INSTITUTE FOR THEOLOGICAL ENCOUNTER WITH SCIENCE AND TECHNOLOGY

BULLETIN

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As I write this little message I am deep into editing the Proceedings of the ITEST Workshop on Secularism versus Jewish and Christian Secularity. As the excerpts printed in this issue show, much of the conversation centered around the "role of the laity" in proclaiming the Good News. It is an issue which concerns all Christians. None of us is exempt from the call to "go forth and preach to all nations." For most of us, however, our first task is to preach to those in our own "neighborhood." For many of us that "neighborhood" is the scientific/technical community and/or the university, especially church-related universities which, it seems, are becoming more secular.

Several of those present mentioned what should be a truism in our contemporary world but does not seem to be one, namely, we "preach" most effectively by being what we profess. In the old days we used to call this "good example." Nonetheless, we preach best in our neighborhoods by exhibiting that we really believe in the Lord Jesus Christ and that that belief directs our lives. We can talk eloquently, as St. Paul tells us, but unless we display our love for the Lord and for his brothers and sisters here on earth, we might as well spare ourselves the trouble. This applies to all of us — myself included, as I am well aware.

Another theme that received a lot of attention at the Workshop was the nature of secularism and how deeply we have all been "infected" by it. We are all children of the Enlightenment to some degree or other. This shows even in the way we formulate questions to ourselves and to others. Clearly, there will be something in this volume for all of us to ponder.

Don't forget the October Workshop on *The Science and Politics of Food*. In the meantime, have a good summer "when the living is easy." I would also wish those south-of-the-equator members a pleasant winter season.

Robert Brungs, S.J.

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ANNOUNCEMENTS

1. You may have already received your invitations to the ITEST October, 14-16, 1994 workshop: *The Science and Politics of Food.* We also invited people working in the various rural life ministries around the country since their input could add a valuable dimension to the discussions. Response has been positive thus far with phone calls indicating interest in the topic as well as in the essays and the edited proceedings. If you know individuals who might be interested in attending, please invite them. We can supply extra brochures (invitations). Please note that we have a special student rate. We urge you to register early since we expect a good number to attend and are limited to approximately 50 participants at Fordyce House.

2. Plans for the October, 13-15, 1995 workshop are well underway with a presentation of the topic: *Population* and the tentative title, "Reproductive Science and Population." We encourage you to follow closely the reports on the September, 1994 United Nations' International Conference on Population and Development, in Cairo, Egypt. In fact, there has been much discussion already both in the international commercial and religious press (electronic and print) on this "hot" topic of population growth particularly in Third World countries.

3. The ITEST Board is exploring the possibility of examining for the March, 1996 workshop the issue of Environmental Ethos. What, for example, motivates people to espouse (sometimes) diametrically opposed attitudes and actions on the environment? Is this "ethos" more subtle than the various media outlets portray? We plan to invite essayists representing "both sides" to this weekend. If you are aware of a good prospect, please call us or write us at the ITEST offices. Many speakers/lecturers (from all sides) are often booked a few years in advance.

4. PLEASE NOTE! THIS IS A REPEAT ANNOUNCEMENT: A few members have asked us to charge their yearly membership dues to VISA or MASTERCARD. It is not cost-effective for us, as a small organization to "buy into" the credit card business at this point. Therefore, we ask members outside the United States to pay with an international money order or personal check with US dollars. Some non-U.S. members find it convenient to pay for two or three years at one time. We have mechanisms in place to note that on the membership records.

5. A few people have called asking us to identify the "mysterious" packet of 6x9 inch pages they received in the mail from ITEST. Those pages are the "supplement" or correction pages of our latest publication, *Beauty in Faith, Science and Technology* - the proceedings of our ITEST 25th Anniversary Convention. We noted in the Announcements (page 2, #8) of the Spring, 1994 bulletin that Versa Press had done a poor job in reproducing many of the black and white photographs and that we would be issuing "corrective" pages as soon as possible. Therein lies the solution to the puzzle of the "mysterious packet."

6. For the last two issues we have been including a FAX (314)-535-0402 on the first page of the bulletin. Since the FAX equipment is not located in the ITEST offices, we do not have propriety over its use. We share it with other offices. For the time being, therefore, we will use that line in the RECEIVE mode only. In other words, you may send us messages, but we will not respond via FAX unless it is an emergency. In all your correspondence via FAX please use both Fr. Bob Brungs' name and ITEST.

7. Work on the Summary Volume, in the PAUSE mode for the past few months, is progressing slowly but surely. This is a very major task. Even if this task is not complete in the calendar year, 1994, the '94 dues-paid members will receive a copy.

From the ITEST Proceedings, March 1979. Dr. Hugh Martz, Valparaiso University . . . What is the role of law in society? I view the law as serving the people and as allowing them to maximize their expression, freedom and choice. I think that's consistent with our democratic system of allowing the people to participate, to create their own destinies as much as possible. That's the approach I took in my paper. I noted that there appears to be a substantial increase in the amount of government regulation, particularly at the federal level, in the past few decades. Our Constitution, under the commerce clause and under the clause of whatever is deemed to be proper and necessary, allows Congress to enact practically any kind of regulatory law and to implement any kind of agency deemed necessary.

SOME EXCERPTS FROM THE MARCH, 1994 WORKSHOP ON SECULARISM

The essayists set the tone for the animated discussions that followed at the March, 1994 workshop entitled Secularism versus Jewish and Christian Secularity. One participant, Tom Quinn, in discussing the vocation of the laity, urged serious reflection on the documents of Vatican II, pointing out that the emphasis in the documents (particularly "The Apostolate of the Laity") was on personal responsibility. Unless the laity assume personal responsibility for grappling with the problems of the secular spirit in society, not leaving it to the clergy, little progress will be made.

Thomas Quinn: Personal responsibility, at least according to my reading and study of the documents of Vatican II, is one of the very significant things that came out of that Council, in terms of what the people of God are expected to do. The first thing they're expected to do is demonstrate some personal responsibility, not leave it all to the clergy. The debate will not be joined, if debate it's going to be, until we all exercise responsibility. I don't think it will make any difference whether we speak about an offensive or defensive position. We're not going to get our hands around the issue of how to deal with secularism until there is a sense of responsibility developed among the people in the pews. In the present situation, that sense of responsibility can only be started from the pulpit. Because of the past when Father and Sister had the answers, the laity have to be told to develop a sense of personal responsibility and that that personal responsibility be exercised.

Edmund Pellegrino: The assumption that the reappearance of the clergy might resuscitate Catholic students is probably not true. I've been as impressed as the others by the clergy's defection. It's a strong word but it shows a defection from a mission in a Catholic university when lay faculty members must create a series of studies called Catholic Studies within the framework of a Catholic institution.

James Childs: I would say then that all believers have a vocation to witness to the hope within them and, therefore, their participation in the ethical struggles, at whatever level they encounter them, becomes the living out of that vocation.... That [dialogical encounter] is certainly a part of the vocation of the laity whether in a university situation, in business or in the sphere of science and medicine. That is the vocation of the whole people of God.

