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AN APPROACH TO RURAL DEVELOPMENT: THEORY AND APPLICATION*

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INTRODUCTION

INDIA continues to be preponderantly a land of villages with 'living conditions' almost totally unfit for most people to live and work. Not that no efforts have been made in the past to improve rural life, but 'progress did not take root.' In all our efforts we seem to have come up against a stone wall which made development of people all but impossible. That stone wall is the neglect of interaction between the innate educability of man and the challenge of environment. We seemed to have overlooked the fundamental fact that development of an individual is a process which can occur only through such interaction. It will be my object today to elaborate on the significance of this interaction and the theory behind it for the development of man and community and to show how the interaction can be exploited to improve rural life within constraints of available resources and technology. The term 'living conditions' as used here refers to environmental conditions in respect of provision of public services such as water, hygiene, public health, sanitation and education to which every person has an access and which enables man to live as man as part of the community; and the term 'rural development' as used here refers to development of people in the villages as distinct from development of agriculture and allied village industries.

EARLIER EFFORTS FOR IMPROVING LIVING CONDITIONS

Broadly, efforts commenced on a large scale since Independence under programmes of social welfare. They included medical relief, basic education and agricultural extension services. In practice, activities developed under various Ministries and Departments on an ad hoc basis and lacked coordination under a bureaucratic set up with duplication of expense and tendency to conflict. Side by side, voluntary agencies were also carrying out their social service activities in their own way. But they did not have any basic approach to rural development. Moreover, their programmes covered only a fraction of the rural population of the country. It was also felt that the boys and girls should be required to develop social outlook as part of

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their education, so that they may serve the rural poor in later life. This also did not work the way it was supposed to work. The basic reason for the predicament on all these fronts was that the official personnel or the voluntary workers or the boys and girls could not put up with the nearly intolerable living and working conditions in the countryside for longer durations when they came to work in the villages. Then emerged the idea of multipurpose centres of rural uplifts which were so to say a half way house between cities and villages.

Starting with the Second Five Year Plan, the centres came to be developed through experiment in community development as part of the economic plans and later under the pressure of growing population, through minimum needs and 20-point programmes. Throughout and in-between the plans, several ad hoc isolated programmes (with impressive acronyms) have been fashionable, but they failed to make any dent on rural poverty. The presumption under all these programmes seemed to be that to eradicate poverty, it was necessary to control population and make available adequate income to the poor so as to enable them to feed, clothe, shelter and educate themselves properly. Unwittingly, however, in drawing the poverty line it came to be placed much above the basic need of man for food through inadequate understanding of the basic concept of energy need thereby grossly exaggerating the incidence of nutritional poverty. This defeated in part the objectives of these ad hoc programmes. It rarely, if ever, occurred to the planners that poverty eradication also means improving the environmental conditions in the villages which alone could bring content and meaning to the programmes relating to feeding, housing, health, education, extension services etc. Fulfilment of the basic necessities of life, concomitant with radical environmental imptovement, alone can create the necessary conditions for healthy interaction between man, community and environment towards development and progress.

The Nutrition Issue

Is nutritional poverty so widespread a problem as made out by planners with some 40 to 50 per cent chronically undernourished for lack of minimum income ? An uncritical acceptance of this estimate is bound to lead to programmes which on the one hand open opportunities for the non-poor to grab the benefits intended for the poor and on the other hand lead to the neglect of improvement of environmental conditions leaving the really poor as dependant as ever on Government for crash programmes to employ and feed them. The question needs dispassionate examination.

It is a fact that some 40 per cent to 50 per cent of the people in the countryside live on intakes below the prescribed or recommended norms for energy requirement. However, that does not mean that they are all undernourished and starving. To place such an interpretation is to contradict the very definition of requirement. For, requirements are based on measurements of habitual energy intake in healthy active individuals representative of each age, sex group and level of activity and therefore, represent the averages. These averages, often called norms, are published

by FAO and periodically updated. It follows that if the population is healthy and active about half the people will have their intake below the prescribed norms of requirement and half above. If, therefore, about half the people in India have their intake below the published norms and the distributions are not too skew, inference ought to be that they must be for the most part healthy and active, and not undernourished. It also follows that if everyone below the published figure for energy requirement is to be called undernourished, everyone eating above the published figure for requirement must be overnourished. Indeed, this interpretation accords with the old FAO definition, namely, *"if a person eats below the level of average requirement, he becomes thin and wastes away, while if he eats above it, he becomes fat and is exposed to the hazard of obesity."* It follows that the more serious problem in India today is overnutrition and not undernutrition. We are hound to reach such an absurd conclusion when the dividing line between undernutrition and overnutrition is the average itself.

As long back as 1947, Widdowson had pointed out that individuals of the same age and sex, engaged in similar activities vary widely in their intake. Further numerous studies have shown that intake varies widely in the same individual, even when it is averaged over several days without any significant adverse effect on the body weight and level of work output. A person eating less than the average requirement cannot therefore be considered as undernourished regardless of this inherent intra-individual variation. I have shown elsewhere (Sukhatme, 1982*a*) that when appropriate allowance is made for this variation, the incidence of undernutrition is at best of the order of 20 per cent and not 40 to 50 per cent.

