolution modeling; biochemistry and microbiology such as the origins of life, evolution over deep time, and extremophiles; geochemistry such as ancient terrestrial life and biosignature detection; and the engineers, roboticists, and instrumentalists involved in probe design, remote sensing and astrobiology surface packages." This definition was left deliberately broad to allow researchers to classify their work as astrobiological if they chose to consider it so.

The questionnaire was divided into three main sections: general details, astrobiology research, and astrobiology teaching. The first section contained a few questions regarding the research institute or university department with which the recipient of the questionnaire was affiliated. It also requested contact information and inquired as to whether any formal academic positions exist at the institution, such as "Professor of Astrobiology."

The second section inquired about current research activity, initially, how many different research groups the respondent was aware of within his or her own university that were active in astrobiology. For each research group, details were requested as to the name of the principal investigator (partly to exclude the possibility of the same group being reported by several different questionnaires), the approximate make-up of the group (the number of faculty staff members, post-doctoral researchers, Ph.D. students, master's students, and undergraduate project students), and the research focus of the group (a single-sentence description).

The third section of the questionnaire focused on astrobiology teaching. Twelve questions were asked with regard to each course offered at the respondent's institution. Along with the title and course code, these questions inquired as to whether the course is provided for undergraduate students, postgraduate students, or both, and whether it is a dedicated astrobiology degree or a single module within a degree course. If a single module, the respondent was asked how many course credits it constituted and what fraction this contributed to the total annual credit requirement for students. The questionnaire also asked how many years the course has been running, how many student places are available, how many applications are received for these places, and how the number of places available and applications received has changed over the running period of the course. The approximate composition of the academic backgrounds of the course students was gauged; the suggested categories were astronomy, biochemistry, biology, engineering, geology (including Earth sciences), and physics. The general response of students to the course as reported on course feedback forms collected by the university was also requested from the survey respondent.

Results

A total of 41 questionnaires were returned, though two of these were completed by individuals outside the UK, which are not included in this summary report. To put this in context, there are some 150 institutions of higher education in the UK (though not all offer a full spectrum of subjects, with only about 100 including the sciences and only some 50–60 being widely considered as research intensive). Six of the returned UK questionnaires reported that, to the knowledge of the respondent, astrobiology research was not being conducted or taught at that university department or institution. It should be stressed here, however, that this information is

inevitably valid only to the extent of knowledge of the respondent and his or her personal understanding of what activities are comprised within astrobiology. Indeed, there were several cases of researchers who apparently were not aware of other groups within the same university that were engaged in astrobiologically relevant research.

Figure 1 summarizes the geographic distribution of both astrobiology research and teaching activities nationwide reported in this survey.

Although there were no reported formal academic positions in astrobiology bestowed by a university, there is a European Union–funded Marie Curie Chair in Astrobiology at the University of Bristol. Also, one researcher (at the Royal Observatory, Edinburgh) reported that he was hired as a lecturer in astrobiology, and another researcher stated that she chooses to refer to herself informally as a Reader in Astrobiology (at St. Andrews, Scotland).

Research

Table 2 summarizes the results returned by the survey on 33 different research groups currently engaged in elements of astrobiology within the UK. The table is sorted by university and lists the relevant school or department, the named Principle Investigator (PI) of the astrobiology research topic, and the brief description of the group's research interests as reported by the survey respondent. The final five columns of Table 2 list the approximate composition of the research group, subdivided into researchers of different career levels: academic staff members, post-doctoral researchers, Ph.D.