Donald Keefe: One of the things we ought to remember is that there's not necessarily a Catholic or a Christian position on every issue that may arise... Clericalism is something that we were supposed to have gotten rid of some while back. The notion that "Father knows best" has been somewhat discounted of late and that's a good thing. The clergy has a range of competence but it isn't a matter of passing judgment upon the impact of say, with due deference to Father Brungs, the genome project. This has all kinds of moral implications. It cannot be judged simply from the theological viewpoint or from the viewpoint of the scientist who happens to be a spokesman-with-collar of the church. These are provinces of the laity. More and more because of the enormous complications of contemporary life and not just in the areas of hard sciences, sociology, cultural life generally has become very complex. It requires a very considerable degree of understanding and sophistication to come to reasoned moral conclusions within it. It cannot be provided by looking it up in whatever handbook the church may see fit to issue.

Father Keefe warns about accepting without question "single voices" who apparently "speak for all" on various issues on society's table and uses examples to emphasize his point.

Insofar as they [members of Catholic 'think tanks] had membership in some organizations with some sort of Catholic cachet attached, their views came to be identified with the view of the church on "xyz." Well, the church may have no view on "xyz." The notion that various Catholic thinkers have discussed an issue is interesting but hardly definitive proof-positive of the matter at hand.

We ought to remember that mature Catholic responsibility is not clerical. It doesn't belong to the experts. We all are supposed to inform ourselves insofar as we can, read as widely as we can, and then come to the best conclusions we can. It may not be the world's most efficient way of arriving at information but it's the only one by which we can avoid having our opinions handed to us ready-made, which is far worse. I think that this is one of the great responsibilities that too many of the laity today are willing to hand over to the news commentators, stars of stage, screen, or radio — someone else in other words.

Edmund Pellegrino: The field has never been riper. ... If the laity has to do it, the laity is going to do it. But I don't think we ought to give up on the idea of a

Catholic or Christian university.

How "secularized" have we become all unwittingly? Bob Morris stresses the need for individual self examination as well as scrutiny of society and the courage needed to act on our findings.

Robert Morris: The first thing I'm going to take away from the meeting is the challenge to examine myself to see how secularized I've become. I don't think that I thought that I was secularized before I came here but that's an examination that I need to do. The other thing that I'm going to take away, and I would hope the students would take away, is the fact that it's clear, whether secularism is alive or dead, that the only people who are going to control it or change it are the laity of the church. We must be informed in order to be able to do that. More importantly, we've got to be courageous enough to do that, courageous enough to do it in the little things and in the big things. I think that all of us are unconsciously going to take away that same message.

Is denial of the transcendent an identifying marker of some scientific views? Professor Blackwell explains:

Richard Blackwell: This turn toward the secular, as we might call it, has resulted from the view of many scientists, certainly not all, that the scientific mindset not only does not appeal to the transcendent but more strongly that it can and should deny the transcendent altogether. By secularism, we mean the view that only the natural world is real and that that world is adequately understood by natural reason alone, especially the scientific mode.

In the arts too, perhaps more subtly, the denial of transcendence often rears its ugly head in the abasement of the human being.

Helen Mandeville: I began, as I say, by defining secularism for the purposes of my essay. Note that I'm talking about the arts — my assignment said "humanities" but by "humanities" I mean the "arts." I defined secularism as a rejection of transcendence, an explicit or implicit denial of a world or power or meaning beyond the human. This rejection of transcendence often takes the form of a denial of human dignity. There is an exhibit in London now which, I think, is a good example of it, namely, Lucien Freud's paintings. He has these huge, meaty haunches of bodies with practically no emphasis on the face. This, in effect, says man has no spiritual nature. To my mind that's a denial of transcendence. In much of contemporary photography there's a denial of transcendence.

I'm not saying that presenting a human being as ugly is a denial of transcendence. Rodin, for example, has some sculptures like that. I think of one particularly, titled *The Old Lady*. She has sagging breasts; she's wrinkled; she's basically ugly. But there's a sense of real dignity about her. So, I think that, as long as the artist explores human dignity and invests the character with human dignity, there is transcendence. Eudora Welty does this in her WPA photographs. Look at her photographs in contrast to those of the other WPA photographers who simply demeaned the people they photographed. As long as that sense of the spiritual dimension of a person or the dignity of the person, which I see as spiritual, is present, we will find that their transcendence is there. We can't deny the transcendence.

People looking for a meaning beyond this world, beyond just matter, are finding spirit. To my mind, from my background and with my orientation, spirit points to transcendence.

Dr. Pellegrino adds another aspect to the definition of secularization - the human being as the center and sole determinant of all "...history, morality and purpose in the universe" with no reference to a higher being.

Edmund Pellegrino: I too will give you my working definition of secularization which is very close to what you've heard from others. Perhaps we may be able at this meeting to come up with some agreement on the notion of one aspect of secularization. There are many others. I'm talking more about the process — secularization — whereby humans move from a position of belief in a transcendent power. . . . That transcendence is vested for the monotheistic religions in God. In other religions it is found in various other forms of the transcendence. Secularization is a movement from belief in the transcendent to a position of disbelief and denial of such power. We see it in the assertion — one aspect I would add to what's already been said — of the centrality of humans as determinants of history, morality and purpose in the universe.

. . . . Medicine is a good arena in which to study this process of secularization for the following reasons: First, medicine has been from its beginning always intermingled with the sacred, with the divine. In many cultures today medicine still is the mediation between man — men and women — and whatever those forces are that brought about the thing we call disease, illness — distemper with the universe. The purpose of healing in those primitive views was somehow healing this relationship. That relationship has been attenuated over the centuries. In the earliest days of Hippocratic

medicine, one of the most important theses was separating medicine from the Orphic religions as a secular enterprise based in what was then the Greek philosophical notion of observing reality. A second piece was separating it from philosophy as a purely empirical science.

That process of secularization has proceeded..... The impact of this secularization is what we must look at certainly in the contemporary world where it is felt, because medicine deals with those issues which bring us most concretely and unavoidably in confrontation with the transcendent. Any serious illness is a spiritual challenge in which the person so afflicted must come to some conclusion about where we stand — I'm using transcendent, but we're talking here about God — in reference to God and His place in our particular confrontations with finitude.

The second area, of course, is in the ethics of medicine. Here it makes a very great difference. It is not simply a matter of finding religion everywhere, because we have the usurpation of the divine by the human. Let me list some of those things so you know what I'm concentrating on and where I'm coming from. . . .

We know about the absolutizing of autonomy, the human individual as the creator of his or her own values, the rejection of any religious source for morality, anything outside of man, the rejection of the transcendent. The unqualified endorsement, therefore, of moral relativism, cultural, historical and religious. That brings me to the increasing acceptance of euthanasia, and so on. I won't go through all of that. I'll list a few:

We see such things as erecting a distinction between having a life and living a life; the equalization of animal and human life; those who argue that a dog has a greater claim on human life than a disabled human being; the capitulation to the technological imperative in all forms of reproductive biology; the deconstruction of the Hippocratic oath itself to accommodate autonomy and the desacralization of medicine; the devaluation of the lives of the young, the old, the weak and those on the periphery. The movement from a covenant of trust to a consumer/provider relationship, which you will see increasingly when health reform takes its fullest expression, governed by contract law rather than ethics; the move from ethics to economics as the primary motivating factors in the healing relationship; the physician converted from healer to case manager and fund holder; the physician as functionary in an industry, that ghastly metaphor for what we do, the health care industry; the movement from *primum non nocere* to *primum non expendere*; the abandonment of the notion of the moral community.

