

IMPAKT

TÉNYEK A TUDOMÁNYOS ALAPKUTATÁSRÓL

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Szilárd:

Csak a tényeket írom le –
nem azért, hogy bárki is
elolvassa, csakis a Jóisten
számára.

Bethe:

Nem gondolod, hogy a Jóisten
ismeri a tényeket?

Szilárd:

Lehet, hogy ismeri, de a
tényeknek nem ezt a változatát.

[*Leo Szilard, His version of the Facts.*
S.R. Weart & Gertrud Weiss Szilard (Eds),
MIT Press, Cambridge, MA, 1978, p.149.]

Back to basic

The Government's Technology Foresight exercise is intended to help the country make money out of science by supporting key areas of UK science — in other words, backing winners. Is supporting basic, blue-sky research across the spectrum of science no longer a luxury that Britain can afford? According to Keith Pavitt, basic research is an economic necessity, not a luxury.

The main justification for the large-scale funding of basic research must be its contribution to economic, social and political objectives. A necessary (but not sufficient) input into improving economic efficiency in Britain is world-class basic research (including basic engineering research), closely associated with postgraduate training and linked to business practice. Policies to substitute more obviously and immediately 'relevant' research would be economically inefficient, and based on a profound misunderstanding of how basic research supports technological practice.

This misunderstanding often begins with the assumption that the main output of basic research is published 'information' that is useless for practical purposes and freely available to anyone in the world. So, the argument goes, such research should be given lower priority than 'strategic research' which is more relevant to practical needs. But this assumption is not supported by the evidence. A number of recent studies show that technological practitioners find basic research useful, less for the direct information inputs that it provides, and more for augmenting the technologist's capacity to cope with complex problems — in the form of networks of researchers trained in the latest theories, techniques and instruments. In this context, the academic engineering disciplines play a central role in integrating information from a variety of scientific disciplines, and in stimulating their development (e.g. from computing to cognition).

So what are the main implications of such studies for those who shape UK science policy?

1. World-class basic research is an economic resource. World-class basic research, closely linked to post-graduate training, is an effective means of combining good research training with rapid access to the latest world developments in theory, techniques and instrumentation. It is particularly important to remember the contribution of pioneering curiosity-driven research to the development and testing of equipment, techniques and skills in instrumentation that later turn out to have widespread industrial applications. Historical examples include the uses of techniques from analytical chemistry in industrial process control, and the now widespread uses of the cathode ray tube and the computer. And today's electronics industry is using techniques derived from curiosity-driven physics in such fields as synchrotron radiation, ion implantation and electron microscopy. For this reason, the distinction between 'blue-sky' and 'strategic' research often turns out to be impossible to make in practice.

2. The economic benefits of basic research are localized. The main economic benefits of basic research are not easily transmissible information, available on equal terms to anyone in the world. Instead, they are geographically and linguistically localised, since they result from the transmission of mainly tacit (e.g. non-published) information through personal contacts.

(Continued on the next page)

3. Governments should subsidize basic research for economic reasons. Business firms cannot capture *all* the economic benefits of their investments in basic research, as some information inevitably 'leaks out', whether via publishing of research results or movement of R&D staff. Left to itself, therefore, the market would under-invest, which is why governments in all advanced market economies spend substantially on basic research.

4. Basic research is a 'public good' but not a 'free good'. Countries and companies can benefit economically from basic research performed elsewhere, only if they have the Waldegrave is set to fail. Last summer's Annual Review of Government Funded R&D already projects further decline across the board. On the same day as the White Paper was published, the DTI's Advanced Technology Programmes were cancelled, thus removing any mechanism for utilizing the results of Technology Foresight in any meaningful way. In addition, any reader of the White Paper can not have failed to notice that the chapter on defence was clearly written by a reluctant hand who wanted nothing to do with the OST's strategy for science.

On the international front rarely has such complacency been shown by a government minister. The OST produced a report on international comparisons of R&D expenditure and it seems that William Waldegrave is not familiar with its contents. Britain is the only OECD country apart from New Zealand and Turkey that has seen a decline over the last decade in expenditure on R&D as a proportion of GDP. It is the only country apart from former Yugoslavia and Iceland where business expenditure on R&D has fallen as a proportion of GDP over the same period. Is our science minister living under the illusion that once again we lead the world and that everyone else is simply out of step with us?

William Waldegrave can not just wring his hands and say that this state of affairs is all down to business short-termism. Government must bear responsibility for having let such a situation arise. Tax incentives, venture capital support and a whole host of other methods are used throughout the world to encourage companies to invest in R&D. In Britain we do nothing. William Waldegrave must do more than 'change the culture' in the boardroom. He must change the culture in the Conservative Party, the DTI and, most importantly, the Treasury.

While the need for cooperation between government and industry is hinted at there has been scarce thought on what this really means. When a government has no semblance of industrial policy whatsoever it is extremely difficult to see how research can be managed to the best advantage. The Technology Foresight exercise is claimed to be all things to all people, but while it may help to identify some narrow objectives it will not provide solutions to the country's technological balance of payments problems.

Regrettably, after nearly a decade since the Government withdrew from near-market research — an ideological experiment that went disastrously wrong — it is still the market that is expected to drive our science and technology policy. The OST has managed to shed some ideological baggage but only on its own territory. There is no indication that anyone else in Whitehall has followed suit.

The problem of a weak minister in a weak department is that there is little he can do. I am sure that William Waldegrave is well intentioned, and I am certainly sure that many in the scientific community rejoice that Peter Lilley is reported to have turned down the job immediately after the General Election.

I am becoming more and more convinced that we need a Ministry for Science and Technology. William Waldegrave may be our science minister but is still better known to the public for being in charge of the Citizen's Charter. The DTI after its mauling by the Thatcherites in the 1980s is probably incapable of being reformed and we should reconsider what role it should play in supporting technology. There is a clear need, if not for a takeover of departments' R&D budgets, for a reformed public expenditure process that does much more to protect science spending.

There are many areas where greater political effort is needed than we have seen in the eighteen-month life of the OST. There are a whole raft of initiatives needed for technology transfer, many of which particularly relating to technological networks have been identified by the excellent work on innovation undertaken by the Economic and Social Research Council. Tax incentives and attribution of EC research funds are two areas where the Treasury should be made to look again. If there is to be no R&D peace dividend then the MoD must reconsider what role it has in supporting civil industry. The list goes on.

I wish to end on a positive note. It may be that we have turned the corner and that we have a Government that takes science seriously. But what we also need is a scientific community that takes politics seriously. Scientists must articulate to politicians what they are trying to achieve and why science and technology should be supported. Equally scientists should examine the promises of the OST with a healthy academic scepticism. I believe there has been at times a willingness to welcome new initiatives on their face-value alone without proper scrutiny of their underlying worth.

The pronouncements of science ministers (and their shadows) should be considered by scientists with the same degree of scrutiny as they would new research. Genuine dialogue by all sides can only be healthy and will hopefully lead to a stronger consensus for the future.

L. Moonie
SPA (1993) 7

Basic research is like shooting an arrow into the air and, where it lands, painting a target.
[Homer Adkins, *Nature* 312 (1984) 212]

Optics, Astronomy Strong Fields for British Physics in 1980s

Each month this feature exploits ISI's unique publication and citation data to illuminate current trends in research and to reveal research performance. A quantitative approach defines each story and an accompanying commentary highlights the most prominent results of the analysis.