What is true of the estimate of undernutrition is also true of the estimate of the poverty line. Space does not allow elaboration. In both cases, the conclusion is the same, viz. that the current estimates of the extent of undernutrition and poverty are gross overestimates and that this gross overestimation occurs because averages are mistaken for the minimum energy needs of man.

Unfortunately, a figure of order lower than 40 to 50 per cent does not appear respectable enough for most authors. There is reluctance to entertain any suggestion for examining the rationale of the current method of estimating undernutrition and poverty. The matter is made worse by the publications such as those by Reutlinger and Selowsky of the World Bank (1976) who use average requirement to define the extent of undernutrition and poverty, but conveniently ignore any consideration of the problem of overnutrition that must arise when the average is accepted as the minimum need of man. It is therefore natural that many nutritionists and economists should remain unconvinced that the extent of undernutrition and poverty can be so low as 20 per cent or even lower. Is it not a fact, they ask, that our average intake is only about 2/3rd of the average intake in the West, and that our protein intake is only about half and even of that most of it is of vegetable origin ? Very true, but energy intake for given work output as stated above is used with variable and not constant efficiency that we are taught to believe in current literature.

Again, some experts ask that if the extent of undernutrition is so small, how can we account for the fact that most children in India are smaller in height and weight than their counterparts in USA ? Indeed, according to Gomez classification of weight for age, some 80 per cent of the children in India are undernourished and that some 20 per cent are severely so. Here also, the answer is simple. It is not intake alone but days lost in morbidity from diarrhoea and related diseases which also influence the rate of growth. One simply cannot injest food during diarrhoeal episodes when protein is being rapidly excreted. So high is the incidence of morbidity in villages that by the time a child is 3 years old, he has already lagged behind by 10cm in height and 3 kg in weight compared to his counterpart in USA.

I am afraid, when a certain approach suits certain interests, poor countries are invariably hustled into action on the ground that it is far more important to save starving children than to talk about methodology. This is precisely what happened to the protein gap issue 15 years ago. The example is worth recalling again. The United Nations Committee on Science and Technology had before it a report on 'International Action to Avert Protein Crisis,' drawn up by a committee of nutrition experts. The report said that protein malnutrition was a major problem and that if children grew into smaller adults in developing countries, this was the direct result of deficiency of good quality protein in their diets. "Unless, therefore, this deficiency was made good," so runs the report, "the economic, social and physical development of the people will be completely arrested." Fortifying the diets with amino acids using modern food technology was advanced as a powerful instrument with which to achieve the goal without appreciably adding to the cost of the foodgrain diet. However, when available evidence was further examined, it was found that what diets lack was energy to anabolise the protein and not protein *per se*. It was true that foodgrain diet does not have protein adequate for satisfactory growth of rats, "but man is not rat." Thus there was no basis for action to enrich diets with protein. Even mother's milk has no more than 5 to 6 per cent of its calories in the form of protein. If people in the West eat more animal protein, it must be because they cannot resist the temptation of eating animal products and they can afford them.

Much the same is true of energy intake. This is not difficult to explain. Take for instance the addition of drink to our diet. Many of us take a glass or two of wine or beer and many more prefer stronger drinks. The energy that these give is surely not dictated by physiological need. One simply enjoys taking a drink and the larger amount of food such as fish and chips that is consumed with it. Fortunately, body has a mechanism to dissipate what one eats in excess of biological needs. If the body did not possess this homeostatic mechanism, man would not have perhaps dared to indulge in eating the way he does. But then he would ask, "what is life for if not for enjoyment ?"

For the same reason, the argument that life of the poor is governed by a vicious circle of inadequate income leading to low intake, low intake leading to low body weight, low body weight leading to low level of productivity and low

productivity leading to still greater poverty cannot be true within a homeostatic range. Below the lower limit of homeostasis, a person will, of course, be undernourished and will need help. But that proportion is much smaller than what is estimated. To overstate the problem of poverty and that too so grossly and occupy oneself with nutrition intervention and other special programmes to combat it is to (*i*) allow the non-poor to compete for the benefits intended for the poor and to (*ii*) accord lower priority to education as an instrument of change in the living conditions of the society, leaving the really poor where they were or even worse off. It is hardly surprising that under such conditions, 'natural selection' should operate over large part of the rural areas to determine man's survival adversely influencing his life expectation and health. In this situation, policy to combat poverty clearly requires an orientation radically and fundamentally different from the one that has prevailed over so many years in the past.

Interaction between Man and Environment as the Basis of Reorientation

It is not that there is no provision for increasing environmental amenities in current plans and programmes. In particular, funds are made available for digging open wells to provide water, to chlorinate wells to ensure safe water for drinking, to build or expand school buildings and even to build community latrines and install water pumps. However, by themselves such projects cannot bring about a change in the habits for improving the quality of life. Only interaction between the innate educability with which man is endowed and the environment under a sustained stimulus of appropriate social action can ensure such change. Thus hygiene cannot be built into the lifestyle of a child by merely giving him 'takehome' packets of food. More important is to ensure that children come together in Balwadi and play, learn and eat together what they bring from home. In this process, they learn to improve hygiene as readily as they learn to speak and communicate at home without a special effort. The point to emphasise is that a child is born with an innate capacity to learn and it is the responsibility of the school to provide appropriate environment as a tool of achieving a way of life suited to culture, needs and resources. Again, the same is true of well water for drinking. Chlorination alone cannot help reduce contamination. What is needed is a social action organised around the well to ensure that women have no direct, but only an indirect access, either through a common hand pump or a stored supply of water in a tank built at some distance from the well. Experience shows that a fence built at some distance from the well is all that is needed to reduce the risk of contamination from *E. coli* and other pathogenic organisms through the soil acting as a filter.