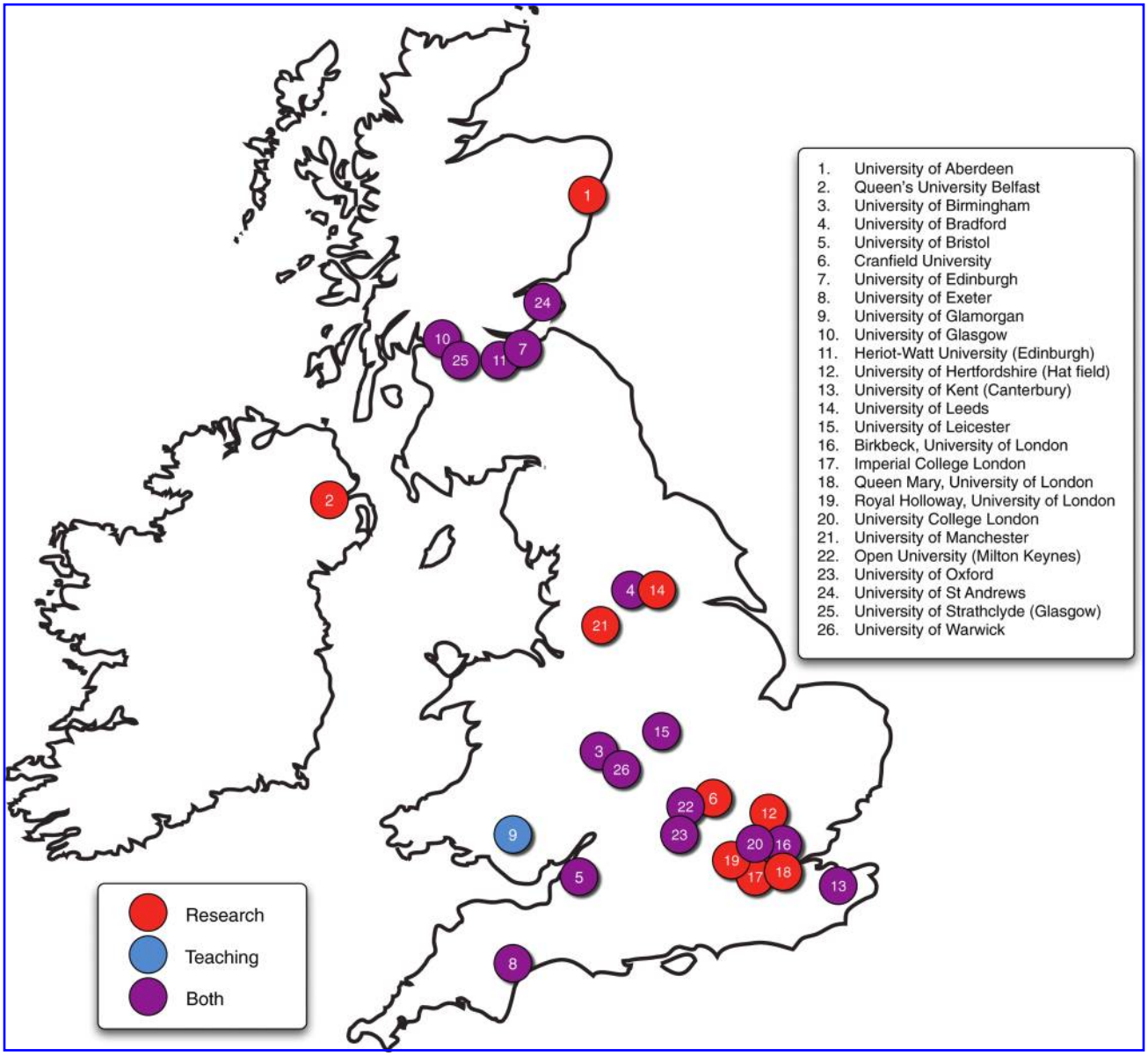

FIG. 1. Map of the United Kingdom indicating locations of astrobiology activity in universities and research institutions nationwide, color coded for research (gray), or teaching (white), or both (black). Color images available online at www.liebertonline.com/ast.

Table 2. Summary of the Results Returned by the Survey on 33 Research Groups Currently Engaged in Elements of Astrobiology within the UK

				Group composition				
Institution	*Department*	*Research group Principle Investigator*	*Research description*	*Academics*	*Post-doctoral researchers*	*Ph.D. students*	*Master's students*	*Undergraduate project students*
University of Aberdeen	Department of Geology and Petroleum	John Parnell	The Geofluids research group is interested in the origin and measurement of organic matter in rocks of astrobiological interest.	2	—	4	—	6
Queen's University Belfast	Astrophysics Research Centre	Don Pollacco	The exoplanets group works on discovering exoplanets with SuperWASP and their characterisation via multiwavelength observations.	2	3	3	—	1
		Alan Fitzsimmons	The solar system group works on the determination of the physical characteristics of comets and asteroids with an emphasis on Near-Earth Objects	1	1	1	—	1
University of Birmingham	School of Physics and Astronomy	Ian Stevens	Searching for extrasolar planets, magnetospheres of extrasolar planets and theoretical studies of the atmospheres of extrasolar planets, with an emphasis on the detectability of biosignature lines	1	—	3	—	—
University of Bradford	School of Life Sciences	Howell G.M. Edwards	Raman spectroscopy of extremophiles and biogeological Mars analogues	1	1	2	1	6
University of Bristol	School of Chemistry	Richard Pancost	The organic geochemistry unit (OGU) investigates biogeochemical processes including the lipid signatures of organisms living in extreme environments, such as deep sea cold seeps and geothermal environments, and also into palaeoclimates	1	—	2	—	1
	Department of Earth Sciences	David Catling	Split between University of Bristol and University of Washington, Seattle, USA, David Catling leads research into the coupled evolution of planetary surface and atmospheres, and the co-evolution of life and biogeochemical cycles on Earth. The group is involved in Mars Global Surveyor and Mars Odyssey orbiters, and the Phoenix lander	1	—	1	—	—
Cranfield University		David Cullen	Development of *in situ* life detection technologies for astrobiological use. Examples include the Life Marker Chip (LMC) instrument development programme for the ESA ExoMars mission and flight of the LMC on BIOPAN-6	1	2	2	—	—
University of Edinburgh	Institute for Astronomy	Ken Rice	The formation and evolution of planets and planetary systems Most of the work is computational and theoretical, although the group is becoming increasingly involved in observational projects	1	—	2	—	2
University of Exeter	School of Physics	Mark Mc Caughrean	The Exeter group conducts a very coherent program of research in star formation and exoplanets. Current expertise relevant to astrobiology includes space-based transit searches for terrestrial planets (CoRoT) and direct imaging and spectroscopy (GPI). The group plans to grow its activity in the area of exoplanet detection, characterisation and modelling over the next few years, in part through a joint initiative with the applied mathematics group at Exeter, with potential participation of the nearby Meteorological Office	3	3	4	—	3
	School of Biosciences	Andrew M. Shaw	The role of charged mineral surfaces in the catalysis of pre-biotic reactions	1	—	—	—	2