We received a paper from Father Miguel Lorente, S.J., Professor of Physics at the University of Oviedo, for reprinting in the ITEST *Bulletin*. We are printing the first part here. We shall complete it in future issues. Father Lorente's address: Res. San Ignacio; Doctor Casal, 9; Oviedo, 33001 Spain.

CONTRIBUTION OF JESUITS TO NATURAL SCIENCES IN XVI-XVIII CENTURIES

In the meeting of the European Jesuit Scientists (Aix-en-Provence, September, 1989), P. Ziggelaar told us how to present the scientific work of the Jesuits through the ages: "We should publish Jesuit contribution to science for the sake of the history of science, of the Church and of the truth, but, also honestly admit and regret their errors, particularly when due to their background as religious, just as this same background also gave them advantages."

In this article, I want to expand on this idea and to develop some methodological principles I consider useful in the study of the contribution of Jesuits to the history of science. These priciples are the following:

1. The sources for the knowledge and evaluation of Jesuits in science are to be taken from general histories of science, where the standards are more universal and the criteria are applied independently of a particular scientific community. Afterwards one can use particular monographs for some individual Jesuit.

2. To get more impartial judgments, books not written by Jesuits should be consulted, although their critiques and evaluations should be compared with comments written by Jesuits.

3. In some cases, books on the history of science do not mention the ascription of a particular scientist to the Society of Jesus. Therefore, the way of finding Jesuits names in alphabetic indexes is to find their names in Jesuit catalogs. (Sommervogel, for instance)

4. Those historians are to be selected who stress the original contribution to new ideas, concepts and methods in sciences, as well as the influence on other scientists and new developments in theoretical and experimental sciences.

5. Those aspects are to be considered that are related to the religious and social activities, such as witness to the faith in the scientific community or help for the welfare of people.

6. Jesuits have a deep background in humanistic and philosophical studies. Hence, their contribution to science is based, in many cases, on philosophical presuppositions and cultural innovations in their own ages. This motivation and worldview should be uncovered in the presentation of their scientific work.

Following these principles I have carried out some preliminary work, collecting information from current history of science. [See Box on Page 7.] I present a list of some Jesuit scientists with their principal contributions taken from the books quoted.

MATHEMATICS

Christophorus Clavius (1537-1612), professor of mathematics at the Collegium of the Society of Jesus in Rome, played a leading part in establishing the Gregorian calendar. His *Opera mathematica* (Mainz, 1612) consisted of five folio volumes. His excellent translations and commentaries of Euclid (1574) quickly became the standard text and remained so until the 17th century. His large textbooks of arithmetic, geometry, algebra, harmonics and astronomy were used in all the Jesuit Colleges, thus making Clavius the instructor of mathematicians of Catholic Europe.

In 1582, Gregory XIII introduced a new calendar (known as the "Gregorian" or "New Style" calendar) based on the system of the Neapolitan physician and astronomer Luigi Lilio. Since Lilio died before the official adoption of his system, it fell to Clavius to carry out the immense calculations involved and to publish them in an enormous volume, the *Romani calendarii a Gregorii XIII P.M. restituti explicatio* (Roma, 1603).

(A. Koyré; Taton, 42,71)

Paul Guldin (1577-1643), the Austrian Jesuit is remembered for his famous theorem: If any plane figure revolves about an external axis in its plane, the volume of the solid so generated is equal to the product of the area of the figure and the distance travelled by the centre of gravity of the figure. Though this theorem had been propounded much earlier by Pappos, the Greek text was not rediscovered until long after Guldin.

(J. Itard; Taton, 216)

Cavalieri, an indirect disciple of Galileo, has often been called the father of integral calculus. When Cavalieri presented his geometry of indivisibles in 1629 he had been preceded by Kepler in 1615 and by the Jesuit Gregory de St. Vicent (1584-1667) who in 1625 had developed an excellent technique of his own, based on the classical method of exhaustion. Unfortunately, the loss of most of his papers during the fire of Prague prevented his publishing the *Opus geometricum quadraturae circuli et sectionum coni* until 1647. Misjudged in his time, he has remained so to his day, partly because of his extreme rigour and laboured explanations, and partly because of his mistaken attempts to square the circle.

(J. Itard; Taton, 215)

Torricelli, Roberval, Fermat and Wallis also managed to square hyperbolas, i.e. they integrated functions of the type x^{-r} where r is a positive rational number. Only the quadrature of the ordinary hyperbola, that of Apollonius in which $r=1$, continued to resist their methods. . . It was left to Gregory de St. Vicent to establish this connection, albeit implicit, in 1647, when he showed that abscissas in geometric progression correspond to areas in arithmetical progression. . .

Moreover, by studying Archimedes' treatment of the parabola and of the spiral, Cavalieri and de St. Vicent discovered (well before 1630) that the two had many similarities.

(J. Itard; Taton, 218, 219)

The Jesuit Vincent Riccati (1707-1775) is mentioned "by the introduction in 1757 of the hyperbolic functions, whose close connection with trigonometric functions was established by Wallis and Lambert in 1768." He was the son of the famous mathematician Jacobus Riccati who discovered the solution of nonlinear differential equations. Riccati's equation is named for him.

(R. Taton; Taton, 413, 398)

Mathematicians tried for a long time to remove the uncertainty surrounding the validity of Euclid's parallel axiom. . . In 1733, the *Euclides ab omni in aevo vindicatus* (Euclid vindicated from every blemish) by the

BIBLIOGRAPHY

* R. Taton, *History of science*, volume II (English translation, Thames and Hudson, London 1964).

* J. L. Heilbron, *The Elements of Early Modern Physics*, University of California Press, 1982.

* C. Truesdell, *The rational mechanics of flexible or elastic bodies*, en L. Euler, O. O. Serie II, 11-2 (S.H.S.N.), Zurich 1960.

* C. Gillispie (ed.), *Dictionary of Scientific Biography*, N.Y. 1981.

* C. Sarton, *A History of Science*, Harvard U. Press, 1959.

* A. G. Crombie (1977), *Augustine to Galileo*, 1964.

* Mary Hesse, *Forces and Fields: The concepts of action at a distance in the History of Physics*, Th. Nelson, London, 1961.

* George L. Harris, "The Mission of Matteo Ricci, S.J.: A case of study of an Effort at Guided Culture Change in China in the Sixteenth Century," *Monumenta Serica*, vol. XXV (1966), pp. 1-168 (*Journal of Oriental Studies*, UCLA).

* Santiago Garma (ed.), *El científico español ante su Historia*, Diputación provincial de Madrid, 1980.

* Otto Volk, "400 Jahre Mathematik und Astronomie an der Universität Würzburg: Alma Julia Herbipolensis, 1582-1982," *Celestial Mechanics* (Dordrecht), 28, pp. 243-250, 1982.

* Peter Dear, "Jesuit Mathematical Science and the Reconstruction of Experience in the early seventeenth Century," *Stud. Hist. Phil. Science* (London), 12, 2, 1987.

* Steve J. Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of Jesuit Scientific Tradition," *Science in Context* (Cambridge U. Press), 13, pp. 29-66, spring, 1989.

* P. Ostwald, "Jesuiten als Wissenschaftler" in *Die Jesuiten in Bayern, (1549-1773)*, A. Konrand Verlag, München, 1991.