What is true of hygiene and well water is also true of the school campus. A fence built around a school in agreement with panchayat and the school authorities, as in the case of well helps to maintain the surroundings clean and to grow fast growing trees and trees of economic importance within the campus besides providing ground for children to play and interact with each other. If these activities are preceded by careful preparation and involvement of teachers, parents and the

Sarpanch of the village and enough time is allowed, it is found that there is almost a complete transformation in the lifestyle of people with regard to hygiene, use of water for drinking and cleanliness of surrounding areas.

The use of community latrines is a further step in the same direction. It is admittedly a most difficult step. However, if they are connected to 'Gobar' gas plant along with other tanks for animal dung and agricultural waste and gas connection for cooking is made available to participating households, then experience indicates that the villagers may not mind the source of the cooking gas. In any case, the excreta can be used for lighting and similar public use, there by contributing greatly to the improvement of village hygiene and sanitation and the remaining tanks for providing the cooking gas. The amount of gas may be small, but the fact that it can serve to cook one's meal brings delight, hope and confidence to the villagers.

Of course, there is a large time lag in persuading children to develop the habit of using community latrines. It calls for a sustained effort and encouragement from teachers. However, once the teachers and the children understand the need and importance of using them and that this habit has the potential of reducing diarrhoeal episodes and related diseases, the time lag should not be intractable. Childrens' age is the gge to learn and to incorporate into daily life what they learn. If China can overcome the difficulties in using community latrines in their daily life, it is in part due to their efforts in the school to emphasise the strong scientific basis of this culture. Unfortunately in India, some of us influenced by the materialistic philosophy, tend to belittle the change so brought about in the lifestyle as poor substitute for the change that can be accomplished from using modern technology (e.g. toilets and waterpipes as in cities) forgetting that a lasting change must be value and culture based and must automatically ensure use of appropriate technology within resources which the society can afford. By over-emphasising physical inputs and technology and ignoring educability in the sense described here, I fear that an opportunity to build a viable self-sustaining change is being thrown away. But before elaborating further, it is necessary to examine how precisely this interaction originates and what is its nature and size. In brief, the theory behind this approach needs to be clearly stated, illustrated with application, preferably on data on energy intake and expenditure of individuals engaged in fixed tasks, against the background of the nutrition issue raised in the previous section.

The Source, Size and Nature of Interaction

According to current concepts, the energy requirement of an individual maintaining body weight and engaged in fixed tasks is near constant over short periods from day to day and week to week. Available data, however, indicate a different situation. Figs. 1 and 2 show data for two subjects typical of such evidence reported by English physiologists on young army recruits (Edholm *et al.*, 1970). Energy intake was measured by 'weigh as you eat' method and expenditure was calculated by