University of Glasgow	Department of Chemistry	Laurence D. Barron	Involvement with astrobiology through interest in fundamental aspects of chirality and absolute enantioselection, an important topic in considerations of the origin of biomolecular homochirality and the chemical origin of life. Co-investigator on Project Urey for the ESA ExoMars mission to use chiral microfabricated capillary electrophoresis to identify and classify amino acids in the Martian regolith	1	—	—	—	—
Heriot-Watt University (Edinburgh)	Department of Chemistry	Martin R.S. McCoustra	Laboratory-based astrochemistry directed toward understanding the formation and processing (by heat, light and charged particles) of icy materials in the wide range of environments in which these materials appear. The application of ultrahigh vacuum surface science methods to characterising both the physical and chemical behaviour of relevant molecular solids under realistic conditions of temperature and pressure	1	1	3	—	1
University of Hertfordshire (Hatfield)	Science and Technology Research Institute	William E. Martin, J.H. Hough	Polarization and nonlinear properties of chiral molecules, especially biological precursors and biologically active molecules of relevance to exosolar planet signatures	2	1	—	—	—
University of Kent (Canterbury)	School of Physical Sciences	Mark J. Burchell	Investigations into the possibility of panspermia and the survival of microbial life in shock impacts, using hypervelocity gas gun equipment	1	—	1	1	1
University of Leeds	School of Chemistry	Terence P. Kee	The role of reduced oxidation state phosphorus in the evolution of planetary geo- and biospheres	1	2	2	—	1
University of Leicester	Space Research Centre	Mark R. Sims	Life Detection Instrumentation and Analogue Studies	1	2	1	—	—
Birkbeck, University of London/University College London	Centre for Planetary Sciences	Ian Crawford	The UCL-Birkbeck Centre for Planetary Sciences (CPS) includes those research groups listed under UCL as well as the collaborations reported here with Ian Crawford at Birkbeck. CPS collaborations between Earth Sciences departments at Birkbeck and UCL include astrobiological research into the habitability of volcano-ice interfaces and extremely alkaline environments as well as the possibility of terrestrial meteorites on the Moon	1	—	2	—	—
Imperial College London	Department of Earth Science and Engineering	Phil Bland	The Impacts and Astromaterials Research Centre (IARC) initiative brings together planetary scientists, facilities and resources from the Department of Earth Science and Engineering (ESE), Imperial College London and the Mineralogy Department of The Natural History Museum (NHM) into a multidisciplinary centre committed to the characterisation of the processes and materials that dictate the nature of planetary bodies and systems	4	3	2	—	—
Queen Mary, University of London	Astronomy Unit	Richard Nelson	The group researches the theory of planet formation as applied to the solar system and extrasolar planetary systems. Specific to astrobiology, one student is working on the theory of terrestrial planet formation in extrasolar planetary systems	1	—	1	—	—
Royal Holloway, University of London	Department of Earth Sciences	David Waltham	The influence, or lack of influence, of anthropic selection effects upon the makeup of planet Earth	1	—	—	—	—
University College London	Mullard Space Science Laboratory	Alan Smith	MSSL leads the team developing the PanCam system for ExoMars and the payload for the UK penetrator consortium (MoonLITE, Europa/Titan penetrator) and other instruments for life detection on rovers, as well as research on plasma-magnetosphere interaction and influence on planetary habitability (Venus Express, Mars Express)	5	4	2	1	1

(*continued*)

Table 2. (Continued)

Institution	Department	Research group Principle Investigator	Research description	Group composition: Academics	Post-doctoral researchers	Ph.D. students	Master's students	Undergraduate project students
	Astrophysics	Ofer Lahav	The Astrophysics group works on modelling early stellar system formation and planet distribution, and orbital statistics from radial velocity measurements. The Star Formation and Astrochemistry group is concerned with the formation of crucial prebiotic molecules in the interstellar medium	2	2	2	1	2
	Atmospheric Physics Laboratory	Alan Aylward	The Atmospheric Physics Laboratory conducts both modelling and observational work on Extrasolar planetary atmospheres and detectability of biosignatures	4	3	3	3	2
	Institute of Structural and Molecular Biology	John M. Ward	Microbiological work on extremophiles, radiation resistance and survival in the martian surface, as well as microbial diversity and biosignatures in volcano-glacier environments	1	—	2	1	—
University of Manchester	School of Earth, Atmospheric and Environmental Sciences	No PI, but a Group Board	The Isotope Cosmochemistry and Geochemistry Group conducts analysis of extra-terrestrial materials by development of new analytical techniques that push detection limits to new levels	5	8	8	1	2
Open University (Milton Keynes)	Department of Physics and Astronomy	Glenn White	The Astronomy Research Group carries out research in several areas of astrophysics including extrasolar planet discoveries, observations and modelling, particularly of habitable zones. The group also includes astrochemistry, and research on Darwin and similar space missions	10	7	12	—	—
	The Planetary and Space Science Research Institute	Ian Wright	The Planetary and Space Science Research Institute carries out research in many areas of astrobiology, including martian meteorites, interplanetary dust, exploration of planetary bodies, and extremophiles	9	22	18	—	—
University of Oxford	Department of Earth Sciences	Martin Brasier	The group is focussed on early life and biomarkers on Earth—determining the environments inhabited by early life, and rigorously testing the null hypothesis that purported fossils or biomarkers are abiogenic before accepting a biological explanation	1	1	6	2	—
University of St Andrews	School of Physics and Astronomy	Keith Horne	Part of the Astrophysics group focuses on planet formation and detection, as well as some work on habitability, as part of the Astrobiology Initiative of the Scottish Universities Physics Alliance	3	4	3	—	—
	School of Geography and Geosciences	Tony Prave	The biogeochemistry group documents Earth System behaviour and development during two main time periods, the Palaeo proterozoic (the Great Oxidation Event) and the Neoproterozoic (Snowball-Earth scenarios)	1	—	—	—	—
University of Strathclyde (Glasgow)	Biomolecular and Chemical Physics	Helen J. Fraser	The Astrochemistry Group researches the molecular processes involved in star and planet formation and the subsequent potential for the emergence of life, using laboratory experiments, parabolic flight experiments, observations and theoretical chemistry	1	1	2	—	1
University of Warwick	Department of Physics	Peter Wheatley	The Astronomy and Astrophysics group includes research into the search for, and characterisation of, extra-solar planets	2	1	1	—	2