* Carmelo Oñate Guillen, "Los Jesuitas y la Ciencia Moderna (siglos XVI a XVIII)", *Letras de Deusto* (Bilbao), 21, pp. 297-324, 1991.

* Agustín Udias and William Stauder, "Jesuit Geophysical Observatories," *Am. Geoph. Union Eos Trans.*, 72, 16pp. 185-189, 1991.

Italian Jesuit Girolami Saccheri threw much fresh light on the indispensable role which this axiom played on the structure of the Euclidean edifice. Although Sacheri thought he had proved Euclid correct, he was the first to discuss the consequences of denying the parallel axiom and to suggest the construction of a geometry independent of it. Unfortunately, his book was not read widely enough to have much influence.

(R.Taton; Taton, 418)

MECHANICS

The first general treatise on theoretical mechanics, *La statique ou les forces mouvantes* (Paris, 1673), appeared in 1673, an incomplete posthumous work by a man now forgotten even to historians of science, the Jesuit Ignace-Gaston Pardies. In the preface, Pardies says he wishes to make one body of mechanics, and his description organizes all aspects of the subject then investigated. Unfortunately, he did not live to carry out all his promises. While he appears to have done many experiments, he always attempts mathematical proofs. . . . While Leibniz and the Bernoullis scarcely note Pardies, they had read his book and profited from it.

At the beginning of his treatment of flexible bodies, Pardies introduces the continuous string and applies all arguments to it, without the intermediary of a discrete model. Like nearly all writers of the day he uses infinitesimal constructions. . . Pardies observes that the form of the strings remains unchanged if we solidify any part, or, further, if we replace the part above two points A and B, on each side, by suitable forces acting along the tangents at A and B. This we recognize at the first occurrence of the tension in a curved flexible line; Pardies does not calculate this force, but in the concept we see the first of the two devices whereby John Bernoulli was to achieve his solution of the catenary problem. Pardies static principle is the continuous generalization of the theorem of Stevin, viz., *the point of intersection of any two tangents lies on the vertical through the center of gravity of the include portion of the cord, no matter what the line weight may be.* Since some shadow of a correct proof is given, we may justly call the result Pardies' theorem. It forms the basis of Leibniz's solution for the catenary. . .

Pardies then considers the problems of breaking strength proposed by Galileo, but from a basically different standpoint. While Galileo had considered the beam as rigid prior to rupture, Pardies attributes everything to elasticity. Indeed, he goes so far as to try to reduce all phenomena of bending and even of compression to extension. For example, he claims that in

the compression of a beam the longitudinal fibers bulge outward and try to extend the annular fibers; from the resistance of these to extension arises the great compressive strength of beams, which can be further increased very notably by iron rings. . . Thus, to Pardies, and to him alone, belongs the credit of first attempting to introduce the elasticity of a beam into calculations of its resistance.

(Truesdell, 50-53)

In 1657, Gaspar Schott (1608-1666) published *Mechanica hidraulico-pneumatica* in which the experiments of Otto von Guericke in Magdebourg were described for the first time. Fifteen years later von Guericke himself published his own book with the title: *Nova experimenta de vacuo primum ab Gaspari Schott edita et nunc melius peracta ab Otto von Guericke iterum edita.* He also published *Cursus Mathematicus* in 28 volumes, the first reference book on Astronomy and Physics.

(M. Daumas; Taton, 325. Volk, 244-5)

At the initiative of Bishop of Würzburg, mathematical and astronomical studies reached a high level with the arrival of F. Herberti (1715-1789) as professor of Mathematics at the University of Würzburg. In his book *Observationes meteorologico-thermometricae ad annos 1765-6* he describes the latest results of experimental and mathematical physics and astronomy: Shadows of Jupiter satellites and pendulum clock. On June 6, 1761 Huberti, with a mirror telescope, participated in the observation of Venus' eclipse organized by the royal astronomer E. Halley — a first in the history of astronomy. These observations helped determine more accurately the sun's parallax and, therefore, the mean distance between the sun and the earth.

(Volk, 245)

ELECTROMAGNETISM

Gilbert (who first proposed a model to explain magnetic forces with his magnetic philosophy) had fervent admirers like Galileo and Kepler and even had followers among such staunch Aristotelians as the two Jesuits, Nicolas Cabeo and Athanasius Kircher. In his *Philosophia magnetica* (1629) Cabeo made a praiseworthy attempt to discover the mathematical laws governing the propagation of magnetic forces, and showed that at every point of a magnetic field the forces must have a magnitude and a direction satisfying fixed geometrical conditions. Kircher in his *Magnes, sive de arte magnetica* (1654) attributed tidal phenomena to the magnetic attraction of the moon, as Gilbert had done before him, but denied that the earth was a large magnet, since a magnet of that size would attract magnetic bodies with so great a force that they could not be raised again. This objection was interesting, for Gilbert had completely overlooked it.

Father Leótand, who shared Kircher's views on this subject in his *Magnetology* (1668) was the first to have considered magnets as aggregates of small elementary magnets with equal directions, though earlier experiments on breaking magnets ought to have suggested this hypothesis long before.

Gilbert's idea of a magnetic soul, Kepler's love of animistic notions, Cabeo's and Kircher's use of the non-material magnetic field to bolster qualitative physics . . . called for a decisive attack and Descartes was quick to launch it.

Robert Boyle was the first to show that air plays no part in magnetic attraction . . . Reviewing the theories of Cabeo, Gassendi and Descartes . . . he found that no choice need be made between them, since all alike had rightly discarded the old physics of qualities.

(R. Lenoble; Taton II, 314-15, 318)

Otto von Guericke's *Experimenta Nova* (1672) opened a new chapter in experimental science . . . Von Guericke, like Kircher, whom he quoted, denied that magnets have any magical or medicinal properties . . . In his *Experimenta Nova,* he describes experiments of electrical repulsions, which was also observed by Cabeo.

(R.Lenoble; Taton, 318,472)

(To Be Continued)

Pope John Paul II has named Dr. Robert J. White, a neurosurgeon and professor at Case Western Reserve University in Cleveland, a member of the Pontifical Academy of Sciences. White, 68, is chairman of the Brain Research Institute and the surgical neurology department at the university's MetroHealth Medical Center. His appointment to the academy, which includes more than 20 Nobel Prize winners among its 80 scientists and mathematicians, was announced at the Vatican, June 22. His research on the modification of circulation and metabolism and its effects on the brain and spinal cord has led to the development of new therapies for treating head and spinal cord injuries. Dr. White has been a member of ITEST almost from its beginning. Congratulations, Robert.

We want to thank Father William A. Wallace, O.P. of The Catholic University of America for permission to reprint this article. It originally appeared in *THE CATHOLIC HISTORICAL REVIEW,* 2-23-94. Any comments or questions may be addressed to him at 3407 Cool Spring Road, Adelphi, Maryland 20783.

Copernico, Galilei e la Chiesa: Fine delta controversia (1820) gli atti del Sant' Uffizio. Edited by Walter Brandmüller and Egon Johannes Greipl. [Pontificia Academia Scientiarum.] (Florence: Leo S. Olschki Editori. 1992. Pp. 498. Lit. 80,000.)