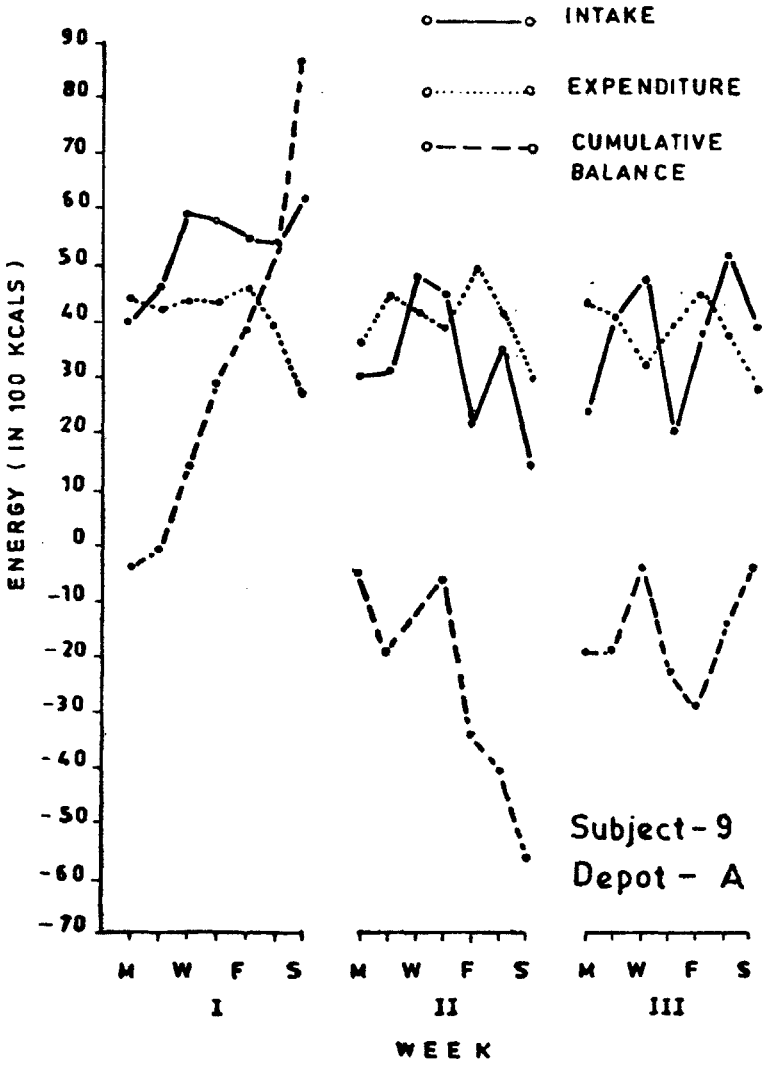

FIG. 1. Daily energy intake, expenditure and cumulative balance in different periods.

timing activities and measuring energy expended during each activity as estimated from the amount of oxygen consumed using integrated motor pneumotochograph (IMP) for the purpose. The study was conducted during the 2nd, 5th and 8th weeks of a nine-week period of training.

It will be seen that cumulative energy balance varied considerably from one week to another. Furthermore, it was often all positive or negative to the tune of several thousand kilocalories each. If energy is used with fixed efficiency, as assumed in current nutrition literature, these subjects would have gained or lost weight to the tune of 4 to 5 kg during the nine-week period covered by the study.

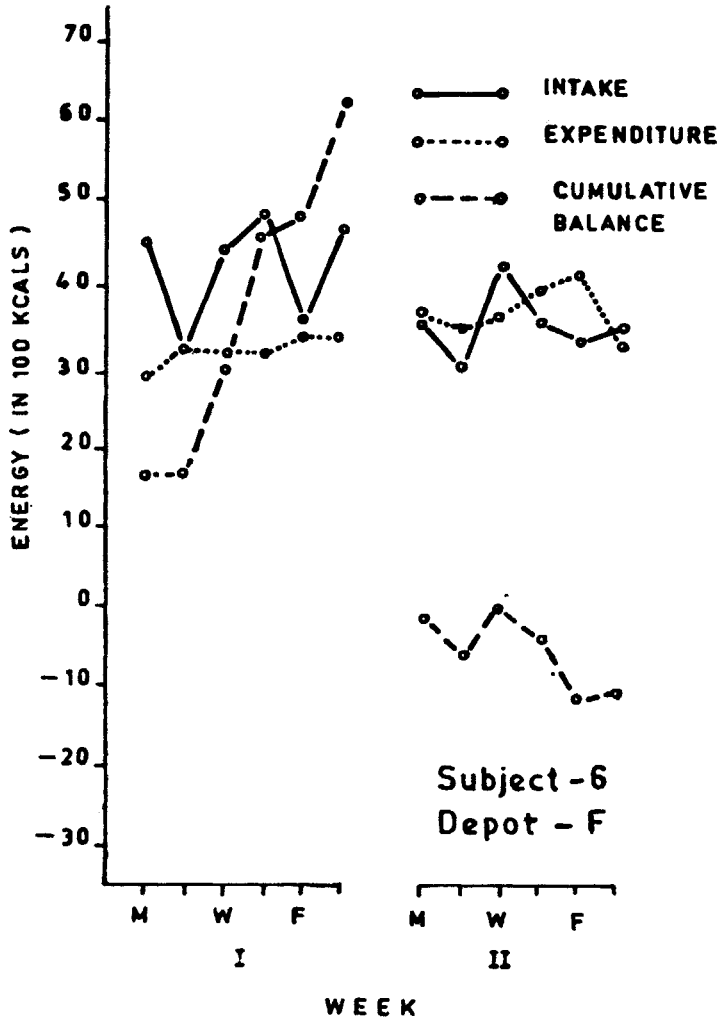

FIG. 2. Daily energy intake, expenditure and cumulative balance in different periods.

Since the subjects maintained their weights within narrow limits, it must be concluded that energy is used with variable efficiency from day to day over short periods. The process which enables a man to maintain body weight (body content of heat, to be precise) and carry out assigned tasks on a range of intakes is called homeostasis. It would appear that the real controlling variable of the homeostatic process is not energy intake or expenditure as commonly believed but co-factors like dissipated heat which is known to increase as intake increases above the lower threshold limit, thereby conferring on man a wide though strictly limited range of energy requirement in regulating body weights.