Where the location of the university is not obvious from the title, the city is indicated in brackets. As far as possible, the figures presented are for the number of researchers within the group who are actively involved in elements of astrobiology; the total group size is often larger than that listed here.

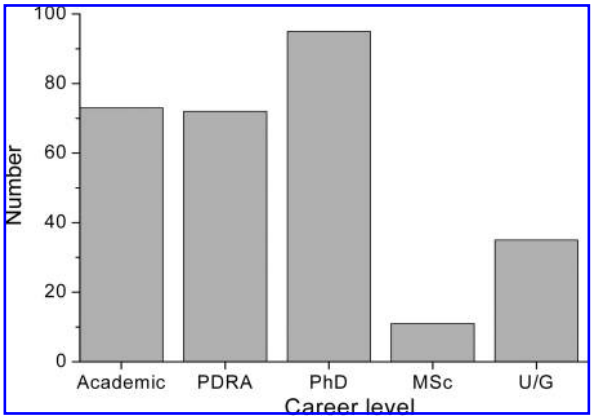

FIG. 2. The career-level breakdown of astrobiology researchers within the UK.

students, master's students, and undergraduate project students. As far as possible, the numbers listed here are for researchers more or less directly involved in research of an astrobiological nature, and not the total number of researchers within a particular group. This table is based solely on the information provided by returned responses during the 2007–2008 surveying period. It should be noted that these data, such as the exact number of researchers within a particular group, are by their nature variable over time and so may have changed slightly before publication.

The total number of astrobiology researchers in universities throughout the UK is thus found to be 286 in 2007. This is broken down into career-level categories as follows: 73 academic staff members, 72 post-doctoral researchers, 95 Ph.D. students, 11 master's students, and 35 undergraduate project students, as plotted in Fig. 2.

Of particular interest is the recent emergence of several large interdisciplinary centers for planetary science and astrobiology with the UK. For example, the Open University (OU) at Milton Keynes (though this is what is popularly referred to as virtual university, in that it teaches solely by distance learning and has a campus staffed with permanent academics who conduct research and prepare teaching materials) has founded the Centre for Earth, Planetary, Space and Astronomical Research (http://cepsar.open.ac.uk). This is an interdisciplinary fusion of three different departments: Earth and Environmental Sciences, the Planetary and Space Sciences Research Institute, and the Astronomy research group within the Department of Physics and Astronomy. While astrobiology is not in the title, the staff conduct a wide range of astrobiology-related research.

Similarly, University College London (UCL) and Birkbeck College, University of London, have also launched a virtual research center with a strong element of astrobiology: the Centre for Planetary Sciences (CPS; www.cps.ucl.ac.uk). The CPS at UCL/Birkbeck is not only interdisciplinary but also inter-institutional, and brings together researchers from two separate colleges of the University of London (University of London is a federal system of "colleges" with their own departments and faculties, which elsewhere would be considered separate, small, universities). The CPS incorporates staff from the Department of Space and Climate Physics (based at the Mullard Space Science Laboratory) and the Department of Physics and Astronomy (including the Atmospheric Physics Laboratory and the Star Formation and Astrochemistry groups), all at UCL. It also includes staff from the Schools of Earth Science at both UCL and Birkbeck. Interestingly, neither the OU or UCL/Birkbeck model formally incorporates biology departments, though biology is represented in their research.

A wider multi-institutional grouping consists of six universities in Scotland, which collaborate as the Scottish Universities Physics Alliance (SUPA). This has developed a coherent inter-institutional approach to research and teaching. SUPA includes the University of Dundee, the University of Edinburgh, the University of Glasgow, Heriot-Watt University, the University of St Andrews, the University of Strathclyde in Glasgow, and the University of the West of Scotland. SUPA operates an astrobiology initiative and collaborates on both research and teaching.

