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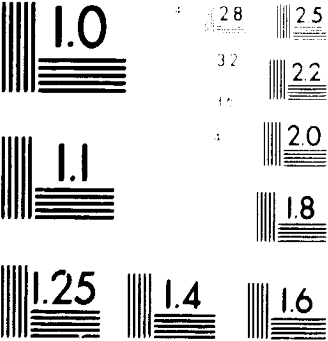

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ANSI and ISO TEST CHART No. 2

13542

GENETIC ENGINEERING AND BIOTECHNOLOGY-SOME PREREQUESITS FOR THEIR DEVELOPMENT IN DEVELOPING COUNTRIES

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1983

received from Mrs. Benzroch

INTRODUCTION

By a coincidence, as we meet here in Dubrovnik today to discuss how the developing countries can benefit most from genetic engineering and new biotechnology it is almost to the day an anniversary of the two most important discoveries which are and may represent the scientific foundation of our high expactations as well as high concern-a cornerstone of a new era of civilization.

Foutrthy years have passed since Oswald Avery the American scientist and his associates made observations suggesting that the hereditary substance of bacteria is deoxyribonucleic acid, or DNA.Their discoveries opened a whole new field of genetics; a field which has since been pursued with utmost vigor.Oswald Avery was immediately aware of the importance of his discovery,witness a letter that he wrote to his brother Roy,describing his discovery:"If we are right,and of course that's not yet proven then that means that nucleic acids are not merely structurally important but functionally active substances in determining the biochemical activities and specific characteristics of cells-and that by means of a known chemical substance it is possible to induce predictable and hereditary changes in cells.This is something that has long been the dream of geneticists.The mutations they induced by X-ray and ultraviolet are always unpredictable,random and chance changes. If we prove to be right-and,of course it is a big if-then it means that both the chemical nature of the induced stimulus is known and the chemical structure of the substance produces is also known-the former being thymus nucleic acid-the latter Type III polysaccharides,and both are thereafter reduplicated in the daughter cells-and after innumerable transfers and without further addition of the inducing agent,the same active and specific transforming substance can be recovered far in excess of the amount originally used to induce the reaction-sounds lake a virus-may be a gene.But with such mechanisms I am not now concerned-one step a time-and the first step is,what is the chemical nature of the transforming principle? Someone else can work out the rest.Of course the problem bristles with implications.It touches the biochemistry of thymus type nucleic acids which are known to constitute the major part of chromosomes but have been thought to be alike regardless of origin and species.It thouches genetics,enzyme chemistry,cell metabolism,and carbohydrate synthesis,etc.But today it will take a lot of welldocumented evidence to convince anyone that the sodium salt of deoxyribose nucleic acid,protein free,could possibly be endowed with suc biologically active and specific properties.......It's lot of fun to blow bubbles,but it is wiser ti prick them yourself before someone else tries to.So,there is the story,Roy-right or wrong it's been good fun and lots of work.....Talk it over with Goodpasture but don't shout it around until we're quite sure or at least as sure as the present methods permit.It's hazardous to go off halfcocked,and embarassing to have to retract later.....I cannot leave this problem until we have got convincing evidence...Then I look forward and hope we may all be together-God and the war permitting-and live out our days in peace".

The peace came two years later and it took only an additional eight years before in 1953 James Watson an American and Francis Crick a'Britisher elucidated the structure of the thymus type nucleic acid,known today as DNA.The structure of the DNA they discovered explained and answered all the questions posed by Oswald Avery the years earlier.Through Watson and Crick model of DNA one could explain the relationship between the inducing stimulus and the chemical structure of the substance produced.It provides explanations how the thymus type nucleic acid can replicate in the daughter cells in innumerable generations of cells and how the DNA(the major constituents of chromosomes) lays the basis for genetics, enzyme chemistry, cell metabolism. More specifically by knowing the structure of DNA a basis is laid for inducing predictable and hereditary changes. Finally, it explains how this substance determines the biochemical activities and specific characteristics of cells.

And this is exactly the essence, the basis and the excitment underlying modern genetic engineering and new biotechnology: predictability and hereditability! Though not more than thirty years have passed since these crucial discoveries were made we are already discussing the unpresedent benefits likely to stem from these discoveries, particularly for the poorer segments of mankind.

But before we in developing countries will be able to reap the benefits from these advances a lot of hard work will be required to change certain traits in our mentality. First we must understand the multidisciplinary character of the new scientific field and its extraordinary scope. Once we have gained this understanding, a lot of hard work will be rquired to change past habits in education, training and organization order to best incorporate the new understanding in our thinking process. Only then will developing countries be able to mount the effort of sufficient strength and concentration to advance their development which will in the near future so much depend on gaining substantial capabilities in genetic engineering and biotechnology.