To bring out the quantitative significance of the situation, I have also presented in Table I, analysis of variance of energy intake and expenditure for subjects

of Depot Centres A, B and C together and of energy balance for Depot Centre F. The analysis is presented for the 5 day period from Monday through Friday. This was done because the subjects were not given fixed tasks to perform on Saturday afternoon and Sundays. It will be seen that the mean square between periods is significantly larger than the mean square between days within periods in both groups of Depots A, B, C and Depot F. It follows that the variance of a single observation can be written as $\sigma_w^2 = \sigma_p^2 + \sigma_d^2$ and that of the mean daily intake over 'p' days as

$$\sigma_p^2 + \frac{\sigma_d^2}{p}. \qquad \ldots(1)$$

where σ_p^2 is the true variance between periods independent of p and σ_d^2 is the variance between days within periods. The implication of (1) is that as p increases, the second component of the variance decreases, but the first component remains intact. This means that day to day observations of intake, expenditure or balance in man engaged in fixed tasks cannot be considered as random. Suppose we have such data represented by the model

$$y_{it} = \mu + p_i + e_{it},$$

where y_{it} is the observed energy balace during the i^{th} week on the t^{th} day, μ is the overall mean, p_i is the random effect peculiar to the i^{th} week with variance σ_p^2 and e_{it} are the effects due to the day-to-day random variation of the same individual with variance σ_e^2. Then the implication of (1) is that firstly, p_i cannot be considered as a random effect but that it includes the genetic effect peculiar to the individual, arising from the individual's inherited capacity to cope with intake and adjusting the expenditure and secondly, σ_p^2 will contain the genetic component of variance. Further successive values of e_{it} cannot be assumed to be independent. It follows that requirement for any day or period is dynamic, varying over a range whose limits are indeterminate but the width can be depended upon to be larger than 4 σ_p.

Table I shows that the coefficient of variation of daily intake based on estimated value of σ_p is of the order of 10 per cent. This means that requirement cannot be considered as fixed even over short periods as assumed under current concepts. It must be concluded that part of the variation reported by Widdowson (1947) and ascribed to differences in energetic efficiency between individuals is due to variation in intake in the same individual and that the magnitude of this variation is far from negligible. In absolute terms, this means that an adult individual engaged in moderate level of activity can vary his intake over a range which is at least as large as 1100 kcals i.e. from 80 per cent to 120 per cent of the prescribed norm, without significantly affecting his work output and body weight.

TABLE I

Analysis of variance of daily energy intake in kcal/kg and expenditure in kcal/kg of body weight in different groups of centres (Monday to Friday)

Depot Centres	Energy Intake kcal/kg			Energy Expenditure kcal/kg			Energy Balance kcal/kg		
	A + B + C			A + B + C			F		
	d.f.	M.S.	Estimates of true variance	d.f.	M.S.	Estimates of true variance	d.f.	M.S.	Estimates of true variance
Between subjects	14	462	10	14	129	1	5	317	12
Within depots									
Between weeks	28	336	42	28	123	12	6	179	22
Within subjects									
Between days within weeks	180	124	124	180	57	57	60	50	50
σ_w^2		166			70			72	
σ_w		13			8			8	
% C. V.		22			13			21	
Var. of daily mean		67			24			32	
% S. E.		14			8			14	

The inference that the variance of daily requirement is stabilised as p increases to a value of σ_p^2 that is implied in (1) is not easily verified since available data are limited to non-continnous periods in most experiments. But it is known that no variance can remain stable over time unless successive observations were serially correlated. In other words, requirement must evolve over time in some stochastic stationary process until the variance is stabilised to σ_p^2. Simple auto-regressive models were tried out to see how well they describe the behaviour of mean intake, expenditure and balance over time. The results of this exercise for one depot centre D are given in Table II. It will be seen that the variance of the mean intake, expenditure and balance does not vary inversely as the length of the period but that it decreases slowly, thus confirming that successive values are serially correlated over the first few days and that when the period is about 5 or 6 days, the variance appears to stabilise as suggested by equation (1). The data reported by Edholm *et al.* must therefore be interpreted to mean that habitual intake of man (that is man's requirement) varies with a standard deviation given by $\pm \sigma_p$. It would appear that not only energy requirement is regulated from day to day, but the variance is also regulated. How this is achieved is not yet known but there apparently is some mechanism which enables man to throw out disruptive forces of variation and incorporate the random variation into the hierarchical

TABLE II

Variance of an individual's mean energy intake, expenditure and balance based on p successive days as proportion of unit variance for p = 1. Depot centre D.

Period in days	Observed			Expected	
	Intake	Expenditure	Balance	r=0.00	r=0.30
1	1.00	1.00	1.00	1.00	1.00
3	0.43	0.63	0.55	0.33	0.49
4	0.27	0.37	0.31	0.25	0.39
5	0.28	0.29	0.29	0.20	0.32
6	0.21	0.32	0.25	0.16	0.27

pattern that is characteristic of longitudinal stochastic stationary series of energy balance in man engaged in fixed tasks. The analysis shows that Markov type 1 is adequate to describe the process over short periods and that consequently the variance of the mean daily intake over p days may be written approximately as

$$\frac{\sigma_w^2}{p}\,\frac{1+\rho}{1-\rho}, \qquad \ldots(2)$$

where ρ is the serial correlation of the first order.

The fundamental question still remains—where does the variation in daily energy intake come from when man is engaged in fixed tasks and also essentially maintains his body weight ?