These interdisciplinary and inter-institutional research centers and alliances serve to improve communication between groups, foster greater collaborative work, and strengthen grant proposals. The constituent research groups within these interdisciplinary centers are listed separately in Table 2. Due to the inter-institutional nature of the Centre for Planetary Science at UCL/Birkbeck, one part of the astrobiology research activity is entered in Table 2 under Birkbeck, and the other parts are listed under the different groups at UCL.

As mentioned above, there is no astrobiology funding source in the UK analogous to the NAI in the US, though the STFC supports much astrobiology work and initiated, in 2006, a regular astrobiology fellowship scheme. This cross-disciplinary "Aurora Fellowship in Planetology and Astrobiology" aims to assist the career development of promising young researchers and enable the UK to exploit to a greater degree the European Space Agency's Aurora program of exploration (www.scitech.ac.uk/Grants/Fells/Auro/Contents.aspx). Table 3 summarizes the Aurora Fellowships awarded so far (www.scitech.ac.uk/SciProg/Aurora/fund/acd/foaHome.aspx).

Teaching

Table 4 summarizes results from the 15 astrobiology courses reported in the survey questionnaires. These represent a wide variety of different course formats, including short modules within traditional undergraduate degrees or postgraduate courses, optional lecture series with no formal course credits, a community education course, and a complete undergraduate degree. For the undergraduate modules, these courses constitute between one-sixteenth (University of Warwick) and one-quarter (some Open University degrees) of the total number of course credits required for graduation from the degree. The majority of astrobiology courses are targeted at undergraduates, though many of the respondents associated with such course work reported that postgraduates are also welcome to attend the lectures. Most of these modules attract between 10 and 30 students.

Two of the longest-running astrobiology courses in the UK are organized by the University of Leicester and the University of Kent as undergraduate modules; both have been running for over 5 years. Another early course, Introduction

Table 3. Summary of the Science and Technology Facilities Council (STFC) Aurora Fellowships Awarded in Planetology and Astrobiology in the 2007 and 2008 Academic Years (www.scitech.ac.uk/SciProg/Aurora/fund/acd/foaHome.aspx)

	Name	*Host institution*	*Fellowship research*
2007	Axel Hagermann	Planetary and Space Sciences Research Institute, Open University	Understanding the interaction of planetary surfaces with their atmospheres, using mathematical modelling of the processes involved to give a more detailed understanding of these processes than hitherto
	Manish Patel	Planetary and Space Sciences Research Institute, Open University	Investigating the dependence of habitats for life upon light with particular emphasis on the identification of possible habitable environments on Mars and the possible constraints imposed on these by the ultraviolet light levels
	Giovanna Tinetti	Atmospheric Physics Laboratory, University College London	The detection of biosignatures, *i.e.*, indicators of biological life, on extrasolar planets, focussing on planetary and atmospheric modelling of the environments of Earth-like planets to assist in interpretation of spectral observations of exoplanets
2008	Matthew Balme	Department of Earth Sciences, Open University	The extent to which recent geological activity on Mars has been influenced by changes in its climate and in particular how this relates to surface water flow, utilising a variety of methods including computer modelling, laboratory experimentation and the analysis of recent data from Mars Express and Mars Reconnaissance Orbiter
	Henner Busemann	School of Earth, Atmospheric and Environmental Sciences, University of Manchester	Determining the abundances of noble gases and their isotopic ratios in a range of materials including meteorites, interplanetary dust particles and material collected by the Stardust mission to comet Wild 2 to study the conditions and processes responsible for terrestrial planet formation in the very early Solar System
	Peter Grindrod	Department of Earth Sciences, University College London	Undertaking laboratory experiments, computer modelling and observations of martian landforms in order to determine the quantities of ice and chemically bound water present on Mars, together with the most likely sites for these on the planet, to allow production of a global-wide map of ice-related features

to Astrobiology, has been run in parallel at both Birkbeck College and UCL since its inception in 2004. However, from September 2008 it has been taught at Birkbeck only, due to the demands of duplicating a course.

The SUPA astrobiology initiative runs two post-graduate modules: Introduction to Astrobiology (SUPAIAS) and the Science of SETI (SUPASET). These are taught via videolink across four universities in Scotland.

The University of Glamorgan has developed astrobiology into both a community education program and a full-blown undergraduate degree. Glamorgan's Centre for Astronomy and Science Education (now the Division of Earth, Space and Environment) developed a program of education to rekindle an active interest in astronomy and science in the general public, supported by the European Social Fund. This undergraduate module in astronomy and astrobiology, Alien Worlds, began in 2004 with 250 students attending classes located in community centers across South Wales. The module could be taken as a stand-alone course or for credit toward a degree. The Alien Worlds course concluded in June 2008, after teaching 612 students, and a new astrobiology-containing community course is being revalidated.

The University of Glamorgan also initiated a complete degree in astrobiology in September 2005. This BSc in Astrobiology (BSc is a Bachelor of Science award for an undergraduate degree in the UK) is reported to have been the first such undergraduate degree in astrobiology in the UK (Brake *et al.*, 2006), though it reportedly recruited low student numbers, and the degree may be revalidated at a later time.

As shown in Table 4, a total of around 880 students in the UK study some aspect of astrobiology every year. Many of the courses report that the number of students enrolling each year has remained relatively constant since the course was begun, fluctuating from one year to the next but with no clear growth in numbers over time. The Open University course does, however, report a growth in student numbers from 360 in 2005 to around 500 in 2008.