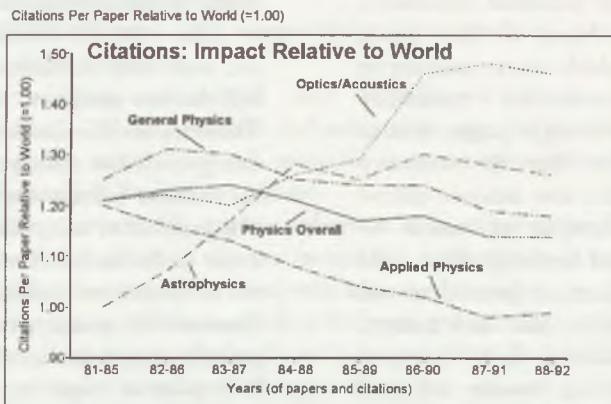
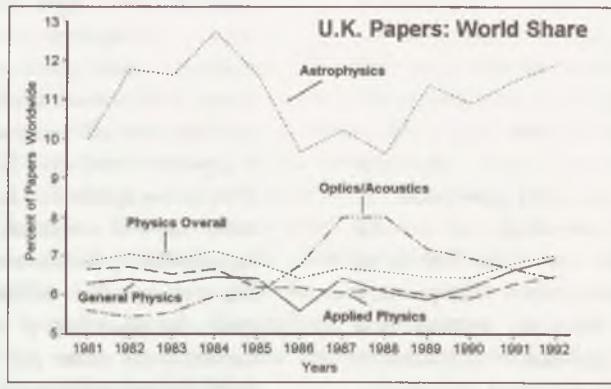
Nearly a year ago, *Science Watch* presented publication and citation statistics on British science papers published during 1981-91 (see *Science Watch*, 3[6]:1-1, August 1992) and noted a sharp decline in citations per paper relative to the world for U.K. clinical studies, as well as a similar dip in citation impact, albeit more modest, for Britain in the physical sciences (including physics, chemistry, and earth sciences).

Several readers expressed interest in obtaining a closer look at the physical sciences, since even in the data presented it was clear that the overall weakness highlighted was not universal across all subfields. In fact, according to figures for 1987-91, U.K. papers in analytical and inorganic chemistry, and in astronomy/astrophysics, scored +47% and +24%, respectively, when compared to the world's citation impact. Moreover, one critic wondered why optics/acoustics, a subfield in which Britain exhibited a citation impact score of 39% more than the world average during 1987-91, had been assigned to engineering, technology, and the applied sciences, instead of being grouped under the physical sciences. *Science Watch* was willing to take a closer look, this time focusing on physics.

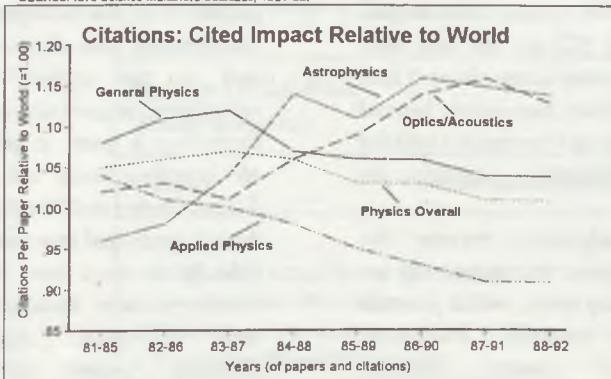
In the interval, data for 1992 became available. This time, as requested, papers published in optics/acoustics journals were analyzed as part of physics. The other subfields considered to be physics include general and theoretical physics, applied physics/condensed matter, and astronomy/astrophysics. All four were grouped together to obtain figures on U.K. physics overall. A further innovation was the inclusion of physics papers from the multidisciplinary journals *Science* and *Nature*. Such papers were not considered in the previous study. The results of the new analysis are summarized in the three charts.

The topmost plots the United Kingdom's annual world share of papers in physics and physics subfields in the ISI database, 1981-92. For Britain, astronomy/astrophysics is clearly the subfield within physics in which the nation is most dominant, at least in terms of output. Optics/acoustics surged ahead in world share during 1986-90, but has since fallen back. U.K. world share has been fairly constant in the other (and larger) subfields listed, which contributed to a relatively stable world share figure for U.K. physics overall.

The two charts below provide two pictures of relative citation impact. The middle chart depicts citation impact based on both cited and uncited papers, whereas the bottom chart considers the impact of cited papers only. Although there are some differences in these two, the trend lines tend to be the same. Relative impact figures for general and theoretical physics, applied physics/condensed matter, and of physics overall show a steady decline. A very different picture emerges for optics/acoustics and astronomy/astrophysics, which rise dramatically both in impact and in cited impact.



SOURCE: ISI's Science Indicators Database, 1981-92.



Current Contents (1994) 3

Citation analysis as a method in the qualitative evaluation of research

The bibliographic database compiled by the Institute for Scientific Information (ISI) and published in various citation indexes, the largest of which is Science Citation Index (SCI), provides a vast amount of raw data with immense manipulative possibilities. There is debate about the validity of some of the uses and interpretations of the data, also in the pages of your journal [1,2]. A short examination of this powerful bibliometric tool seems appropriate.

In 1963 the advent of the ISI heralded a new era in the analysis of published science output. The primary objective had been the creation of a bibliographic tool that would enhance the retrieval of published information by avoiding some of the innate problems to which subject indexing by means of controlled vocabulary (thesaurus of terms) is prone. It soon became evident that the secondary capability of the new database offered hitherto unthought of access to information and its sources. One could now link publications (journals as well as specific articles, individual authors, corporate affiliation) in a variety of ways. As Garfield, founder and chief executive of ISI pointed out, 'Indeed, it seems that the many sociological applications of SCI are the only ones that some scientists know about. I find that many scholars have never learned that SCI is first and foremost a tool for information retrieval — searching the literature' [3].

Acknowledgement became the name of the game: whose paper(s) are cited, how many times, which journals carry cited material? Publishers, especially of science journals, publishing scientists, information scientists all pricked up their ears and took notice. The relatively new field of bibliometrics, or scientometrics, came into its own. The ISI data have provided careers for some who spend their lives manipulating its data and repackaging it as management information for decision makers, especially in the realms of research

funding, academic appointments, and tenure. Others have had their careers enhanced or curtailed as a result of such packaging. Science journals are affected — who wants to publish in a title that is not included in the ISI database? Somewhere along the line certain assumptions seem to have acquired a priori status, such as: *As all 'worthwhile' journals are indexed by ISI, it follows that all 'worthwhile' citations to a person's work will be found in an SCI citation search.* The first part of the statement is untrue, not all 'worthwhile' journals are indexed by ISI (not by any definition of any qualitative equivalent of 'worthwhile'); therefore, the rather glib conclusion is totally erroneous — and dangerous.