Used to the concept of phenotypic value y as made up of genotypic (g) and environmental components (e), it is customary to take for granted that the two, nature and nurture, are independent in an individual. Apparently, however, this is not the case. The two interact, as they must, to give the variance of the phenotypic value by the following equation :

$$V(y) = V(g) + V(e) + \text{Cov}\,(g, e). \qquad \ldots(3)$$

It follows that the covariance term in the equation must be equal to the stabilised value of the variance of daily mean intake viz. σ_p. This indeed is so, for the fact that the mean square between periods is significantly higher than the mean square between days within periods in the same individual implies that daily intakes within periods are more alike to each other than are daily intakes between different periods. This is like members of the same household being more alike to each other than are members between different households. When this result is extended to apply to the stochastic stationary process of the Markovian type of order 1, it is found that high intake is followed by high intake and low by low values with varying lengths between peaks and troughs averaging about 4 days, thus demonstrating the associative hierarchical nature of the longitudinal observations. The data on the same individual can, therefore, be interpreted by the method of intra-

class correlation to state that for given total observed phenotypic variance, higher the association between the different values within the same period, i.e. higher the value of $\bar{r}$, smaller would be σ_d^2 and greater would be σ_p^2. In other words, the ratio of σ_p^2 to σ_w^2 can be said to represent the fraction of phenotypic variablity which is due to genetic causes. In quantitative genetics, this ratio is called the repeatability of the character. Since observations refer to the same individual, the heritable variation can only be interpreted as arising from interaction between genetic entities in individual and the environment in which he is brought up. In Gandhian philosophy, if I may use this phrase, it is truly a variation that comes from within and gives man the power to regulate and change himself.

Substituting then $\bar{r}\,\sigma_w^2$ for σ_p^2 in (1) and noting that $\sigma_d^2 = (1 - \bar{r})\,\sigma_w^2$, the variance of the mean daily intake may be written as

$$\sigma_w^2 \left\{ \bar{r} + \frac{1 - \bar{r}}{p} \right\}. \qquad \ldots(4)$$

When the longitudinal observations over time are described by a stochastic stationary distribution of a Markovian type of order 1, it has been shown (Sukhatme & Prem Narain, 1982) that $\bar{r}$ is approximately given by

$$\bar{r} = \frac{2\rho}{(p-1)(1-\rho)}. \qquad \ldots(5)$$

On substituting for $\bar{r}$ in (4), we get for the variance of the daily mean intake the expression shown in equation (2) above. The relationship of $\bar{r}$ with p is shown in Fig. 3 and shows how $\bar{r}$ stabilises as p increases. Table I shows that σ_p^2 is small relative to the total variance, but it is far from negligible accounting for some 20 to 25 per cent of the total variation on average. The answer to the question as to why the variance of the mean stabilises is then to be traced to the presence of intra-class correlation arising from interaction between the two components g and e. It is the intra-class correlation which gives regulation the genetic basis much like what is found in the regulation of glucose in blood in a fasting state, body temperatgre pH etc. under endocrine control. The finding accords with the findings of evolutionary biologists like Mayr (1963), and Dobzhansky (1970) who postulated stabilisation of genetic variance as a prerequisite of extended hierarchic construction.

To summarise the phenomenon or process of returning to the steady state represented by the limits $\pm\ \sigma_p$ known as homeostasis arises from the presence of the covariance term in equation (3) and implies adaptive regulation of variance and not forced adaptation. The process represents a short-term ability but it is a continuous process for regulating intake as a fairly wide though restricted range which goes on within the framework of the broader process of ontogenic growth. It is

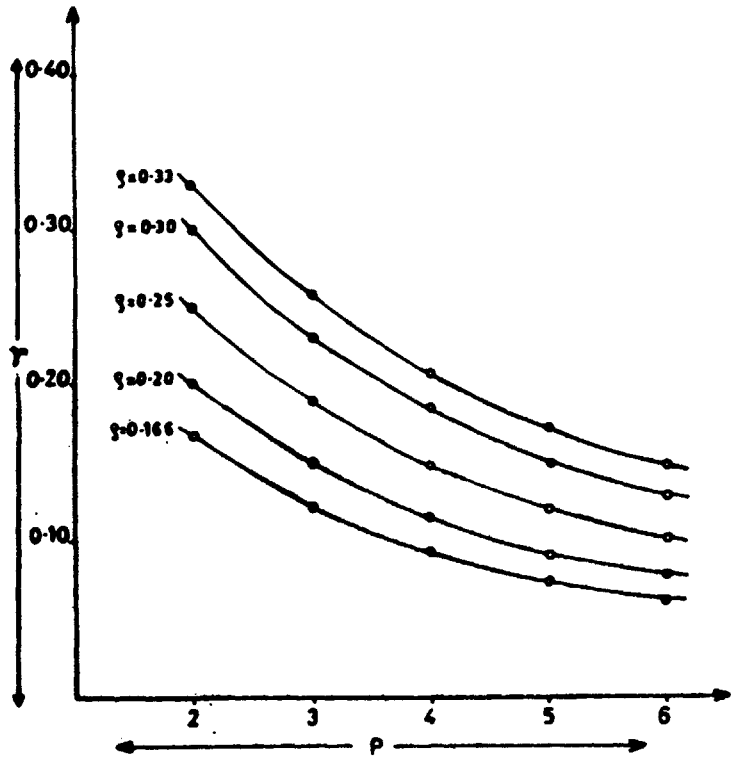

FIG. 3. Relationship between autoregulation and intraclass correlation.

because man has this short-term but continuing ability superimposed on his long term growth that man, in responding to the challenge of environment, is able to change the rate of energy flow, speeding it sometimes and slowing it down on other occasions to cumulate energy balance to the tune of several thousand kcals and yet maintain his body weight and carry out assigned tasks.