In addition to requesting information on the existence of astrobiology courses at universities throughout the UK, the survey asked respondents to approximate the proportion of course students from different scientific backgrounds: Astronomy, Biochemistry, Biology, Engineering, Geology, and Physics. These disciplinary composition percentages are listed in Table 4. The total number of students attending each course in 2007 and these compositional break-downs were taken to calculate the approximate proportion of astrobiology students nationwide from different scientific backgrounds, as shown in Fig. 3.

The pie chart in Fig. 3 displays only the information where both an approximate number of students and their academic backgrounds were given in the questionnaire. Thus, data from roughly 310 students distributed across 14 courses nationwide are included. Although the OU runs an astrobi-

Table 4. Summary of UK Astrobiology Courses, Sorted by Host University

Location	Course title	Course level	Full degree or module	Years running	Approx. current student number (per year)	Student academic background (%)					
						Astronomy	Biochemistry	Biology	Engineering	Geology	Physics
University of Birmingham	Astrobiology[I]	PG	—	1	3	100					
University of Bradford	Bioinorganic chemistry	PG	M.Chem module	1	5		90	5	5		
	Raman spectroscopy in astrobiology	PG	M.Sc Analytical sciences module	1	15		90	5	5		
University of Bristol	Geobiology (EASC 20024)	UG	module (10/120)	2	30					100	
University of Exeter	Astrochemistry: from astronomy to astrochemistry	UG	module (15/variable)	3	20		50	50			
University of Glamorgan	Alien Worlds	UG	module	4	140	10	1	4	24	3	6
	BSc Astrobiolgy	UG	degree	2	2	50					50
University of Kent	Space Astronomy (PH709)	UG	module (15/120)	6	12	66					33
University of Leicester	Life in the Universe (3677)	UG	module	8	25	30					70
University College London/Birkbeck College	Introduction to Astrobiology (C472/EASC064U)	UG	module (15/120)	4	25	55		5		45	5
Open University	An Introduction to Astrobiology (S283; Part 2)	UG	module (30/variable)	4	~500						
University of Oxford	Paleobiology	UG	module (1/4)	5	12					100	
Scottish Universities Physics Alliance (SUPA)	Introduction to Astrobiology (SUPAIAS)	PG	module	1	25	75					25
	The Science of SETI (SUPASET)	PG	module	1	15	90					10
University of Warwick	Exoplanets (PX437)	UG	module (7.5/120)	1	50						100

The course code is given in brackets where known. Informal courses earning no course credits for their students are indicated with a superscript *I*. Course level indicated as either undergraduate (UG) or postgraduate (PG). If a single module within an undergraduate degree, the proportion of course credits awarded for the astrobiology course out of the total required for graduation is given where known.

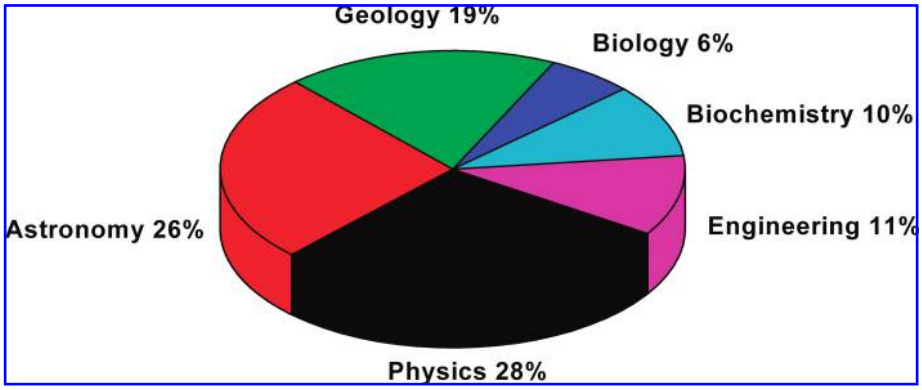

FIG. 3. Pie chart showing the approximate composition of undergraduate and postgraduate astrobiology students by academic background. Color images available online at www.liebertonline.com/ast.

ology course as a module within an undergraduate degree, the roughly 500 students studying astrobiology at the OU are not included in the collated results of the pie chart in Fig. 3. This is because it is not a meaningful distinction to categorize these students by their backgrounds due to the varied career routes they take before enrolling in a course at the OU (distance learning courses in the UK recruit from a much wider range of ages and prior experience than traditional on-campus courses). In addition, it was reported that 52% of the University of Glamorgan Alien Worlds course attendees were from non-academic backgrounds, so these have also been excluded from the pie chart of disciplinary composition.

It can be seen in Fig. 3 that physics and astronomy students account for 54% of people taking astrobiology courses, with biology and biochemistry accounting for only 16% combined, and geology and engineering students accounting for 19% and 11%, respectively. If students of astrobiology were uniformly distributed among the component disciplines that make up astrobiology, it might be expected that bioscientists make up a greater proportion. This apparent bias in the numbers of students coming to astrobiology from different backgrounds will be addressed in the Discussion.