The 1991 ISI database contained just under 6000 journals, of which the SCI database comprised 3213 titles [4]. These are the so-called source journals that provide the material from which the citation indexes are constructed. The problem of using the inclusion of a title in the list of ISI source journals as a qualitative indicator can be illustrated by an analysis of the source journals that make up the SCI. The SCI journals represent the whole spectrum of current information published in the biological, chemical, mathematical and physical sciences, as well as the applied sciences of agriculture, engineering and medicine. Preference is given to publications of an interdisciplinary nature, such as *Science*, *Nature* and *New Scientist*, as are the acknowledged core journals in each field. In the same year, 1991, BIOSIS, which produces Biological Abstracts and Biological Abstracts/RRM (Reports, Reviews and Meetings), indexed 7608 titles or source journals [5], more than double that of the total covered by the Science Citation Index and 25% more than all the titles in the full ISI database, which includes the social sciences and humanities. Most of the items indexed by SCI would be found in Biological Abstracts/RRM; but that would probably represent only 30% or 40% of the items indexed

in that prestigious source. That means that citations that appear in 60-70% of the journals that BIOSIS acknowledges as of sufficient value to index are not reflected in citation studies that are based on ISI data.

The principles of citation indexing are sound and provide an additional strategy to retrieve published information through the linking of related publications, often from sources that are not included in its own database, but are cited in the ISI source journals. In this way, subject retrieval is enhanced far beyond the relatively modest or select primary database.

The limitation of the citation analysis game that many scientists, administrators and even information professionals seem to be unaware of, or have lost sight of, is that ISI only gives citation status to those items that are cited by the authors who publish in its source journals. Thus, a paper may be cited over and over again in a highly esteemed specialist journal that does not form part of the ISI database, but this cannot be determined, as ISI produces the only citation index of the scientific literature.

Correctly qualified statements such as 'Statistics compiled by the Philadelphia-based Institute for Scientific Information (ISI) indicate that 55% of the papers published between 1981 and 1985 in journals indexed by the Institute received no citations at all in the five years after they had been published' [6], are repeated without the important rider 'indexed by the Institute'; even more alarmingly, the information is likely to be misinterpreted as 'statistics show that 45% of publications are never used and are therefore useless!' The concepts 'scientific information needs', 'wants' and 'use' touch on another long and inconclusively debated issue that falls outside the immediate focus of the present discussion.

The positive response to the quality assessment potential of the data contained in the ISI database is understandable. We live in an era of

dwindling resources and responsible administrators must make very tough financial decisions. The need for an authoritative objective approach to the evaluation of research output has been a real concern for many years. The peer review system is imperfect and prone to (even unintentional) bias. Evaluation through impartial computer manipulation of the perceived value of a scientist's (published) work is indeed a marvellous method.

Unfortunately, this powerful tool is prone to (mostly) unintentional abuse. It is essential that those who conduct scientometric research based on citation analyses should acknowledge the limitations of the source data. Such results present a valid and valuable perspective of one of the parameters involved in addressing a very complex problem.

S. Steynberg,
Suid-Afrikaanse Tydskrif vir Wetenskap
89 (November/December, 1993) 531

Ezt természetesen nem annyira a kutatók jóléte érdekében terveztek így, hanem elsősorban azok teljesítményének növeléséért. Ugyanis azzal, hogy számos intézet azelőtt Tokió összes városrésze között volt elosztva, nemcsak a munkatársaknak kellett átlagosan napi két órát közlekedési eszközökön eltolniük, hanem a különböző szakterületek érintkezése is szenvedett emiatt.

Tsukubában ezzel szemben ez az előrendő érintkezés könnyen megvalósítható: A rokon intézetek gyalog, vagy kerékpáron néhány perc alatt elérhetők. A laboratóriumok és azok modern felszerelési szintje gondoskodik arról, hogy a 11000 Tsukubában alkalmazott kutatóknak és technikusnak (170000 lakos mellett) — legalábbis szakmailag — ne legyen oka a panaszra.

Az élet minőségével inkább a munkahelyen kívül elégdetlenek. Rafinált laborok felépítése más dolog, de hogy e körül egy élő város alakul-e ki, az egy másik dolog. A két kisebb város és négy falu, melyekben eddig 86000-en laktak, még most is felismerhetően a mezőgazdasági struktúrát mutatja.

Igy nem különös, hogyha a kutatók feleségei hiányolják Tokió kultúrális-, szórakoztatási- és áruajánlatát. Nem utolsó sorban azért is, hogy a gyerekeknek ne kelljen iskolát változtatniuk, számos család vált szét, míg a feleség a gyerekkel Tokióban él, addig a férfi Tsukubában, az egyik "agglegénytornyban" lakik, és minden hétvégén az otthon és a munkahely között ingázik.

Igy a vonzó környezet ellenére és a drága kutató berendezéseknek (Tsukubába az állami kutatási támogatás egy harmada jut) egyfajta elszigetelődés jön létre, melyet "videki gondolatnélküliségnek" lehetne nevezni? Némely kormányzati tervező meg van erről győződve, és olyan terveket szűr, hogy Tsukubába egyfajta városi érzés valósuljon meg: Tsukuba Tokio bolygóvárosává alakuljon át.

A várost a jövőben egy 58 kilométer hosszú gyors autópálya kösse össze közvetlenül Tokióval. És ez még nem elég: A tudomány városának lélekszámát az elkövetkező 75 évben egy millióra kívánják emelni.

Botskor Iván a "Japaninfo" insider szolgálat kiadója Japánról tudósít
Bild der Wissenschaft, 12 (1993) 40

Akademgorodok — japánul

Vegyük az összes Max Planck Intézetet, az egész Fraunhofer Társaságot, három középnagy szövetségi németországi egyetemet, egy szakfőiskolát — és költöztessek át ezeket egy, a Lüneburger Heide-n lévő szép helyre. Ne rázza a fejét!

Egy ilyen tervet Japánban már régen megvalósítottak, ez a Tsukuba technopolisz.

1961-ben a japán kormány azzal a gondolattal kacérkodott, hogy Tokio teljes állami apparátusát egy új helyszínre telepíti át. Brasilia mintájára, a főváros tehermentesítése érdekében egy teljesen új alapításra gondoltak. Mi több, a hatvanas évek elején a Miti arról álmordott, hogy Tsukubában a Standford University és a Silicon Valley együttes japán változatát hozzák létre.

Míg a miniszteriumok távolról sem lelkesedtek ezért a tervért, a kutatóintézetek teljesen üdvözölték azt. Az ő belegyezésük 1963-ban eldöntötte a dolgot: Tokiótól hetven kilométerre északra, egy abban az időben főleg mezőgazdaságilag hasznosított területen épüljön fel Japán nemzeti kutató laboratóriuma. A példa azonban inkább a merev szibériai "Akademgorodok" volt, nem pedig a laza Silicon Valley.

Milyen sikeres ma Tsukuba Science City? A Science and Technology Agency, egy tokói miniszterium jellegű hatóság egyik jelentése szerint Tsukuba határozottan elmarad a hasonló külföldi központok mögött. Ez mind a kutatási produktivitásra, mind a felhasználásra orientált kutatás kimutatható eredményeire igaz. Ezenkívül azt is hiányolják, hogy az a koncepció, ami szerint az ottani technológia transzfernek működnie kellene, még nem alakult ki.

Ezenkívül Tsukubában a japán viszonyokhoz képest rendkívül sokat költöttek az anyagi infrastruktúra kiépítésére.

Szemben a többi, szüntelenül akut helyhiánnyal küzdő japán kutató intézményekkel az 1980-ban elkészült tudomány-város egy nagyvonalú kampussal rendelkezik, melyben mesterséges tavak, magas fák és egy, az egyes intézeteket egymással összekötő széles utakból álló hálózat található.