While accepting that development of man arises from the interaction between him and the environment—a question arises as to how this finding can be reconciled with the known fact that genetic code with which he is born is fixed and there is no known way in biology to change it ? Recent research has amply shown that the one to one relationship between the gene and protein that was thought at one time to be universal does not hold in the case of man and that a large number of DNA sequences, both within and between genes, remain untranscribed into RNA. Evidence also accumulates to show that the untranscribed DNA controls the production of protein products according to the needs and functions of each cell.

It is apparently then in the brain that information on the current status of metabolism and needs for protein products of each cell is processed and decisions made on the genes to be activated to meet them. This capability for flexibility,

also called plasticity, is a species trait of humans. The needs of the different cells continually change and as a consequence, the genes needed to be activated to meet them also change. If then the rate of metabolism is found to be slowed down or speeded up from day to day, as experimental evidence shows (Sukhatme) it must be in part, the consequence of this flexibility in activating genes in the brain's attempt to maximise efficiency of utilising energy consumed by man. The basic mechanism usually takes the form of signals at the occurrence of an unusual value for intake or expenditure. The signals in their turn set in motion a series of chain reactions to bring about internal metabolic changes for adapting to them. Eventually, the disturbance is thrown out and the homeostatic process is established. Implicit in the whole functioning is the decisive role played by environment to which man responds with his genetically born educability. The fact that genetic code is rigid in indicating the order of assembling amino-acids to make the protein plays no part in this whole process. It is the RNA which takes decisions on executing this code which it does by simultaneous decisions on the genes to be activated and used in each cell. It is fortunate indeed that man enjoys this capacity for plasticity and versatality in action. It is these which enable man to do conscious thinking and find appropriate solutions to meet the challenge of the environment. This is the way a child for example learns to speak, think and progress under appropriate environment. This in fact is the way quantitative behavioural traits, also called creative evolve in an individual, offering man a choice of strategy over a wide, though limited range. Space preclules further discussion of this in this paper.

Inter-Individual Variation

A question also arises that if intra-individual variation is a fundamental source of variation accounting for so large a part of the total observed variation in intake, will not the innate interindividual differences due to genetic origin be smaller than those estimated from the habitual intake ? Will they remain as large as twofold and threefold as originally estimated by Widdowson when she observed that in every age sex group she found 2 among 20, one of whom ate twice the amount of the other and yet all were engaged in similar tasks ? It is important to know this first before the implications of the theory developed here for social change are further discussed.

Using the standard notation the additive model underlying the data situation discussed so far may be written as

$$Y_{it} = b_i + w_{it}, \qquad \ldots(6)$$

where the overall mean intake is zero, the effect b_i reflects the genetic component and w_{it}, representing the observed energy balance on the t^{th} day is related to the value $w_{i,t-1}$ of energy balance on the previous day through autoregressive Markovian process of order 1. Implicit in the model is the assumption that y_{it} is distributed around b_i with variance σ_w^2 and b_i is distributed around zero with variance σ_b^2

which includes the component of genetic variance. It follows that the conditional distribution of b given y may be written as

$$\int (b/y) = \int (y, b)/\int(y). \qquad ...(7)$$

It can be shown assuming normal distribution that the best estimate of b is given by

$$b = \frac{\sigma_b^2}{\sigma_b^2 + \sigma_w^2} y = \text{say } \theta y. \qquad ...(8)$$

It follows that the habitual average intake must be scaled down to read as $\bar{\theta} y$ in order to provide an estimate of the inter-individual differences due to genetic origin.

The pooled analysis of variance of intake for subject in Depot Centres A, B and C in the Edholm study given in Table I will show that the ratio θ works out to approximately 0.06. Applying the result to estimate the inter-individual variance based on true differences, it is found that σ_b^2 is only about 1 and not 10 that we would have estimated it to be if w_{it} were independent of $w_{t,t-1}$ and σ_w^2 had not stabilised. It appears that in the Edholm study intra-individual variance accounts for most of the observed phenotypic variance. We may, therefore, confidently look to interaction between man and environment under a sustained stimulus to bring about a change in the lifestyle.

It is important to recall here that in the environment in which humans have evolved the pressure of natural selection was not on the development of any special physical feature or trait, but on the individual to respond to the challenge of the environment. In other words, the pressure is on the development of intelligence. Consequently, while humans are all products of heredity, they are even more importantly products of manmade environment, i.e., culture, upbringing and society. It is the flexibility and versatality arising from this interaction between brain and the surroundings that gives man the power to do conscious thinking and to innovate appropriate ways in keeping with values on one hand and science, technology and resources on the other.

Other Experimental Evidence

There is considerable other evidence to show that man enjoys wide flexibility in his intake even while engaged in the same tasks and essentially maintaining body weight. Space does not permit elaboration.