Discussion

Success of the surveying process

As with any survey, there is a need to be aware of potential sources of bias or systematic distortions in the data collected. Obviously, the results reported here are only as representative of the complete community of astrobiology researchers and teachers as the subset of people who volunteer their time to provide the requested information. The primary concern of this survey is, therefore, on completeness. Two potential issues relate to the comprehensiveness of the results reported here. First, has the survey reached all relevant academics and in fact been completed and returned? Second, has the concept of what constitutes astrobiological research and teaching been delineated satisfactorily in the first place?

Prior to this survey, there existed no comprehensive contact list of relevant academics. At the outset of the surveying process it was hoped that astrobiologists would complete the questionnaire for their own activity and pass it on to colleagues or related researchers at other institutions, who would in turn respond with their details and forward the survey to others. The intended outcome was that the questionnaire would self-propagate through the astrobiology community and percolate far beyond the original distribution list compiled by the ASB. This strategy was not entirely successful, and often academic staff were understandably reluctant to volunteer their time to complete an unexpected questionnaire, without being contacted directly by the author (L. Dartnell) on behalf of the ASB. The result was that not many questionnaires were received from academics who had not already been identified by the ASB.

Another selective bias is possible in the returned survey data. It may be inevitable that the results listed here are skewed toward reporting multiple research groups within the same university and missing some smaller research groups in other universities. This may occur in that, once one researcher has responded with details on his or her own group, there is a higher chance that he or she will also provide details of other groups in the same university and encourage colleagues to also respond.

With 34 different research groups and 15 astrobiology courses reported throughout the UK, however, we are confident that this survey indeed captures a comprehensive snapshot of astrobiology activity in the UK. This assertion is supported by two facts. First, the many different questionnaire distribution methods ensured a great degree of overlap in coverage, and it is a reasonable assumption that the vast majority of relevant researchers did indeed receive the questionnaire. Second, the activity of several of the research groups and taught courses was reported independently by more than one individual. This strongly suggests that the questionnaire had indeed saturated the community and the response rate among all relevant groups was good.

A possible refinement to the data-collection process for future surveys would be to provide the questionnaire on an on-line surveying website. This could improve the convenience of providing information and so yield a higher response rate of completed surveys.

Concerning the second issue, due to the interdisciplinary nature of the field it is also difficult to classify clearly which researchers' work ought to be included under the umbrella of astrobiology. By way of an anecdotal example, one respondent was clear on the fact that he did not consider himself to be an astrobiologist and did not in fact care for the

label! More specifically, a PI in a research group, for example, may have an explicit interest in astrobiology and be actively publishing within the field, but the post-doctoral research assistants and research students in the group may not all be engaged in astrobiology research. Efforts were made within this survey to ensure that numbers are only reported for researchers who are, more or less, directly involved in astrobiology, so the figures reported in Table 2 are often less than the total size of a particular research group.

Discussion of the results

Astrobiology within the UK appears to be in a healthy state. The broad spectrum of fields engaged in astrobiology are well represented: from astronomers to geologists, microbiologists and biochemists, instrumentalists and engineers. Astrobiology has come from an early beginning of a few scientists individually pursuing interests of an astrobiological nature, to large interdisciplinary research centers that incorporate many tens of people and span several departments in a university. The SUPA course on astrobiology even spans several different universities across Scotland with, as stated above, lectures being delivered to distant students via a state-of-the-art video linkup.

The total number of UK astrobiology researchers (including academic staff down to undergraduate project students) calculated by this survey for 2007 is 286, distributed among 33 different research groups in 25 universities. By way of comparison, the NAI reportedly consists of approximately 600 investigators arranged in 16 teams (Committee on the Review of the NAI, 2008), and the total number of researchers involved in astrobiology in the US is likely to be several times this figure.

While the UK may be behind the US in terms of the absolute number of active researchers, it was apparently the first to establish a bachelor's degree in astrobiology, at the University of Glamorgan. No US university offers a standalone degree in astrobiology, though a number offer a degree in a traditional discipline with a certificate or a minor in astrobiology (Committee on the Review of the NAI, 2008). It is also possible for non-science majors to take an astrobiology module at some US institutions, such as the University of Texas in Austin (Oliveira and Barufaldi, 2009).

On the whole, this survey revealed that the astrobiology courses currently being run at UK universities receive very positive feedback from their students. A major contributing factor to this may be that most of the courses are lecture modules, or parts of modules, that are optional within a longer list of possible courses, or in fact are completely voluntary additional courses. Thus, astrobiology students are preselected to be more likely to have an existing interest in the field and to appreciate its teaching.

The Open University conducted a survey of its students who completed the Astrobiology S283 course in 2006 (see Table 3), with 67% of students responding. Ninety-four percent of respondents replied that they enjoyed studying the course, and 90% stated that they would recommend it to other students. Although several students remarked that they enjoyed the breadth of the course, one student commented that most of the course material was physics- or geology-related, with less content on chemistry or biology. This is perhaps expected to be a common issue with astrobiology courses around the world. With such an interdisciplinary subject the course organizers may need to be especially careful to devote equal attention to the varied fields that comprise astrobiology and avoid any biasing toward the organizers' original disciplines.

