After all, if the last line of defence against extinction is a targeted breeding programme, we had better know what we are doing when it comes to making the crosses

post-glacial recolonization in European and other habitats, a process that emanated from various southern refugia and that often involved crosses among conspecific populations in hybrid zones (Hewitt, 2000). But if there are no field biologists who know their flora and fauna, geneticists will neither have material to work on, nor will they know the biology of the organisms they are studying. In this sense, there is a natural predisposition towards a symbiosis between genetics and biodiversity—a union that current progress in DNA technology is forging.

Awise, J.C. (1994) *Molecular Markers, Natural History and Evolution*. Chapman and Hall, New York, NY.

Bachmann, K. (1998) Species as units of diversity: an outdated concept. *Theory Biosci.*, **117**, 213–230.

Badr, A., Muller, K., Schafer-Pregl, R., El Rabey, H., Effgen, S., Ibrahim, H.H., Pozzi, C., Rohde, W. and Salamini, F. (2000) On the origin and domestication history of barley (*Hordeum vulgare*). *Mol. Biol. Evol.*, **17**, 499–510.

Böhle, U.-R., Hilger, H.H. and Martin, W. (1996) Island colonisation and evolution of the insular woody habit in *Echium* L. (Boraginaceae). *Proc. Natl Acad. Sci. USA*, **93**, 11740–11745.

Darwin, C. (1859) *The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*. Murray, London, UK.

Doolittle, W.F. (1999) Phylogenetic classification and the universal tree. *Science*, **284**, 2124–2128.

Graur, D. and Li, W.-H. (2000) *Fundamentals of Molecular Evolution*. Sinauer, Sunderland, UK.

Heun, M., Schafer-Pregl, R., Klawan, D., Castagna, R., Accerbi, M., Borghi, B. and Salamini, F. (1997) Site of einkorn wheat domestication identified by DNA fingerprinting. *Science*, **278**, 1312–1314.

Hewitt, G. (2000) The genetic legacy of the Quaternary ice ages. *Nature*, **405**, 907–913.

McCarthy, J. and Hilfiker, R. (2000) The use of single-nucleotide polymorphism maps in pharmacogenomics. *Nature Biotechnol.*, **18**, 505–508.

Nei, M. (1987) *Molecular Evolutionary Genetics*. Columbia University Press, New York, NY.

Purvis, A. and Hector, A. (2000) Getting the measure of biodiversity. *Nature*, **405**, 212–219.

Schafer, A.J. and Hawkins, J.R. (1998) DNA variation and the future of human genetics. *Nature Biotechnol.*, **16**, 33–39.

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Would you buy a tomato from this man?

How to overcome public mistrust in scientific advances

What is the difference between a genetically modified (GM) tomato and a mobile phone? One is a triumph of science and technology that benefits millions; the other is a GM tomato—an object of fear and suspicion. The popular press may tell you that mobile phones fry your brain, but tell that to an upwardly mobile city type who simply cannot live without this device. Then tell the same person that GM tomatoes taste better and last longer, and the reply will probably be ‘so what?’ GM foods have struck fear and distrust into the public without providing sufficiently attractive benefits. It seems that no amount of ‘educating’ the public will overcome the resistance to GM food; rather, the public wishes to be involved in a dialogue on new technologies that affect them. The GM debate is but the tip of an iceberg, whose treacherous depths

threaten many areas of the life sciences if not explored. It has unambiguously sent the message that scientists must become more engaged with the public in order to demystify their research.

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After a long and arduous debate, the Swiss finally agreed, in 1998, to support research involving the genetic modification of organisms, hence averting a decision that would doubtless have had pan-European consequences. In the

meantime, public trust in GenSuisse, the Internet-based public information provider established in response to the threatened ban, has fallen. The reason is simple: GenSuisse was founded by the Basel pharmaceutical industries. Message one from the Swiss experience: the public is highly sceptical of anything that smells of industry—the Monsanto factor. Message two: the public wants a continuous dialogue, not merely information in times of need. Given that the EC aspires to co-ordinate and fund science on a European level, it would be fitting that it also concerns itself with a European strategy for public outreach. At present, the most efficient means of pan-European communication is the press, the irony being that it is also the least likely to communicate a balanced story, and most likely to serve its own interests.