The book here being reviewed was the work cited by Pope John Paul II in his discourse to the Pontifical Academy of Sciences on October 31, 1992 as evidence that the Church had already reversed Galileo's sentence of 1633 against teaching Copernicanism when it granted the *imprimatur* for the publication of Canon Giuseppe Settele's *Astronomia* in 1820. This explains the subtitle: in that year, 1820, the Copernican controversy was effectively terminated, although it took an extensive search by Brandmüller and Greipl through the acts of the Holy Office to find that out. Their heavily documented study provides a fascinating account of the workings of the Holy Office and the Congregation of the Index in a situation where conflicts of personalities abounded, in this case with Canon Settele, the Commissary of the Holy Office (Fr. Benedetto Olivieri), the Master of the Sacred Palace (Fr. Filippo Anfossi), and the pope himself (Pius VII) among those involved. Olivieri and Anfossi were both Dominicans of the Province of Lombardy, and they became the chief protagonists in the debate. In the background was new scientific evidence for the earth's motion, which makes the findings of the study relevant to the history of science. It has been commonly held that definitive proof of the earth's revolution around the sun was not available until Friedrich Bessel measured the parallax of a fixed star in 1838, and similar proof of the earth's rotation on its axis, until Léon Foucault's experiments with the pendulum in 1851. The fact that this event took place in 1820 suggests that the Holy See was better informed on scientific matters than previously supposed. More importantly, the circumstances under which the *imprimatur* was granted give indication that this closure of the "Galileo Affair" was quite adventitious. Had Canon Settele not had difficulty getting permission to publish his book, it is now hard to say when the Roman authorities would have brought the famous case to an end.

All of this is thoughtfully and thoroughly presented in the volume under review. Following a brief preface and bibliography, it is divided into two parts: a commentary of some 130 pages, followed by documents that take up the remainder of the work. The commentary reviews the history of the status of heliocentrism in the Church from 1633 to 1820, explains the relationships between the Congregation of the Index and the Holy Office, provides biographies of the principals involved, sketches the course of events, examines in detail the arguments that were offered pro and con granting the *imprimatur*, and ends with how the *causa finita* was arrived at and the aftermath of the decision. As a divider between the two parts there are sixteen plates with portraits of the *dramatis personae*; in addition there is a chronological listing of all the documents, and a complete index of names. The text is in Italian throughout, with translations from the German having been provided, where required, by Friedrun Mazza and Sigrid Spath.

Giuseppe Settele was professor of astronomy at the *Sapienza* (now the University of Rome) and had just completed the second volume of his *Elementa di Ottica e di Astronomia.* He asked his colleague Olivieri, professor of Old Testament but also Commissary of the Holy Office, a post he held for twenty-three years, whether he could openly teach the earth's motion in the volume without running into difficulty with the Church. Olivieri quickly replied in the affirmative. Meanwhile, Settele's publisher, Filippo de Romanis, submitted the manuscript to Anfossi for the *imprimatur,* since, as Master of the Sacred Palace, Anfossi had jurisdiction in the matter. The latter refused, citing the Decree against Copernicanism of 1616 as his ground. De Romanis objected that times have changed since then, to which Anfossi replied that the Bible remains the same and that it teaches that the sun rises and sets but the earth remains fixed for all eternity. That was on January 3, 1820, and thus the battle began. There is a suspicion that more than Scripture was here involved, for Settele had taken an oath of fidelity to the French regime — required of all faculty at the *Sapienza* in this Napoleonic era, but expressly forbidden by Pius VII. Anfossi, like most of the clergy, had refused to take the oath and bore a grudge against those who did. Settele, for his part, was loyal to the pope but could not afford to obey him in this matter since it would cost him his job at the *Sapienza*. An excellent scholar himself, apart from his competence in physics and astronomy Settele was one of the founders of the science of archeology,

doing major research on the excavations under St. Peter's. He was also a literal-minded person, and fortunately kept a personal diary of all the events that subsequently transpired. This is still preserved in the archives of the University of Rome and provides additional documentation for the present book.

Born in 1748, Anfossi had been appointed Master of the Sacred Palace by Pius VII in 1815 after a distinguished career as teacher and preacher in his order, culminating in the publication that year of a treatise against Gallicanism and in support of the Church and the Holy See. In the new capacity he was engaged primarily in combatting the errors of Jansenism, evolutionism, and materialism. As a Dominican he was committed to the Thomistic revival, but he was a man of limited intellect who knew little of the science of his day; moreover, he was against revolution and change of any type and so regarded with suspicion *novatores* such as Copernicus and Galileo. Conservative to the point of being reactionary, Anfossi was yet a man of principle who could not act against his conscience. Even those who disagreed with him, including Settele, admitted that he acted out of the best of motives and was above reproach.

Olivieri, who was Anfossi's junior by about twenty years, emerges as the true hero of the piece. He had taught philosophy in his order, and Hebrew and textual criticism of the Old Testament at the *Sapienza* and the Propaganda; later he served for a brief period (1834-1835) as Master General, stepping down from that post when Pope Gregory XVI tried to dictate how the *generalizia* should be run. While Commissary of the Holy Office he wrote a voluminous history of the Church in the eighteenth century, locating it in the context of intellectual developments within the period; he also composed several philological treatises and a refutation of Fr. Marco Mastrofini, who in 1816 attempted to demonstrate the Trinity from metaphysical principles. At his death in 1845 he was working on a manuscript that related the Church to modern science; this remained unpublished until 1872, when it was put in print at Bologna by a confrere, Fr. Tommaso Bonora, with the title *Di Copernico e di Galileo*.

Olivieri's defense of Settele is outstanding not only for its erudition but also for its ability to enlist the pope and most of the cardinals who were then engaged with the Holy Office or the Index in support of granting the *imprimatur*. He was also exemplary in the patience he exhibited toward Anfossi, who objected to his every move and placed roadblock after roadblock in his way. Early in January of 1820 it appeared that the *imprimatur* would be quickly granted by the pope himself, but, as it turned out, this did not happen. It was not until December 26th of that year that Olivieri was finally successful. The first copies of Settele's *Elementa di Ottica e di Astronomia*, Vol. II, then quickly came off the press at the Officina de Romanis, on January 10, 1821.

Olivieri's arguments cannot be discussed here in detail, for they concern not only matters of biblical exegesis but also the ramifications of Settele's work as this relates to previous decisions of the Holy See against Copernicus, Galileo, Foscarini, and others involved in the heliocentric debate. Suffice it to mention the new scientific proofs of the earth's motion which had been invoked by Settele in his volume. These were in the works of two Italian astronomers, Giovanni Battisti Guglielmini and Giuseppe Calandrelli. The first was professor of mathematics at the University of Bologna and the second was director of the observatory at the Jesuit college in Rome, though he himself was not a Jesuit. Olivieri pointed out that, in experiments performed at Bologna between 1789 and 1792, Guglielmini offered the first physical proof of the earth's motion (p. 168).[1] Similarly, Calandrelli had measured the parallax of star alpha in constellation Lyra and so had offered what Olivieri identifies as *una dimonstrazione sensibile* of the earth's annual motion (ibid).[2] These new evidences, plus the advances that had been made in Biblical hermeneutics, convinced Olivieri to take the firm stand he did against Anfossi. When one reads the story of how he did so, one can appreciate Pope John Paul II's enthusiasm when welcoming Brandmüller and Greipl's account as marking the end of the Copernican controversy.