This conclusion seems to be supported by the composition of astrobiology students from different academic backgrounds, as displayed in the pie chart in Fig. 3. A disproportionate number of students are taking astrobiology courses from physics and astronomy backgrounds, rather than biosciences. These data from 2007 suggest that attendance of courses in "astrobiology" seems to be biased toward the "astro" rather than the "biology." The underlying cause for this apparent bias is as yet unclear. Is it that physics and astronomy departments have been more proactive in establishing astrobiology courses for their students, and biology students, for example, are lacking in opportunity? Or, alternatively, is it that biologists have open access to such courses but are less willing to leave their academic "comfort zone" and learn about physics and astronomy aspects, than visa versa? Thus, it remains to be seen whether this apparent bias in astrobiology students is due to lack of opportunity or lack of interest.

Comparison to research activities in the UK

It is informative to compare the range of teaching to the range of research activities in the UK. Here, an analysis has been performed with the use of abstracts submitted to the ASB conferences in 2006 (Canterbury) and 2008 (Cardiff). Based on the departmental affiliation of the lead author, it is possible to determine the background of the research environment and compare it to the teaching environments, as seen in Fig. 3. A total of 75 abstracts were submitted to these two meetings, and the results are shown in Fig. 4. One combined group is given for physics and astronomy in Fig. 4, as many departments use a combined title, which makes it difficult to separate them. Also, where research groups use a title, such as planetary science (and do not explicitly feature physics or astronomy), they have been grouped as "geology" (*i.e.,* Earth science). It can be seen that, compared to the teaching results in Fig. 3, the combined physics and astronomy contribution in research (41%) is less than it is in teaching (54%), while geology has increased significantly in

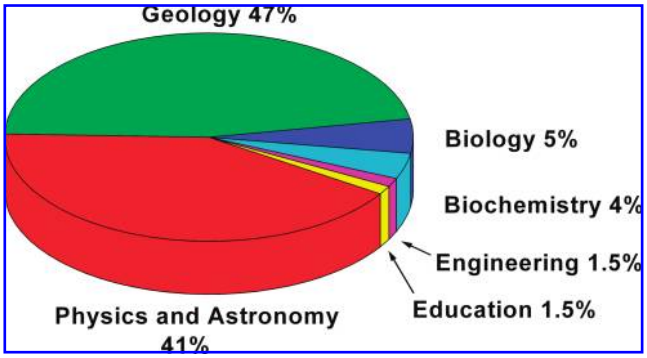

FIG. 4. Distribution of research by departmental subject groupings, as indicated by abstracts for ASB conferences in 2006 (Canterbury) and 2008 (Cardiff). A total of 75 abstracts were analyzed. Color images available online at www.liebertonline.com/ast.

its contribution to research (46%) compared to teaching (19%). While biology-based research is represented at a low level in Fig. 4, there are several examples of what appear to be heavily biology-oriented papers that originated from groups in the "geology" division; it thus appears that biology (and biologists) is being represented in astrobiology research in the UK from inside other subject groupings.

Dissemination of results

To disseminate the results from this national survey as widely as possible, several distribution methods will be followed. The results will be circulated to all participants of the survey and to the entire membership of the ASB, as well as presented at international conferences, so as to distribute this information as widely as possible within the existing community. A report will also be made available on the website of the ASB so that it can be found by any interested person worldwide searching the internet for related key words. Furthermore, the ASB already receives regular inquiries from students around the world as to which UK institutions conduct astrobiology research or offer taught courses, and this published report will serve as an integrated source of information that can be provided to any interested parties.

Conclusions

The survey results presented here will hopefully be of interest to astrobiology researchers and those running, or looking to initiate, taught courses in astrobiology, not limited to the UK but around the world. It is hoped that in the near future a survey will be conducted on astrobiology research and teaching in Europe as a whole, and interested parties in any nation are encouraged to initiate their own similar study and pool results worldwide. The survey reported here, which is the first systematic national survey to be published on astrobiology activity, is offered as an exemplar, the collated data available for subsequent international comparisons. Furthermore, we intend to repeat this study in another decade and, thus, chart the growth of the field of astrobiology. What can already be said regarding growth is that the 4 departments identified as active in teaching astrobiology in 1999 (Cowan *et al.*, 1999) have grown to 15 in 2007. Further, the teaching has both reached downward (to include public access courses such as Alien Worlds in University of Glamorgan) and upward to postgraduate courses. It will be interesting in the next decade to see if this growth continues and, if not, at what level it reaches a steady state.

The gathered results, most notably Table 2 and Table 4, will hopefully prove an invaluable resource worldwide for students who seek to enroll in an astrobiology course or begin graduate research in an astrobiology group. It is also hoped that this study will facilitate some unification among the many smaller, and at times isolated, pockets of activity in astrobiology and help to forge new national and international collaborations.

Acknowledgments

The authors would like to thank everybody who provided data on their research or teaching activities for this survey. We thank the referees for useful comments on the manuscript.

Author Disclosure Statement

No competing financial interests exist for either author.

Abbreviations

ASB, Astrobiology Society of Britain; BNSC, British National Space Centre; CPS, Centre for Planetary Sciences; EANA, European Astrobiology Network Association; NAI, NASA Astrobiological Institute; OU, Open University; PI, Principle Investigator; STFC, Science and Technology Facilities Council; SUPA, Scottish Universities Physics Alliance; UCL, University College London.

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