Kutatás Tsukubában: A nagy intézetek

Intézet	Intézeti munkatársak jelenlegi száma
Földrajzi Intézet	855
Erdőgazdasági és Erdei Termék Kutatóintézet	717
Elektrotechnikai Laboratórium	678
Közmunakágyi Kutatóintézet	477
Nemzeti Ipari Kémiai Laboratórium	346
Japán Kutatási és Technológiai Információs Központ	323
Nemzeti Mezőgazdasági Kutatóközpont	315
Japán Gépjármű Kutatóintézet	303
Gépgyártási Laboratórium	274
Nemzeti Agrárbiológiai Kutatóintézet	253
Gyümölcsfa Kutatóállomás	223
Nemzeti Mezőgazdasági és Környezeti Kutatóintézet	211
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Műanyag és Textil Kutatóintézet	125

Hogyan tovább?

A fizika átalakulásának korszakában élünk, sok fizikus mégis azt vallja, hogy "ugyanúgy, mint eddig, csak többet" kell teljesítenünk; azaz nem óhajtják a tényeket tudomásul venni.

Gondolunk arra, hogy mennyire megváltozott a bennünket körülvevő — a fizika tudományán kívül eső — világ. Az Egyesült Államok Nemzeti Tudományos Alapjának egy korábbi igazgatója mondotta: "Az amerikaiak állandóan azt hallják, hogy világelsők vagyunk a tudományban, és éppen ezért csodálkoznak, hogy mégsem javulnak az életkörülményeik. Úgy tűnik számukra, hogy éppen az nem kifizetődő, ami igazán jól működik országunkban." A német *Fizikus* Társaság ezévi kongresszusán a kutatásokért felelős szövetségi miniszter azt hangsúlyozta, hogy a közvéleménnyel meg kell értetni az alapkutatások fontosságát. Az Egyesült Királyságban a Természettudományos és Műszaki Kutatási Tanács elnöke a "gazdaságreremtő természettudományok" kifejezést használta; az USA kongresszusában a "produkтив természettudományokról" beszélnek. Hollandiában politikai konszenzus jött létre a kutatás állami támogatásának megtérítésében (az anyagi támogatás kielégítő, sőt — több, mint elegendő), de abban is egyértettek, hogy az alapkutatások támogatási aránya túlzott.

Sok ország politikai fórumán hangzanak el hasonló kijelentések [1]. *Elmúlt az az idő, amelyet egyes tudósok normálisnak tartottak, pedig kivételes periódus volt — amikor a kormányok bőkezűen adakoztak országuk kutatási céljaira. Kiment a divatból az a gondolkodási modell ("a reménykedés stratégiája") amikor úgy vélték, hogy valamilyen bűvös intés hatására fog a tudomány nagyon hasznosat produkálni. A tudományos eredmények már nem okoznak izgalmat; azt várják tőük, hogy a nemzetet erősítsek. minden fejlett ipari országban felülvizsgálják azokat az elveket, amelyek alapján a kutatásra pénzt fordítanak.*

Csökkentett prioritás

Egyes országokban különösen nagy feszültség mutatkozik, ha a fizika olyan területeinek támogatásáról van szó, mint például a nagyenergiájú, illetve nukleáris fizika, vagy pedig az ūrkutatás. Ezeknek az ágaknak egyes országokban nagyon alacsony, vagy éppen negatív a prioritása.

A természettudományos eredmények valódi fogyasztója, az ipar, ma nem támogatja az akadémiai intézményeket, így az utóbbiak feladata volna, hogy érveljenek a növekvő kormánytámogatás mellett. Egyes vállalatok a fellendülés időszakában a kutatás területén elért vívmányokkal büszkélkedtek, a stagnálás idején viszont nyomatékosan megkérdejelezik azt a filozófiát, miszerint a cégek szempontjából volna hasznos a kutatásokra fordított beruházás. Az egyik legnagyobb elektronikai vállalat elnöke egyenesen azt állapította meg, hogy az alapkutatások túlzott támogatása árt a cég versenyképességének. Nyugati multinacionális vállalatok fő irányítói — akik ma már elsősorban pénzügyi és nem technikai beállítottságú szakemberek — átprofilírozatják a kutatási szervezeteket. Ók a tudományos ismeretekről azt tartják, hogy

bárhol a világon "megtermelhetők" — adhatók-vehetők. Idézzük az AT&T cég Nobel-díjasát, *Pensiast*: "nem az a kérdés, hogy jó vagy rossz tudományt művelünk, hanem, hogy a vállalat jól fejlődik-e vagy sem". Ne tévesszenek meg az ipari kutatásra mondott olyan varázsszavak, mint például fogyasztói-vállalkozói elv, harmadik generációs K+F-szervezet vagy push-pull-igazgatás, partneri viszony. Az üzenet egyértelmű: a kutatói személyzet létszámát csökkentik, és ezzel párhuzamosan a kutatási programokat eltolják a vállalat szempontjából hasznosnak ítélt, alkalmazott témák irányában.

Azt beszélük, hogy a fizika csatát vesztett olyan cégeknél, mint az AT&T-Bell Lab., Belcore, IBM, Xerox, Philips Research, Exxon. Akadémiai oldalról persze érvelhetnek azzal: ha megváltozott a gondolkodásmód az ipar, az ipari kutatások területén, akkor a kormányok kötelesek a nagy kockázattal járó alapkutatásokat támogatni. Ott van azonban a bökkenő, hogy ez a politikai küzdőtéren csak akkor talál hitelre, ha ki tudjuk mutatni, hogy a piac igényli az új fizikai eredményeket.

Csökkenő érdeklődés

Az egyetemre jelentkező hallgatók az akadémiai területek fontos "input paraméterei" — és ezt számításba kell vennünk.

Hollandiában a műszaki egyetem elsőéves fizikus hallgatóinak száma 1988-ban 827 volt, azóta ez a szám folyamatosan csökken. Az 1988-as tetőzés oka demográfiai (a második világháborút követő népességröbbanás) volt, a csökkenés viszont minden természettudományos szakon hasonló, mint a fizikusoknál. A felvett hallgatók minősége sem a régi. Hollandiában azelőtt hosszú éveken át a középiskolákból kikerülő legkiválóbb tanulók fizikus vagy teológiai-filozófiai szakra pályáztak. Ma más a vonzódás irányá, más szakok is igénylik a legjobbakat. Egy, a gazdasági pályára készülő okos hallgató ezt így magyarázza: *Ezt a pályát — fizika helyett — azért választottam, mivel így én leszek a fizikusok főnöke.* Más nyugati országokban is ez a helyzet; a természettudományos pályákra készülő fiatalok száma csökken.

Atomizálódás?

Az utóbbi években olyan fizikai jelenségeket fedeztek fel, amelyek a gondolkodó emberek számára izgalmat és kihívást jelentenek (ilyen a magashőmérsékleti szupravezetés, az 1987A szupernóva, atomos hűtés, atomoptika, szuperdeformált atommagok, egyszerűbb berendezések, stb.). A Természet kimeríthetetlen [2]. Ez látható ebből a — korántsem teljes — felsorolásból. Ez minden jelenség, amelyet nem láttak előre azok, akik a fizika jövőjének jóságával foglalkoztak. A tanulság: az új tudományos felfedezések szinte állandóan felülmúlják a képzeliőrőnkét.