It is impossible to formulate in detail for each developing country guidelines for establishing, strengthening and reorienting their institutions and structures relevant to development of capabilities in genetic engineering and biotechnologies. However, one can enumerate certain common denominators which apply to almost all of the developing countries regardless of what stage of the development they are at, or irrespective whether their development takes place in a democracy or a dictatorship; under capitalism or socialism.

Tha pattern of development as it takes in developing countries may differ greatly from that occuring in advanced countries. Usually, the initiative for formulating science and technology priorities in developing countries is taken by governments or by corresponding government agencies. In advanced countries however, the initiative usually has a polycentric basis, only merging at the governmental level at the end of the process. The implication is that in advanced countries the scientific and technological infrastructure already exists, which is not the case in developing countries. Therefore, the acute problem in developing countries is how to create and organize such an infrastructure in the shortest possible time. Simultaneously, it is of utmost importance to focus on the already existing institutions which may facilitate the progress of infrastructure construction. These institutions, though usually few in numbers may have particular importance since they are placed at strategic crossroads and influence the essential decision makenings.

It is frequently argued in developing countries that by setting up new goal oriented scientific or technological institutes a sufficient impetus will be given to facilitate the establishment of a new science and/or a new technology. My view is, that this is only true for a short term benefits but in a long run it may even be counter productive. A developing country can make a basic mistake by establishing a so-called national research and development (R and D) center with the specific mission to develop and promote certain scientific disciplines or certain technologies. The limitations and negative effects of such a R and D institute are as follows:

(i) it will be able to train only a very limited number of personnel,

(ii) the scientific and technological know-how acquired by its staff will have a limited impact, since it will not have the resources to disseminate knowledge widely,

(iii) since it can not grow infinitely the replacement of the staff will be slow. As a consequence the staff will gradually age and after a while, such a R and D institute will be overloaded with mentaly sterile people,

(iv) it will have a negative effect on the teaching capacity at the universities,since the better qualified and more selfassurdd scientists will be attracted to the national R and D institute because it is likely to be better equipped and have priviliges compared to the universities.At times one can see links or forms of collaboration between a national R and D laboratory and an university but most of the time collaboration is only a lip service to the university and does not penetrate into the fabric of the university teaching,

(v) on the other hand,when an institute is established to serve industry it will be placed in an unfavourable position when compared to the university.The relatively better qualified are absorbed by the more attractive jobs and positions offered by the university.Therefore,industry which actually needs the most help and the best qualified scienuists and technologists becomes rated lowest on the scientific ladder.If we all argue, and we tend to argue very loudly,that in developing countries industry is the "locomotive" force having the task of pulling the developing countries out of their poverty,then I simply do not see how these countries will help themselves by emphasizing such an organization within their scientific and educational infrastructure.

It is clesr,radical changes in the organization of the scientific and educational infrastructure is required and the minimal <u>sine qua non</u> requirements are as follows:

- to reorganize national R and D institutes as independent institutes whose scientists will be hired and reappointed on the basis of their scientific merits.Those who do not qualify should be steered to other jobs.

- new forms of industry-university collaborations will have to evolve or be created.Two factors will have particular importance:First,to involve faculty scientists and students in working relationships with scientists from industry on research projects with results to be freely published and,second,that at the same time industrial R and D institutes must allow a degree of freedom to their scientific personnel so they may express their potential in performing basic research rather than to insist to engaging them only in solving the day to day problems.

If a restructuralization of the scientific infrastructure in developing countries takes place similar to the one I am here proposing I believe the following beneficial effects would become apparent:

(a) a critical mass of scientists would form making possible a maximum number of personal interactions so necessary for a creative and nurturing environment;

(b) the gap in know-how in existence between the scientists at the university and the industry would be drastically narrowed;

(c) it would create the essential scientific environment in which students would be exposed from the very beginning of their studies to the way of thinking and reasoning required for a critical evaluation of results in the basic sciences.At the same time students will obtain a perspective of the potential which discoveries in basic sciences have to industrial applications.The last point is particularly important-to quote Nikola Tesla,the Yugoslav physicist of the first half of this century: "Of thousand ideas people have only one is good;of thousand good ones only one finds its way to production".Tesla's axiom of science is not appreciated in developing countries most of the time.These steps in science and technology whereby an idea is transformed to a process or product cannot be bypassed by any country,developed or developing.For a nation to make the comitment so it can undertake these steps will require a political decision to allocate a considarable share of national expenditures to education and basic research over a rather long period of time.As Edmundo Flores has recently stated in the journal Science: "One cannot hope for shortcuts,cultural revolutions,blitzkriegs or bargains".Genetic engineering and the new biotechnology are particularly instructive cases in question!