Scientists, on the other hand, are used to communicating the truth of their research in rigorously peer-reviewed articles. Now they must learn to communicate beyond their peers and into the real world. At a COPUS (Committee On Public Understanding of Science) meeting in Edinburgh, this February, a large part of the programme was devoted to a study commissioned by the Wellcome Trust to analyse the public's attitude towards science. The researchers categorized the UK population as fitting into six 'attitudinal groups' characterized by parameters such as age, income, social strata and proportion of males/females. After the presentation, the audience, consisting of scientists, social scientists, communicators, administrators and policy makers, was divided into six groups. Each group was asked to invent an activity fashioned to engage one of the attitudinal groups. Essentially, the message is: the mountain of sceptics and anti-science people will not come to Mohammed.

Public attitudes to science can be significantly affected through the education of the younger generation. Patrick Linder of the Department of Medical Biochemistry at the University of Geneva developed a kit to be used by teachers to demonstrate molecular genetics to school-children (<http://www.expasy.ch/linder/ecole/Protocols.html>). At 3-day courses hosted by the Swiss microbiologist and geneticist, the teachers practised using the kits, and then returned to their schools. But this is not cheap, he reflects; the schools could not afford to buy the kits at 17 000 Swiss francs each (11 000 Euro). Linder funded them through hard-won contributions from, among others, the Swiss Union of Biological Societies, the Society for Molecular Biology and Cell Biology, and industry. Although he hopes to expand the distribution of kits beyond the Geneva area, and to develop more experiments, he notes that money is very hard to come by as industry is not seriously interested in developing and marketing the kits, despite their obvious success. As a working scientist, he also has very little spare time to devote to the kits. Surely this is an example of a cause that should be taken up by the EC and funded EU-wide. After all, earlier this year, the EC announced the allocation of substantial funds for projects that strengthen connections between scientists and schools. Furthermore, such a scheme

A selection of initiatives in Europe:

- ECSITE (European Collaborative for Science Industry, & Technology Exhibitions—<http://www.ecsite.net/>): circulates and co-produces exhibitions, and disseminates information between its members.
- EFB (European Federation of Biotechnology) task group on public perceptions of biotechnology (<http://www.kluyver.stm.tudelft.nl/efb/TGPPB/main.htm>): fosters greater public awareness and understanding of biotechnology and encourages public debate via publications and workshops.
- EGF (European Genetics Foundation—<http://www.eurogene.org/>): annual meetings and open days (GEOD—Genetics in Europe Open Days: www.geod.org) on genetics.
- European Initiative for Biotechnology Education (<http://www.eibe.org/>): promotes skills, enhances understanding and facilitates public debate throughout Europe. The main focus is on teaching materials for 16- to 19-year-olds.
- Eurosciences working group 'Public awareness of science' (http://www.euroscience.org/WGROUPS/SC_AWARNSS/index.html): met on 8 July to formalize the group. It plans an annual meeting on public awareness of science, and a large pan-European meeting on science and technology in 2004 in Sweden.
- BAAS (British Association for the Advancement of Science—<http://www.britassoc.org.uk>): many national, regional activities involving the general public and schools. A major event this year: Creating Sparks, 6–30 September 2000 (<http://www.britassoc.org.uk/creatingsparks/>), South Kensington, London: science meets the arts.
- RI (Royal Institution—<http://www.ri.ac.uk/>): renowned for its children's Christmas lecture series.
- RS (Royal Society—<http://www.royalsoc.ac.uk>) and COPUS (Committee On Public Understanding of Science—http://www.royalsoc.ac.uk/scforall/copus_fr.htm), founded jointly with the BAAS and RI. Press releases, publications, events for the public.
- British Interactive Group (<http://www.big.uk.com/centres/>): site providing links to visitor centres and museums in the UK.
- At-Bristol (<http://www.at-bristol.org.uk/>): a visitor centre offering exhibitions, displays, talks, workshops on science communication, and laboratory demonstrations.
- Paul Scherrer Institut (<http://www.psiforum.ch/>): a visitor centre for the physical sciences.
- GenSuisse (<http://www.gensuisse.ch/>): news, public information and schools resources on biotechnology research via the Internet.
- BICS (Biotechnology Information and Communication Switzerland—<http://www.bics.ch/>): news, articles, links and specific information on biotechnology via the Internet.

Professional communication of science:

- Science journalism schools. EICOS (European Initiative for Communicators of Science—<http://www.eicos.mpg.de/>). Presently: Journalists Hands-on in Molecular Biology Laboratories. 1998: Journalism meets Science: join a laboratory and experience science as it happens. Journalists spent eight days at the Max Planck Institut for Biophysical Chemistry in Göttingen to work with scientists on actual projects.
- Science journalism associations and clubs, many of which are members of the European Union of Science Journalism Associations (<http://www.esf.org/eusja/EUSJA.htm>).
- Colleges offering courses and degrees in the communication of science, e.g. Moray College, Scotland (<http://www.moray.ac.uk/sci/index.htm>), University College, London (<http://www.butler.edu/www/isa/uk/uclcourses.html>) and University of Munich (<http://www.daf.uni-muenchen.de/DAF/STUDIUM/LEHRE/VVAKTUEL.HTM>).
- Spektrum der Wissenschaften (German lay science magazine), Lay courses and seminars (<http://www.spektrum.de/seminar.htm>).