Az új felfedezések szaporodásával a tudományos publikációk száma is egyre nő. Nem tartunk ugyan még ott, ahol az orvosok és biológusok — akik elértek a napi körülbelül 500 közleményszámot — azonban mindenki előtt világos, hogy ez nem folytatódhat: meg kell tanulnunk kezelní ezt az "információs infarktust". Az FOM által szponzorált egyik

munkacsoport kimutatta [3], hogy az egyes tudósok munkájuk folyamán nem igazán tudják megragadni a kitűzött feladatot, mivel azt gondolják, hogy az önmagában is teljesen tiszta és egyértelmű. Nagyon lényeges volna a különböző fizikai ágak közötti információcsere, az együttműködés — "kölcsönös megtermékenyítés". Fontos volna ez a tudomány haladása szempontjából — azért, hogy a fizika felaprózódásával, "atomizációjával" ne elsősorban a politikusok és a szervezési szakemberek foglalkozzanak.

Néhány javaslat

Mit tehetnénk mi, fizikusok, a körülmenyek javítása érdekében? Véleményem az, hogy az emberi tényező a legfontosabb, ezért az akadémiai területek irányítóinak elsősorban a középiskolai tanárok képzésére kellene több figyelmet (és pénzt) fordítani. Rendkívül sokat jelent egy jó tanáregyéniség lelkes irányítása a tanulóifjúság számára azért, hogy ezt a tudományágot válasszák. Helyi szinten, minden kis közösségen kell a tanárokat segíteni a munkájukban; megismerni a problémáikat, melyekben egyes intézetek a segítségükre lehetnek.

Biztos vagyok benne, hogy az, amit az egyetemen a fizikából elsajátítanak: analitikus gondolkodás, metodika, tervezés és nemzetközi együttműködés, igen hasznos az egyén számára akkor is, ha átmegy egy másik tudományterületre vagy pedig más, nem kutató pályára. Legyen üzenetünk hallgatóink számára, hogy ne tekintsék az egyetlen értelmes érvényesülési lehetőségeknek valamelyik fizikai tanszéket — máshol is tudnak igen hasznosan tevékenykedni.

Ma nagyon fontos a közvélemény megítélése számunkra. Nem én vagyok a legilletékesebb arra, hogy erről a témaról nyilatkozzam, azt azonban tudom, hogy a médiát rendkívüli módon érdekelni, hogy új fizikai jelenségekről tudjanak beszámolni. Nő a nemzeti büszkeség, ha vezető lapokban írnak nagy tudósok tevékenységéről. Nekünk ki kell használnunk ezt az érdeklődést.

Maradjunk a realitásoknál, és ne kerüljük meg a pénz problémáját. Elmúlt az az idő, amikor bőségesen áramoltak az anyagiak tudományos célokra. A tudományok rangsorolásában változás történt; a fizika fontossága csökkent. Más területek kutatói mozgatják meg a pénzszereket fantáziáját — a tudomány iránti érdeklődés nem sokkal nagyobb, mint ha zenekarokról, hangversenyekről vagy balettről volna szó. A versenyben a fizikusok előnyben vannak, mivel régi tapasztalatokra támaszkodhatnak a tervezés és a csapatmunka

területén; a politikai arénában az is számít, hogy itt kiterjedtek a nemzetközi kapcsolatok.

Úgy gondolom, hogy nem felesleges néhány tanács, ha valaki a terveihez pénzt akar szerezni.

— Előnyös, ha a projektet nemzetközi szinten, nemzetközi együttműködésben szervezzük, mert ezt szívesen fogadják a politikai körök;

— jó, ha a tervet együtt dolgozzuk ki a hazai akadémiai ipari szervezetekkel, mert akkor várható, hogy az eredmények a nemzetgazdaság számára is használhatók lesznek;

— az is előnyös, ha a terv más kultúralis ágazatok számára is hasznos (például, ha technikai segítséget adunk más területeknek), vagy ha a terv eleve multidisciplináris, tehát többféle testület támogatását elvezetheti;

— támogatni kell olyan fizikusokat, akik széles nemzetközi kapcsolatokkal rendelkeznek, nemzetközi szinten is elismertek. Ez kifelé is bizonyítja a hazai kutatás rugalmasságát és életrevalóságát.

A holnap Európájában az egyes államok fizikus közösségeinek újra lehetségei lesznek pozíciójuk megszilárdítására. Érvényesülni fog a jelszó: "együtt szilárdak vagyunk, de külön-külön elvesszük", azaz a fizikai kutató szervezetek, a kutatási tanácsok fizikai osztályai nemzetközi együttműködés keretében tudnak majd berendezésekhez jutni, és részt vesznek majd nemzetközi projektekben. Ha erre szükség lesz, ne habozzanak hozzájárulni a saját (egyre csökkenő) pénzeszközökiből is, az egyes vállalkozások céljaihoz. Az Európai Közösség (EC) kutatási alapjai növekvőben vannak (lásd az 1994-98-as Kerettervet). Hiszek abban, hogy eljön az az idő — mégpedig a nem távoli jövőben — amikor ezeknek az alapoknak egy részét az EC kutatási tanácsa az alapkutatások támogatására fogja fenntartani. El kell fogadtatni a fizikus kutatók szervezeteit egyenrangú félként ezekben a testületekben például az EUPRO-ban [4].

Nem fejlődhet a mi tudományos területünk, ha hagyjuk, hogy környezetünk elavult fogalmak alapján ítélezze meg a fizikusokat — ez vezet a kutatók rossz közérzetéhez. Az egyes nemzeti fizikus közösségeknek nem csak az a feladatak, hogy bebizonyítsák: "csodálatos dolgokat tudunk felmutatni", hanem az is, hogy megértessek az emberekkel, hogy igenis szükség van a fizikusokra, az ő tudásukra, és ez az igény csak növekedni fog a jövőben. Ha ezt elérjük, akkor biztosak lehetünk abban, hogy az ifjúság, a jövő generációja érdeklődni fog a fizika iránt, és a kutatásokhoz elnyerjük a politikai körök támogatását is.

H. Chang, *Fizikai Szemle* 2 (1994) 87
(fordította: Menczel György)

[1] Roundtable: *Physics in Transition, Physics Today* (1993. február) 36.

[2] D. Klepper — *Physics Today* (1991. december) 9.

[3] Az információrobbanás a fizikában (1993. márc. 20., Utrecht) lásd *Europhys. News* 24 (1993) 86.

[4] EUPRO a fizikai kutatási szervezetek európai szövetsége. Az alapokmányt a következők írták alá: FWO/FNRS (Belgium), CNRS & CEA (Franciaország), DFG (Németország), EOLAS (Irország), CNR (Olaszország), FOM (Hollandia), NFR (Svédország) és SERC (Egyesült Királyság). Várható, hogy a közeljövőben aláírják Dánia, Finnország és Norvégia szervezetei is. Az EUPRO döntése alapján kilenc témában kezdődnek kutatások, ebben együttműködnek a résztvevők, és támogatják a már beindult COST programot (amely az EC által koordinált "a la carte" kutatási terv.). Dr. Chang az EUPRO elnöki tiszttét látja el 1995. május 1-jéig. (*Europhys. News* 24 (1992) 23).