ENDNOTES

[1] These involved dropping objects from a height and measuring their deviation to the east. For details, see Giorgio Tabarroni, "Giovanni Battista Guglielmini e la prima verifica sperimentale della rotazione terrestre (1790)," *Angelicum* 60.3 (1983), pp. 462-486. Unfortunately there is no article on Guglielmini in the American *Dictionary of Scientific Biography,* the main present-day source of information in the history of science.

[2] Calandrelli's work was published in 1806 as *Osservazioni e riflessioni sulla parallasse annua dell'alfa della Lira*, dedicated to Pope Pius VII. It is mentioned in the bibliography to the article on Calandrelli in the *Dictionary of Scientific Biography*, Vol. 3, p. 14, although the author of the article, Giorgio Abetti, gives no indication of being aware of its significance.

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HOW TO LIVE WITH ERRORS?
On the Evolutionary Power of Errors

International Congress, Florence, Italy, October, 1986
Ernst and Christine von Weizsäcker

INTRODUCTION

When children learn to walk and to climb you will let them climb on the sofa or on a chair, but not on the window sill of the third floor. Why? It is because they are likely to fall down, and when they fall down from the sofa it hurts but they can try again. A drop of 8 meters, however, is likely to put a stop to all further exploration. There does not seem to be real learning without allowing for survivable mistakes. So if you feel that learning is a good thing, you have to allow errors to happen. That is essentially the message and we could stop here.

But at this Conference of evolution thinkers, we cannot resist linking our family insights to evolution theory. We shall emphasize that evolution is *not* the eradication of errors, and selection for fitness is but one of the mechanisms of evolution. These considerations will lead us into a new way of looking at errors in all living, learning and evolving systems. They seem to be "error-friendly," an intriguing property of life which we shall discuss at some length. We shall conclude with some reflections on the philosophical nature of errors.

DARWINISM AND THE SURVIVAL OF THE FITTEST

Charles Darwin was fascinated as many before and after him by the richness of forms in the living world. His theory of evolution was meant to explain the dynamics and the history of species. He was, however, not the first to try. What Darwin actually did was to introduce the principle of natural *selection* into an existing body of scientific knowledge on descendence, *variation* of forms and geographical *isolation*. Lamarck's theory of descendence of species through gradual variation existed two generations before Darwin's "The Origin of Species"[1] Moritz Wagner published his first observations on isolation as a decisive factor in the formation of new species some fifteen years before Darwin.[2] Darwin never denied that knowledge. But he saw that isolation and variation were not enough to explain the direction and the mechanics of evolution. He discarded Lamarck's hypothesis of genetic fixation of individually acquired adaptations. The surprising adaptations found in nature he explained by the survival of the best adapted out of a variety of competitors. How that variety came into being and how it recovered after being narrowed down by selection was not so much Darwin's concern; he just took it for granted. Isolation, likewise, was a lesser concern for Darwin. This does not mean that he was not aware of its importance for species formation and hence for the overall richness of forms.[3]

Thus, Darwin acknowledged implicitly already what the "modern synthesis" of Neodarwinism formulated stringently, i.e., that *selection, mutations* (variation, in Darwin's terminology), and *isolation are the three indispensable factors of evolution*. Since the most significant contribution of Charles Darwin to the theory of evolution, however, was the principle of natural selection, that principle received the broadest attention immediately after he had published it.

There were also psychological reasons for the enormous impact of the selection principle. For colonialists and successful industrialists in the late nineteenth century, it must have been a great comfort to learn that beating the weaker competitors was a good thing for all, as it served to keep evolution going. Together with Adam Smith's assertion that the Invisible Hand turned egoistic success into general wealth, Darwin's evolution by selection must have come as a very welcome justification for industrial and social selection practices contradicting the traditional morale. It is reported that the fathers of Social Darwinism became nearly ecstatic when weaker people died by the thousands in the poor quarters of the early industrialised cities of the world. They believed that they were the privileged observers of human evolution at work. Even worse than this industrialist social Darwinism was the racist Darwinism culminating in the German Nazi ideology. That ideology called the Aryan race "superior" and encouraged it with a lot of selection rhetoric to suppress and to kill humans of "competing races." It is obvious to most people nowadays that racist Social Darwinism is both morally unacceptable and scientifically unsound.

By contrast, today's philosophy of free enterprise, also influenced by social Darwinism, is still enjoying broadest public support. This may have to do with the fact that many people see "free enterprise" as the only alternative to Big Government or to communism. According to free enterprise ideology, the world-wide economic victory of the most efficient producers and the eradication of the less efficient is at the end to the benefit of all, when the wealth will "trickle down" to the poor. The moral excuse for this world view is that theoretically it is the eradication of production methods and products, not of human beings, that is going on in the economic world. But as production cannot be separated from people, it is actually people who lose in the economic struggle for life, and it is people who still die by the thousands in these struggles. Some people like us even find the unrestrained eradication of old crafts and "inferior" products undesirable. How do you personally feel about the victory of Coca Cola over a hundred local beverages including drinking water from the well? Are we romantics or are we wrong about evolution theory?

We feel that evolution theory is a wrong theory if it consists *only* of the truism of the survival of the fittest. For biologists, such restricted concepts of a Darwinism reduced to the selection principle are long outdated and discarded as bad biology. Let us try to highlight those elements of evolution theory that serve as necessary complements to the principle of natural selection and are typically neglected in the layman's perception of Darwinism.

Let us first address the old problem of definition of "the fittest." Cautious biologists carefully avoid any positive definition of fitness knowing that only history can give the answer. The dinosaurs in their time would no doubt have impressed every scientific observer with their strength, size and vitality. But "fit" to survive the geophysical disasters of the late Cretacean were not the dinosaurs but those inconspicuous insects and shrew-like early mammals of the time. *Unambiguous scientific statements about fitness can only be made about the past.* "Fit" were the ancestors of those who are still around. Even such cautious statements are not without traps. Imagine the appearance of a prokaryotic parasite specialising on ribosomes as its diet and slowly killing off all ribosome-containing species within its geographical reach. That would be a fantastic evolutionary innovation on the prokaryotic level, a leap forward in evolution. For a certain period in evolution, that parasite would, of course, be called the fittest, according to the above definition. Not long after, however, it would die out itself, when having eradicated the last carriers of ribosomes. And the evolution of both prokaryotic and eukaryotic species would be abruptly stopped. For long term evolution any exaggerated "fitness" in the sense of competitive success seems destructive. Unrestrained fitness is even counterproductive for the long term success of its bearer.

MUTATION AND ISOLATION

As already mentioned, there are two evolution factors equally powerful as the selection of the fittest, namely the continuous production and preservation of variance, and the geographical and ecological limitation of species expansion, usually referred to as "isolation."

All the rise and glory of scientific genetics is associated with the study of inherited variance and with its replenishment by new mutations. It was, however, not until 1930 that mutations became a scientifically convincing element of evolution theory. Until that time, the focus of genetics was on major mutations which as a rule were monstrous and severely incapacitated their carriers. But with the concept and discovery of myriads of minor mutations, most of them recessive and hence for most of their existence unexpressed and invisible, submerged in the "gene pool," mutations became a plausible explanation for the genetic variance, on which selection could work. Our emphasis is on the fact that mutations remain unexpressed for most of the time and that they are therefore *protected* against selection. In fact, many agricultural breeders and human eugenicists have lamented about that insidious property of inferior mutations of being able to escape well meaning selection by hiding under the dominant superior alleles.