Genetic engineering and biotechnology are multi- or trans-disciplinary sciences.However,these terms may have many different meanings.Possibly the worst option is to consider multidisciplinary science as a sum of different monosciences engaged in solving a multidisciplinary problem.The present-day scientists are by training multidisciplinary oriented with a rather broad educational background on which a narrower vocation has it's basis.If we take as an example the modern biology or biologists it is very difficult to imagine how a biologist with a nonbiological education could understand and work in modern biology.A good knowledge in biochemistry,genetics,physics,mathematics,computer science,molecular biology,immunology and classical biology,are required in everyone's scientific curriculum,regardless of the narrower specialization in biology one may have chosen.

Here,then we come to the most crucial point i.e. to the educational system in developing countries.

Due to the intense desire to increase the availability of basic education in almost all developing countries a very broad and extensive network of educational institutions is being established.This rapid expansion of educational systems,from elementary schools to the PhD level,obviously is having a negative impact on the quality of teaching.The qualified man power needed for such an extensive expansion of educational networks have been,and are, lacking hence the educational and scientific standards have been adjusted to the potential of the educators.It is a well established fact that mediocricy breads mediocricy as much as excellence breads excellence.The developing countries are presently faced with the acute problem of conquering mediocricy.Yet,genetic engineering and the nwe biotechnology cannot even have been imagined without excellence in science as well as technology!The question one poses, then,is:how does a developing country get out of this vicious circle?

One of the remedies I propose is that universities,or their departments in a developing country should be periodically rated, If we follow present trends of developments in genetic engineering and new biotechnology then we may come to the conclusion that developing countries could benefit in four major areas which can be expected to be helped by this new science and technology: food,energy,health and the protection of the environment.This notion is in essence correct.However,high expectations will not become easily realized,as I have stated earlier.

If we consider food production,it has many times been stated that genetic improvement of the nitrogen-fixing symbiotic bacteria that nodulate leguminous plants appears to be a rational goal. On paper this approach of improving yields of these crops while simultaneous saving expensive artificial fertilizers looks very promising.Its accomplishment actually requires a high level of expertise in genetic engineering techniques coupled to long filed trials of manipulated plants or microorganisms before meaningful results will become available for evaluation.As you can see,this relatively simple problem of gentics actually requires long studies and highly qualified scientists.Premature import of equipment and pretensions to start production of symbiotic nitrogen fixing bacteria i then obviously unwaranted and even worse,the failure would then discredit the potential of new genetics.

Or let us take an example in the field of energy.Conversion of waste biomass into biogas(low-level technology)is often mentioned as an example of the rational use of local resources for obtaining suitable energy.Unfortunately,the studies so far made are not very encouraging.As a result of the high cost to transport wastes to processing sites and of the relatively low yield of biogas these processes are suitable only for limited applications.Similarly,alcohol production from ligno-cellulosic substrates is still in its infancy.If a developing country has hope to help solve its energy problem by the liquification of solid substrates it must be aware that intensive fundamental research must preceed this application.

One can enumerate other similar examples in the field of health and environment protection.Though,the rewards will be very

I have to reiterate,the only hope for developing countries is a concentrated effort to educate and select its best talents and place them in key decesion-making positions.Though this conclusion may sound obvious and trivial the real facts of political life justifies it.In many developing countries the turnover process of the scientific and bureaucratic hierarchy is a very slow one. For this reason a comprehension of new technologies and what they really offer to development diffuses very slowly through governing structures.Without a radical change in this social domain of developing countries the expectations from the impacts of the new technologies,including genetic engineering and new biotechnology will not be realized.

It is equally true that in many developing countries the best talents have left the country thus diminishing the selective pressure and as a consequence the policy makers are either not adequately advised or worse they are ill-advised.The governments of developing countries must make a conscious effort to bring back home their best talents from advanced countries.The home vountry must provide the potential for good working conditions so science can develop.I am ceratain in reality it is not the low salaries in developing countries that are repulsive but rather the sterile time and atmosphere and the constant fights with the bureaucracy which causes a good scientist to cast off from his home contry.

In conslusion,I would like just to say that I have been so critical because I do strongly believe that the developing countries at this time still have a chance to develop advanced capabilities in emerging technologies including genetic engineering and biotechnology and thereby benefit in many ways.However,radical changes in the educational,scientific and technological structures are urgently needed.I also feel that only public pressure from open discussion can rectify those problems I have refered to.I hope all my criticism would be for the benefit of developing countries themselves,including the one I am coming from.