Basic research is not the same as development. A crash programme for the latter may be successful; but for the former it is like trying to make nine women pregnant at once in the hope of getting a baby in a month's time.

[Sir William Richard Shaboe Doll, *New Scientist* Nov 18 (1976) 375]

Surprises Across the Cultural Divide

"Advanced" countries aren't so advanced in providing opportunities for female scientists

In his career as a physics professor and finally chairman of physics at York University in Ontario, Jim Megaw saw a lot of undergraduates and graduate students. And he was dismayed to note how few were women. But Megaw didn't simply lament the situation and go on to other pursuits: He put on his scientist's hat and set out to collect data on whether the situation was similar in other countries. After he retired in 1989, Megaw sent questionnaires to more than 1000 physics departments around the world, asking what proportion of their faculty and students were women.

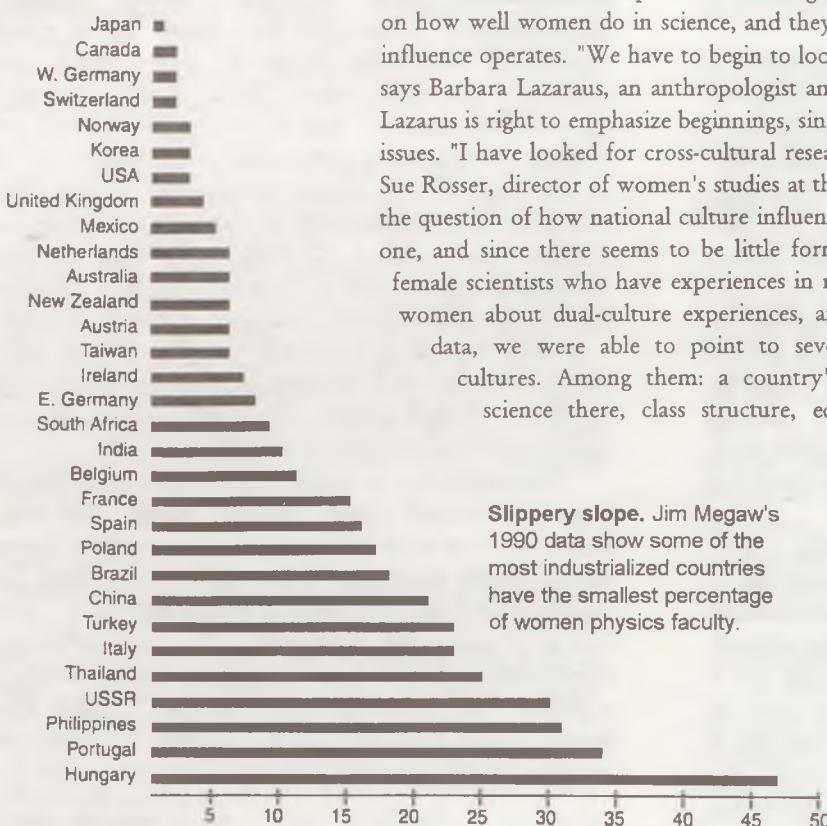
You might think it wouldn't be necessary for Megaw to go to such lengths. After all, aren't there lots of good statistics on women in science around the world? The answer is no. As a matter fact, Megaw's data, from 400 departments that responded to his request, is one of the few studies comparing representation of women in specific scientific disciplines around the world. And in those data, valuable partly because they are rare, are findings that seem to contradict stereotypes about national cultures and how they treat women.

For example, among the countries with the most women physicists were unexpected entries: Hungary, Portugal, and the Philippines, where women represent 30% to 41% of faculty and 27% to 60% of physics students receiving Ph.D.s. On the other hand, countries with large physics establishments, high levels of industrial development, and strong women's rights movements, such as the United States, Britain, and Canada, have among the poorest records, with women representing fewer than 5% of physics faculty, and fewer than 12% of physics students receiving Ph.D.s.

Social scientists interpret data like Megaw's as indicating that culture is a powerful influence on how well women do in science, and they think the time is right to begin studying how this influence operates. "We have to begin to look at some of these cultural and national traditions," says Barbara Lazarus, an anthropologist and associate provost at Carnegie Mellon University. Lazarus is right to emphasize beginnings, since, so far, social science has had little to say on these issues. "I have looked for cross-cultural research on this for years, and haven't found any," says Sue Rosser, director of women's studies at the University of South Carolina in Columbia. Since the question of how national culture influences women in science seems like such an important one, and since there seems to be little formal data, *Science* turned to a less formal resource: female scientists who have experiences in more than one culture. By interviewing two dozen women about dual-culture experiences, and combining those interviews with the available

data, we were able to point to several factors that appear to be influential across cultures. Among them: a country's level of economic development, the status of science there, class structure, educational system, and the presence or absence of support systems for combining work and family life.

In an informal effort of this kind, based on individual experiences, contradictions abound, and our Women in Science 1994 issue cannot purport to support any particular conclusion or viewpoint. Nevertheless, in the absence of hard data, these experiences hint at issues affecting women in many countries — and point up the need for research on this crucial, neglected topic.



Slippery slope. Jim Megaw's 1990 data show some of the most industrialized countries have the smallest percentage of women physics faculty.

Advanced countries, entrenched systems

Though there is little systematic data internationally on women in science, a few sociologists have tried to compile such statistics. One who has is Beatriz Ruivo, who works for the National Board for Science and Technological Research in Portugal. In the mid-1980s, Ruivo was puzzling over why some countries like her own, latecomers to the industrial and scientific scene, have a high percentage of female scientists.

In Portugal, government statistics showed that, as of 1978, 36% of researchers were women. And the pipeline was full: During the 1980s, more than 50% of the Ph.D.s in math, physics, chemistry, and biology were awarded to women. When Ruivo tried to find data from other countries, she was frustrated, so she culled what she could from reports by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). "I realized, looking at the UNESCO publication, that Portugal was not a unique situation," she says. In countries now undergoing economic development, including Mexico, Argentina, and the countries of Eastern Europe, women made

up from 20% to 50% of the scientific researchers, compared to fewer than 10% in the United States and northern European nations such as Germany.

Ruivo's speculation is that in countries that have had large scientific establishments for centuries, science and technology became firmly established as a male domain during an era when women weren't in the labor market. Nations like Portugal, she argues, only began developing science and technology during the 20th century, when "society was more open to women's participation in general." As a result, women were able to establish themselves in these fields.

Despite this apparently hopeful picture, Ruivo says she is "not so optimistic as I was in 1987." Back then, she says, she assumed women in newly industrialized countries would continue to advance. But she no longer thinks so. Although there are plenty of women in science, she says, she has observed that the glass ceiling is firmly in place in Portugal: Women are concentrated in the lower levels of the scientific establishment and are not rising to the top ranks.

Science as a low-status occupation

Ruivo says that the glass ceiling she sees in Portuguese science partly reflects the absence of a strong women's movement agitating for equality and condemning sexist attitudes. In addition, she suggests, in Portugal and some other developing countries, the high numbers of women in science may not reflect society's high regard for women, but, conversely, the low esteem in which academic science is held, compared with jobs in business or industry.

In countries that are still undergoing economic development, basic science isn't as closely integrated into the production of goods and services as it is in the advanced economies of Europe, Japan, and the United States. In developing countries, she says, "to work in scientific research has a different meaning than in advanced countries. It is more of a cultural activity." Not only does it have low status, in some countries it is quite low-paying, making it a pursuit undesirable to men and therefore left open to women.