USA:

- National Association of Science Writers (<http://www.nasw.org/>).
- American Association for the Advancement of Science (<http://www.aaas.org>).
- North American Alliance for the Public Understanding of Science and Technology (<http://www.nsf.gov/od/lpa/nstw/geninfo/alliance/>).
- Access Excellence (<http://www.AccessExcellence.com/>) at the National Health Museum (<http://www.nationalhealthmuseum.org/>): the National Health Museum's Site for Health and BioScience Teachers and Learners.

could be made part of national curricula, and provide the basis for the continuing education of teachers in new developments in the biosciences.

The mountain of sceptics and anti-science people will not come to Mohammed

Although the EC has not yet developed a Europe-wide approach to the public communication of science, independent organizations have. The European Federation of Biotechnology, with remarkable prescience, set up a Task Group on Biotechnology 9 years ago, hence anticipating the GM debate. With a membership of 50 000, which more recently includes industrial interests, the EFB supports scientific conferences, public debates and press conferences. Another aspiring pan-European endeavour is the European Genetics Foundation (EGF) in Sestri Levante, Italy. After the success of the publicly open conference 'Who owns the genome?' in 1999, the EGF is now coordinating the Genetics in Europe Open Days (GEOD) project in 2000. These publicly open conferences on the human genome and genetics take place in Milan, Barcelona, London and Heidelberg in November (www.geod.org). The open days will become an annual fixture.

However, science public relations is still a largely national rather than pan-European exercise. As in many other respects, European countries differ vastly in their efforts to break down the barriers between scientists and the public. Admittedly some have far greater economic concerns than others; public concern over scientific

advances is in general positively correlated with GDP per capita. The UK has a particularly impressive record in the communication of science, which makes it all the more ironic that most of the recent public reaction against scientists has surfaced there. The three organizations that do most are the British Association for the Advancement of Science (BAAS), the Royal Society (RS) and the Royal Institution (RI), which together established COPUS. There are science buses—travelling exhibitions and laboratories—in several countries, and science on the buses in the UK, a campaign of brightly coloured, thought-provoking posters with very few words, which capture the interest of shoppers and commuters alike (<http://www.uwe.ac.uk/fas/wavelength/wave18/burnet.html>). The poster on cloning, for example, challenges its audience with the following words: 'Identical twins are clones, and have the same genes... They may look like Hitler, but behave like Charlie Chaplin'.

The professions serving the public communication of science are starting to blossom in Europe. Universities are establishing courses in the communication of science, and journalists can now visit laboratories, look over a researcher's shoulder for a few days and learn more of the method of science. Back pages of popular science magazines advertise lay courses and workshops given by active scientists. Predictably, the USA is a step ahead. America has had excellent science journalism schools and a highly respected association of science writers (NASW). Every provincial university and institute, no matter how small, has a PR department. National museums and visitor centres host web pages containing a variety of teaching and public information resources, e.g. Access Excellence hosted by the National

Health Museum. On the national network scale, the North American Alliance for the Public Understanding of Science and Technology, a National Science Foundation project, concerns itself with the whole chain of science practice and communication, from basic research through teaching, and on to public understanding.

Once aware and engaged, the public expect to be involved in a dialogue concerning issues that could affect their lives

The activities briefly mentioned here, without doubt, make the public more aware of science, and give non-scientists the tools with which to discuss and think about science. But once aware and engaged, the public expect to be involved in a dialogue concerning issues that affect or *could* affect their lives. Scientists are starting to become more aware of, and engaged with, the public. Indeed, some approaches to teaching science are moving away from the 'life in science' paradigm of the past towards a 'science in life' model. Further up the career ladder, many now realize that the assessment of a researcher's performance by national research councils should reward public communication of science as one of the researcher's activities, rather than penalize it as time spent outside research. Contact with the public has been made. The next frontier is dialogue.

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Bear market slashes at human genome

The dropping guesses about the number of human genes challenges researchers to explain human complexity with so few genes

The media took fascinated note last May when genome researchers started gambling on the number of human genes.

One trend was apparent immediately: the estimates of human gene number—made by the people who ought to know if any-

one did—were low compared with those made just a few years ago, when the number often tossed around was 100 000,