Biochemically, it is easy to imagine genetic systems ensuring expression of all genetic characters and therefore not allowing mutations to hide. But in reality you don't find such systems; whenever they had appeared in the course of evolution they must have died out again. Consequently, it has to be assumed that the "insidious property" of error protection has an evolutionary value. One could, of course, argue instead that error protection is only an unwanted side-effect of error suppression for physiological reasons. But why, then, are genetic errors not suppressed altogether, e.g., by more redundance and repair mechanisms at the level of the nucleic acids?

Much more plausible is the theory, well conforming with Neodarwinism, with Jacques Monod's "chance and necessity" and with Manfred Eigen's "game of life," that genetic "errors" are an indispensable for evolution. It goes a bit beyond Monod to say that mutations need to be protected against selection, for most of the time, in

order for them to be available for the unforeseeable challenges of a changing environment. Empirical evidence for this theoretical concept came from J.W. Drake and others showing that micro-organisms carrying a "mutator gene" (inherited deficiencies in the genetic repair mechanism) inducing high general mutation rates enjoyed selection advantages in rapidly changing environments.[4]

The protection of the weaker competitors goes even further. Many of the species on the Galapagos Islands — where Darwin gave his theory its definitive shape — would not survive in a face to face competition with the corresponding South American species. The Galapagos species are protected by isolation. Less obvious mechanisms of geographical, ecological and behavioural isolation govern both the emergence of new species and the perseverance of existing species in all habitats on the globe.[5] Isolation allows handicapped varieties to explore the potential advantages of their handicap and to undergo a special evolution into directions which might not be conceivable for the non-handicapped ancestral species. When eventually re-entering the territory of the old species, the new one may have learned to use different resources and the two may peacefully coexist. Thus, isolation may help and has in fact helped to increase the number of species even in one and the same habitat and the optimum use of natural resources.

To conclude these considerations on evolution theory, isolation and mutations serve to keep evolution going and the number of species rising, while natural selection always tends to eliminate them. Isolation and mutations make sure that — unlike at the Olympic Games — it is never determined who is the champion, but only who is fit to survive under given conditions.

"ERROR-FRIENDLINESS"

Mutations and isolation have been described as powerful mechanisms to prevent selection from further and further simplifying the organismic world. We shall now proceed to conceptualize and further illustrate these mechanisms.

Christine von Weizsäcker has coined a word in German, *Fehler-freundlichkeit*,[6] which may literally be translated as *"error-friendliness"* to characterize the learning capacity of systems that produce, protect and absorb errors or aberrations. Error-friendliness encompasses *error-production, error-tolerance* and their mutual "friendly" cooperation for the exploration of new opportunities. In this cooperation lies the *use of errors*, which is an absolutely ubiquitous characteristic of all living systems on literally each hierarchical level.

Macromolecules e.g., undergo variations in configuration and sequence of their elements. Genes suffer mutations. Mobility drives molecules and organisms into new environments which in turn offer new opportunities and challenges to both the standard and the aberrant forms. On higher levels, motion instincts and curiosity serve the same purpose. Mutations, motion and curiosity are the key words for error-production.

On the other hand, redundance, cellular or modular organisation, physiological "isolation" mechanisms such as blood vessels or the blood-brain-barrier, regeneration and healing, and, of course, structural stability stand for the necessary accompanying error tolerance, or resilience.

Learning, or the utilization or errors, however, is more than a mechanical addition of error-production and error-tolerance. In all situations where the two cooperate, they become inextricably interwoven. In the end it is hard to distinguish (and, in fact, unnecessary to distinguish) whether errors are actively produced or just tolerated, and whether errors are carefully protected and preserved or just suppressed to keep damages at a tolerable level. Such situations of "friendly" cooperation between error-production and error-tolerance are the creative ones, the ones where real learning — and evolution — take place. This is how systems can deal with the open and unknown *future.*

"Fitness" can guarantee some continuation of existing models under essentially stable conditions. It is, however, insufficient to face the challenges of the completely unknown. To deal with the unknown future successfully, you seem to need that intriguing"friendly" cooperation of error-production and error-tolerance. And as those two are functionally interwoven in creative situations, it becomes scientifically unavoidable, as Christine von Weizsäcker realised in 1976, to introduce a new terminological expression for the creative cooperation between the two components. Error-friendliness, the new term is, as we see it, a design-principle of no smaller weight in the evolutionary process than "fitness."

In order to understand the design-principle let us look at the example of cellular organisation, something which you will agree is highly characteristic of life. The great leap forward, in terms of evolution of multicellular organisms was that the genetic information of the cell was multiplied which provided additional error-tolerance for that genetic information: if one out of a number of cells was aberrant, the function of the cell

cluster would not seriously suffer. This fact evidently would also be the starting point for a play of variations within the genetic information, leading eventually to meaningful cell differentiation. For this consideration it is immaterial if the earlier multicellular organisms in fact emerge out of an assembly of already differentiated cells, since the principle of "error-friendly" cell differentiation would apply to cell populations as well. However, at a certain stage, the advantages of synergistic cooperation of differentiated cells in one organism will have given multicellular beings an evolutionary edge over free-floating and freely combining cells.

Another feature of error-friendliness can be illustrated by looking at the phenomenon of mortality. Physiologically immortal organisms would have to make huge efforts in the avoidance of errors and in error-tolerance. In terms of evolution, they would stagnate and would be less capable than their mortal competitors of exploring new ecological opportunities. The error-friendly species would win over those being only error-tolerant ones.

ERROR-FRIENDLINESS IN TECHNOLOGY AND SOCIETY

Christine von Weizsäcker made her first observations about the design-principle of error-friendliness in discussions in 1976 about technology, notably nuclear energy plants. In the mid-seventies, when the first critical debates began about nuclear plants, most of the critics were focusing on radiation and on the likelihood of major accidents. The reply of the nuclear establishment, quite correctly, we felt, was that low radiation doses had negligible damaging effects compared to traffic accidents and many other civilization hazards; and the probability of major civil accidents was calculated to be sufficiently close to zero to consider the plants as safe. Yet in the wake of the public debate and of some court decisions, more and more safety measures were added so that eventually, at least in West Germany, safety became the biggest cost factor by far in the production of electricity from nuclear plants.

Nevertheless, Christine von Weizsäcker felt dissatisfied with the lines of discussion of that time. Without belittling the dangers of low radiation doses and the accident risk she felt that the chief objection against nuclear plants was their lack of error-friendliness. Assuming as we both did that the owners of the plants would behave responsibly and do everything to prevent accidents, we feared that the world would end up with the costly illusion of an error-free technology. As fascinating as this concept may be for an engineer's mind, we felt that error-free technology was incompatible with human society and human nature. And there we joined again with the critics of nuclear energy in pointing at the vulnerability to sabotage and war even of the most perfectly designed error-free technology.

Nuclear energy is only the tip of the iceberg. Similar considerations can be applied to all large scale technological systems such as the Aswan Dam, large scale crop standarisation, large scale combustion of fossil fuels with unknown climatic effects, or, of course, the SDI programme.