Shobhana Narasimhan, a physicist at Brookhaven National Laboratory, says she saw this situation when she was growing up in Bombay. While women are well-represented in Indian science, she says, there are few women in engineering, which is a more prestigious and lucrative profession than basic science. "As a student in India, I knew many men who desperately wanted to do research in physics or mathematics or some other pure science," Narasimhan says. "However, there was very strong social pressure from their families to pursue a 'real' career." A 'real' career meant designing factories or bridges, not studying DNA. Girls, not subject to the same pressures, were free to pursue academic science or math.

Several sociologists interviewed by *Science* noted that there is a growing sociological literature, across cultures, showing that the lower the status and pay of an occupation, the more likely it is that women will be found there — and that seems to hold for science. South Carolina's Rosser says several studies have

shown that in the former Soviet Union, "a very high percentage of the physicians were women... But that was not considered a high prestige position. The pay wasn't good. It was considered more like we view nursing. The scientific occupations that were highly valued were held by men."

That touch of class

The relatively low status of science isn't the only factor that may open the field to women. Another is class. In some countries, such as India, the nations of southern Europe, and Latin American countries, social class counterbalances gender. Class loyalties provide a bond between men and women of the well-educated upper classes, benefiting women who are born into the elite. University of Arizona astronomy student Sally Oey came away with this impression from a conference on women in astronomy last year: "In certain countries, the pecking order is rich men, poor men, rich women, poor women; and in other countries it's rich men, rich women, poor men, poor women. In the first case, gender is dominant in determining one's standing, and in the second, class is dominant."

During a postdoctoral stint in Mexico, Canadian astronomer Robin Kingsburgh observed how the class system worked to the benefit of educated, privileged women. "In Mexico the class system is very strong, and education is limited to the upper classes," says Kingsburgh, who received her Ph.D. in England in 1992. In Mexican academia, she says, women fare better than in Britain. The chair of the astronomy department at the University of Mexico is a woman, as are about one-third of the faculty, Kingsburgh notes, compared with only six women of 64 faculty members in physics and astronomy at University College, London, where she was a graduate student.

That apparent equality, however, prevails only within the academic scene, which Kingsburgh says feels like an island in a society where women are hardly equal to men. The middle-class male observatory technicians treat her with respect, she says, because of her class status, not because of her gender. The same technicians, riding down the mountain in a truck, "stop and whistle at every woman on the street... Only the upper classes are viewing women as equals."

Satisfying the requirements

Even if a society is fairly open to women, however, young women will never succeed in science as a profession unless they have taken lots of courses in science and math at school. Polish-born physicist Iwona Sakrejda, who recently took a position as an assistant professor at Creighton University in Omaha, Nebraska, thinks the high numbers of female researchers in former communist countries are due partly to educational policies requiring both boys and girls to study math and science through secondary school. That policy, which was in force in Poland when she was growing up, gives students the chance to see whether they like science and can excel at it. "Both boys and girls learned much more at school" in Poland, says Sakrejda. "We had to have science. We had very little choice."

Sakrejda's biggest criticism of schools in the United States, where her two sons are now in junior high, is that physics and math are optional — not mandatory. "It is too easy to get out of science," which students do too often, she says, because it "has a tough reputation."

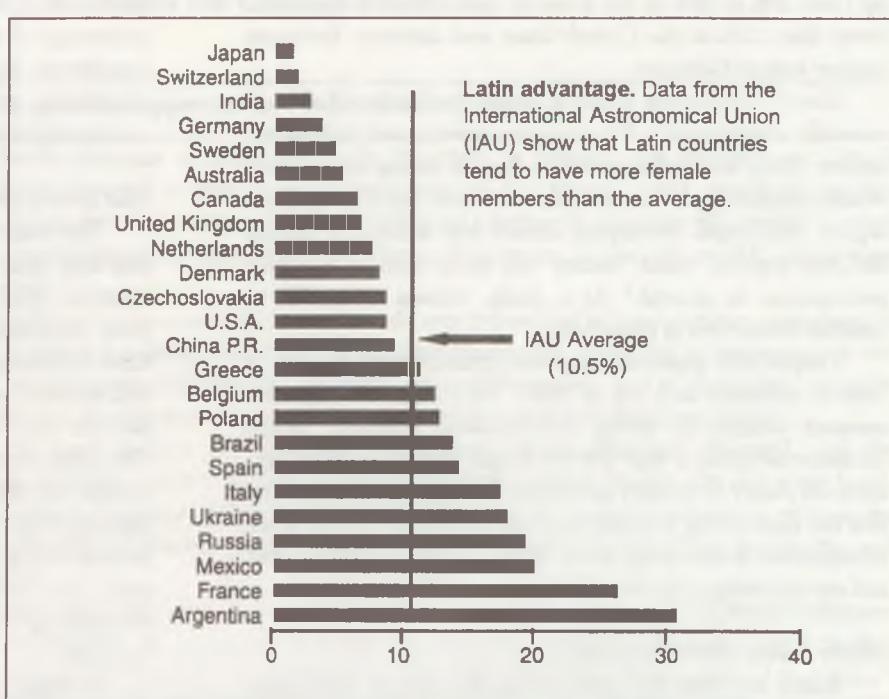
Chiara Nappi, born and educated in Italy and now a theoretical physicist at Princeton's Institute for Advanced Study, thinks mandatory math and science classes, combined with a policy of teaching all science subjects every year, are the most important factors in her country's excellent record in awarding advanced degrees in science and math to women. Since all students are required to take math and science every year, she says, girls can't "chicken out" of science, and therefore don't close doors on themselves before they reach university.

She contrasts the Italian situation with what she sees in the United States, where chemistry and physics are served up in demanding, 1-year "crash courses," which are optional, and consequently avoided by all but the most gifted students. In the United States, "the feeling is either you have [talent in math and science] or you don't," says Nappi. "If you have it, you can take any amount of that subject. If you don't, you should take none." In Italy and other southern European countries, she says, "the feeling isn't that you have it or you don't; the philosophy is that you can learn." Under those conditions, she says, girls tend to do better.

Course requirements seem to work well in some places. But the carrot may work as well as the stick. And one way science can be made more palatable is by teaching it to girls without boys present. Indian-born physicist Narasimhan, for example, says she benefited from an all-girls secondary school in her home town of Bombay. In that environment, she recalls, no subject was considered "unfeminine" and "it never occurred to me that being female had anything to do with whether I would go into arts or sciences."

York's Megaw also thinks all-girls' schools hold benefits for women across cultures. When he pondered results of his international survey of 400 physics departments, he perceived that women were better represented as both students and faculty in predominantly Catholic countries. In those countries, children are more likely to attend single-sex schools than they are in other countries, and Megaw hypothesized that single-sex schools are what make the difference.

As in other areas of this cross-cultural subject, there isn't much data for testing hypotheses, but some support for Megaw's notion does exist. A 1992 survey found that 58% of the female members of the British Institute of Physics had attended girls' schools through age 16 — dramatically higher than the national average of 13%. Similarly, a survey by the



Latin advantage. Data from the International Astronomical Union (IAU) show that Latin countries tend to have more female members than the average.