Doubtlessly, such large scale technologies capture the imagination of engineers. Also, it is commonly believed today that large complex programmes are the most powerful driving force of technological progress. We are not denying this but we say that such progress has so far only been tested for the evolution factor of "fitness" under the prevailing conditions, if at all. Large scale crop standardisation has so far been an economic success but it is doubtful if it will remain successful under changing climatic conditions. The Aswan Dam certainly is an example even lacking fitness in the narrowest sense and the SDI programme may also turn out to be a technological failure not to speak of the political damage it does. Moreover, all such mega-projects seem to lack error-friendliness. They even lack error tolerance and therefore induce both their defenders and their critics to focus and to concentrate on the avoidance of errors under all circumstances. As said before, this is a futile beginning since sabotage, war and severe human errors cannot be excluded. In consequence, societies dependent on megatechnologies tend to become obsessed with their fears of errors and of insidious motives of their real or imagined enemies. The "human factor" becomes a synonym of all such fears indicating that technologies requiring the avoidance of errors are inhuman.

We are now discovering a remarkable irony. Defenders of large scale high technologies like to claim for themselves a monopoly on the spirit of technological innovation while often denouncing their critics of wanting to return to the Stone Age. Under the concept of error-friendliness the picture becomes nearly reversed: technologies requiring error-free functioning, bulky redundancies and enormous capital investments would now appear as binding huge resources from elsewhere, as imprisoning the human factor and forcing the exploratory spirits into the futile direction of error-avoidance and thereby steadily frustrating them; while error-friendly counterstrategies would rather encourage scientific curiosity, human imagination and technological innovation.

Error-friendly strategies today are bound to concentrate on error tolerance first, on resilience against surprising shocks and sabotage, on safeguards against error proliferation and on the prevention of chain reactions. Modular organisation is an important part of the answer, decentralisation and diversity are equally important components. Only at a later stage could one afford to broadly reintroduce into our technological world error-proneness and the protection of "errors."

It should be noted that error-friendliness is not only a matter of technological design. It is, in fact, very much a political, juridical and cultural affair. If the user of technologies is held liable for all damages his activities may provoke he is likely to choose error-tolerant technologies if he has the choice. And since the technological development depends to a high degree on the demand structure, any change in liability legislation will strongly influence the development of error-tolerant technologies.

Let us next relate the concept of error-friendliness to the economic social Darwinism debate. One may find it easier now to challenge the present dogma of free market economics under which the success worldwide of the best competitor is said to work always to increase the wealth of the world community. To be sure, in the days of Adam Smith when the ossified structures of absolutism still suppressed private entrepreneurship and imagination, the free market idea was a highly error-friendly one. It encouraged the exploration of new paths and produced diversity, innovation and technological progress. Errors were not suppressed. They were part of the game but their geographical reach was limited. However, when world trade and traffic began crossing all borders and transforming the diversity of conditions into the uniformity of the world market, the features deplored above of megatechnologies and megasystems emerged. The growing of peanuts in Senegal may be an element of success under the criteria of the world market but it may be a disaster for the Senegalese ecology and nutrition and eventually even for the economy. Errors and contingencies at the Chicago commodities markets can have deadly effects thousands of miles away. No person can be held responsible and the losers have no chance to learn and to adjust. The only lesson currently spreading among the poor in the Third World is that decoupling from the world market and resurrecting some sort of subsistence economy may in the end be the best for survival.

Dogmatic versions of the free market theory ignored the importance of isolation mechanisms which prevented deadly errors from infesting the whole world and left local variations a chance for developing. The time is ripe for economists to acknowledge the concept of error-friendliness as a check and balance to short term economic success.

A CONCLUDING REFLECTION

Errors had a negative meaning through all of the history of science and philosophy. What philosophers were searching for was final truth and not aberrations from it. The laws of physics and mathematics were discovered and formulated with a view to avoid erroneous statements and conclusions. Scholarly teaching was invented to cultivate the art of discovering and eradicating errors. Rather late in history random events and fuzzy sets were incorporated in mathematical theory, and Brownian motion and statistical mechanics in theoretical physics, and that under the condition that at least the statistical properties remained predictable. Shannon's information theory also operates on probabilities and even deals with "noise" affecting appropriate signal transmission. But emphasis is everywhere on keeping the distinction clear between statistical events and errors. Errors are to be avoided. Correspondingly, the technology which is based upon such error-avoiding science is ideally meant to be error-free, and if this is not possible, at least robust against errors.

In this situation it seems philosophically rather daring to introduce the concept of error-friendliness. Can it really be defended? We are not in a position to give a final answer. Let more qualified philosophers deal with this intriguing question. Let us only repeat our observation that for evolution theory error-friendliness seemed a more comprehensive concept with more explanatory power than just mutation, or isolation, to complement selection fitness. Error-friendliness and fitness seem to function as antagonists as physiologists would say, or as complementary entities, in the language of quantum physics. Both are necessary but the two represent contradictory features of reality. Fitness is needed for the survival of error-friendly systems. Error-friendliness is needed (or adjustments and long-term success of all systems facing an unpredictable future. Neither of the two principles is the master (and the other the servant). If either of them is neglected, the other becomes counterproductive.

Present day arms systems seem to be out of balance. They may be extremely "fit" and powerful but they are not at all error-friendly. If they are ever used to any major extent, they don't leave a chance for further learning. As long as the hawks of all countries can persuade their people that the country's security has to be calculated by the destructive power of its weapons

arsenal nothing will change and the doomsday will be inevitable. To escape the deadly logic, error-tolerant security systems have to be designed and implemented. Let us join forces to break the deadly logic. Let us jointly open a window for further evolution.

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REFERENCES

[1] Charles Darwin, *The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life,* Murray, London 1859; new paperback edition e.g., Collier MacMillan, London 1962.

[2] Moritz Wagner, *Die Entstehung der Arten durch raumliche Sonderung,* Collected papers since 1840, Benno Schwalbe, Basel 1889.

[3] Charles Darwin, 1.c.(1962 edition, p. 111) "The importance of isolation is likewise great in preventing . . . the immigration of better adapted organisms; . . . Lastly, isolation will give time for a new variety to be improved at a slow rate."

[4] J.W. Drake, "The Genetic Control of Spontaneous and Induced Rates in Bacteriophage T4." *Genetics* (Suppl.) 73, p. 45-64, 1973. New authors argue that nonetheless the genetic copying fidelity has steadily increased in the course of evolution (e.g., Darryl C. Reanney, "Genetic error and genome design," *Trends in Genetics,* Feb. 1986, p. 41-46). However, that should rather be seen as a function of growing complexity, not as a general repression of mutations.

[5] See e.g., Ernst Mayr, *Animal Species and Evolution,* Harvard University Press 1963.

[6] Christine and Ernst Ulrich von Weizsäcker, "Fehlerfreundlichkeit," in: Klaus Kornwachs (Ed.), *Offenheit, Zeitlichkeit, Komplexitat, Zur Theorie der Offenen Systeme,* Campus, Frankfurt 1984, p. 167-201.

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IN MEMORIAM

We anounce the regretable death of

Sr. (Dr.) Loretta Findysz, BVM.

Sister Loretta died on July 7, 1994, after a long bout with spinal cancer. We ask you to pray for her and for several of our members who are seriously ill. May they feel the restoring hand of the Lord.

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