U.S. National Coalition of Girls' Schools found that 25% of girls' school graduates plan to pursue careers in math or science — four times the national average.

Family-friendly societies

All-girls' schools may help prepare women for scientific careers, but even a well-prepared female scientist may find her career foundering if she cannot combine professional duties with responsibilities at home. Social attitudes and policies toward child care, flexible work schedules, and the role of men in families dramatically color women's experiences in science our anecdotal survey found.

Astrophysicist Sara Beck, for example, contrasts the United States, where she was educated and held her first faculty job, to Israel, where she is a tenured professor at Tel Aviv University. Israel comes out ahead. "The U.S.A. is must a horrible place to try to raise a family and have a career," says Beck. "When I was working in the U.S.A., it was a struggle to find decent day care...and if I missed a half-day of work [because] my kid had a temperature of 104, I was lectured on how this let down the [department]. In Israel there is 3 months paid maternity leave, day-care centers on every block, and if you *don't* take off from work for your kid's birthday party the department chairman will lecture you on how important these things are to kids and how he never missed one while his kids were little."

Beck's contrast between Israel and the United States resembles observations by other women on the contrast between southern Europe and Latin America and countries where the "Protestant ethic" prevails, including the United States, Canada, the U.K., and Germany. "Women in France have more help in terms of having their children taken care of," says Therese Encrenaz, director of space science at the Paris Observatory, who has spent her career in France and travelled

extensively in other countries. "It is much easier to get a woman to take care of your children after school... so you can have a regular day of work. In the United States, the school day ends earlier, and day care is more expensive."

Beyond availability of day care, women speak of a general view of the integration of work and family life that makes more allowances for family in Latin and Mediterranean countries. And that, they say, levels the playing field for the genders. "Here in the United States, the way the universities are structured, the kind of demands that are put on faculty are the kind of demands that can be fulfilled by someone who has a wife at home," says Italian-born computer scientist Maria Paola Bonacina, now an assistant professor at the University of Iowa. The "more relaxed attitude," in Italy and other Latin countries, she maintains, makes it easier for women to maintain a serious career and an intact family.

University of Cambridge astronomer Judith Perry found corroboration for this idea in data gathered by the International Astronomical Union (IAU). "If you look at the percentage of the delegation to the IAU which is female, the thing that is striking is that the international average is around 11%," she says. "If you then separate the Latin countries — France, Spain, Argentina, Mexico," they are, with few exceptions, "above the international average." Trailing well behind that average are the

United States, Britain, Canada, and most northern European and Asian countries.

The Protestant work ethic, argues Perry, makes life revolve around work in countries such as Germany, Canada, and the United States. "To what extent is the Protestant work ethic predicated on the service of women behind the men who are working?" she asks. "A lot of northern Europeans say the Latins...don't do as much," she continues, "but is that true if we look at the whole society and not just individuals? One of the reasons women are more integrated may be that they are leading a healthier life as a society."

In general, a healthier life for societies surely must include changes that enable women to achieve economic equality with men and support systems for balancing the competing demands of work and family life. How those changes will be accomplished remains very much an open question. The answers, no doubt, will depend on class structure, work ethic, and systems of education. For those interested in bettering the position of women in science, all these areas provide a rich — and almost untapped — vein that invites further digging.

Marcia Barinaga
Science 263 (11 March 1994) 1468

To be a woman intellectual is still fraught with contradictions.

[Mary Helen Baroness Warnock, *The Observer* June 3 (1990)]

Die Fakultät ist keine Badeanstalt.

[David Hilbert on the proposed appointment of the first woman professor]

Der Forschungs Index



A kutatási index
A német kutatás vezető intézetei

A Max Planck Intézetek uralják az éghajlatkutatást

Az éghajlatkutatás olyan tudományterület, amely felé az olyan témák miatt, mint az "üvegházhatás" és "ózonlyuk" az utóbbi időben fokozott figyelem irányul. Azonban a szigorú értelemben vett éghajlatkutatás a tudományos publikációk elemzésénél a meteorológia egyéb területeitől, az atmoszférakutatástól és a földtudományoktól csak nehezen különíthető el. A rangsorok adatai lényegében a Science Citation Index (SCI) "Meterology and Atmospheric Sciences" kategóriáját veszik figyelembe.

A publikációs profil azt mutatja, hogy az éghajlatkutatásban a Max Planck Intézetek járnak az élen, azonban olyan nagy kutatóintézetek, mint a jülichi KFA és a münchen-neubergi GSF is nagyon aktívak. A leghatékonyabb azonban a Heidelbergi Egyetem, mely éghajlatkutatási témaiban három év alatt ugyan csak tizenkét közleményt jelentetett meg, de a legtöbb elismerést kapta, mely a tudomány mércéje szerint a jó minőségű munka ismervé. Nagy elismerésben részesült még néhány, Mainzi Max Planck Kutatóintézetből származó publikáció. A rekordot egy 48 idézetet kapott munka tartja, négy további közleményt már több mint húszszor idéztek.

Éghajlatkutatás

A befolyásosak

Intézmény	Idézetek száma (1993 áprilisig)	Publikációk száma (1990-1992)
1 Mainzi Max Planck Kémiai Kutatóintézet	270	66
2 Kaltenburg-Lindaui Max Planck Aeronómiai Kutatóintézet	131	65
3 Jülichi Kutatóközpont	120	58
4 Hamburgi Max Planck Meteorológiai Intézet	101	45
5 Braunschweigi Műszaki Egyetem	99	28
6 Bonni Egyetem	97	32
7 Müncheni Környezeti és Egészségügyi Kutatóközpont (GSF)	96	67
8 Hamburgi Egyetem	86	57
9 Kölni Egyetem	67	41
10 Bremerhaveni Alfred Wegener Sark- és Tengerkutató Intézet	65	25

Az aktívak (1990-1992)

Intézmény	Publikációk száma
1 Müncheni Környezeti és Egészségügyi Kutatóközpont (GSF)	67
2 Mainzi Max Planck Kémiai Kutatóintézet	66
3 Kaltenburg-Lindaui Max Planck Aeronómiai Kutatóintézet	65
4 Jülichi Kutatóközpont	58
5 Hamburgi Egyetem	57
6 Hamburgi Max Planck Meteorológiai Intézet	45
7 Kölni Egyetem	41
8 Frankfurti Egyetem	37
9 Duisburgi Egyetem	36
10 Karsruhei Egyetem	35

A hatékonyak (1990-1992)

Intézmény	Egy publikációra eső idézetek száma	Publikációk száma
1 Heidelbergi Egyetem	4,5	12
2 Mainzi Max Planck Kémiai Kutatóintézet	4,1	66
3 Garmisch-Partenkircheni Fraunhofer Atmoszféra-Környezetkutató Intézet	3,8	16
4 Braunschweigi Műszaki Egyetem	3,5	28
5 Müncheni Műszaki Egyetem	3,2	15
6 Bonni Egyetem	97	32
7 Göttingeni Egyetem	3,0	15
8 Bremerhaveni Alfred Wegener Sark- és Tengerkutató Intézet	2,6	25
9 Bremeni Egyetem	2,4	9
10 Hamburgi Max Planck Meteorológiai Intézet	2,2	45

*Bild der Wissenschaft, 6 (1993) 6-7
(Forrás: USP Wissenschaftsforschung, Bielfeld, a Science Citation Index alapján.)*