But a brief reference may be made to two other examples. The best example of evidence is provided by Edmundson (1979). Working in villages in Java, he has shown that the relative efficiency of work output was higher by some 80 per cent in 10 subjects with the lowest energy intake, as compared to 10 subjects with the

highest energy intake. Heights and weights of the two groups did not differ significantly. Edmundson has further shown that the basal metabolic rate of subjects with high intake (2750kcals) was nearly twice as high as that of the subjects with low intake (1770kcals). He has obtained similar results in village Katavi near Pune. Evidently, a higher level of metabolic efficiency contributes to the relatively efficient performance of the low intake group.

Equally instructive is the illustration from Indira Community Kitchen, Pune. Table III shows the distribution of energy intake of adult young women in the Kitchen preparing 500 to 600 chapaties per day. It shows that the relative efficiency of work output is 60 per cent higher for women with the lowest energy intake when compared to women with high energy intake. The same result can also be expressed in terms of the relationship of body weight and work output. Fig. 4 shows that there is hardly any relationship between body weight and work output at the high level of activity at which women work in the Kitchen. It was taken for granted that since the women were drawn from the poorest of the poor and presumably undernourished, they would help themselves to improve their intake and body weight and make themselves employable as it were for the tasks in the Kitchen. Rolling chapaties at the rate of one a minute for 8 hours in two shifts of 4 hours each calls for hard muscular work and high concentration to ensure that chapaties are rolled to size and baked properly. One has to visit and see for oneself the sight to appreciate the intensity of the work involved. There were marginal changes in body weight, but by and large it remained the same. It is not, therefore, undernutrition as judged by body weight relative to Harvard standard which leads to low level of activity. On the contrary, the relative efficiency of work output per unit of intake is seen to be higher in the lower range of body weights than in the hiher range in the ratio of about 3 : 2.

TABLE III

Distribution of energy intake of adult young women preparing 500 to 600 chapaties in 8 hours shift a day

Calories/Day	No. of workers
1500-1600	2
1601-1700	2
1701-1800	5
1801-1900	4
1901-2000	2
2001-2100	8
2101-2200	—
2201-2300	3
2301-2400	—
2401-2500	1
Total	27

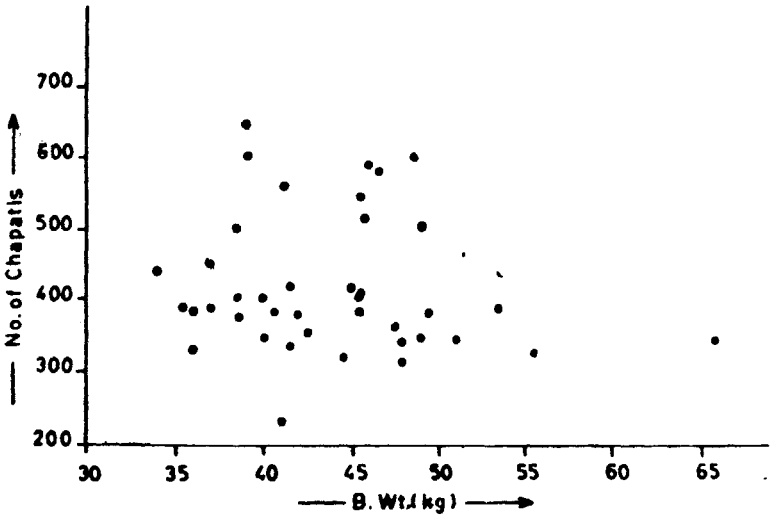

FIG. 4. Indira Community Kitchen relationship between body weight and level of productivity.

In both the projects limited observations have also been made to assess the order of magnitude of intra-individual variation. Broadly, the coefficient of variation of daily intake over time was found to be of the order of 10 per cent and that in daily BMR nearly twice as high. The analysis confirmed that energy is used with variable efficiency which decreases as intake increases over a homeostatic range. In the lower range of the process the body simply works more efficiently.

The fact that an individual is able to maintain homeostasis on a range of intakes does not imply that he cannot further improve level of work output or body weight or both by increasing his intake. Indeed, he may achieve either or both even without increasing his present level of intake. But, in this case, the limits of homeostasis will change since he will be dissipating less of his intake for the same amount of external work. He may even decrease his level of intake and yet achieve increase in work output and body weight. But in this case, the amount of chemical energy in the food which he consumes will be dissipated even less. The situation is graphically illustrated in Fig. 5. At the lower threshold values of 2000kcal an individual functions with about 50 per cent efficiency. This is the maximum amount of energy which metabolic pathways for glucose and fat can convert to ATP. The rest is wasted as heat. For protein, the maximum yield is smaller. At 2500 kcal which is the average requirement for adult males (FAO/WHO, 1975), the efficiency of utilisation is 40 per cent and at 300 kcal it drops to 33 per cent. This means that of the energy released from a given amount of food, only about 40 per cent is available on average for essential anabolic processes and physical activity; the rest is lost as heat. Eventually of course, even the energy used in essential processes appears as heat since "no energy can be lost without a trace." The fact that only about 40 per cent of total energy in the food consumed is used for anabolic purposes as well as physical activity and that this is the maximum

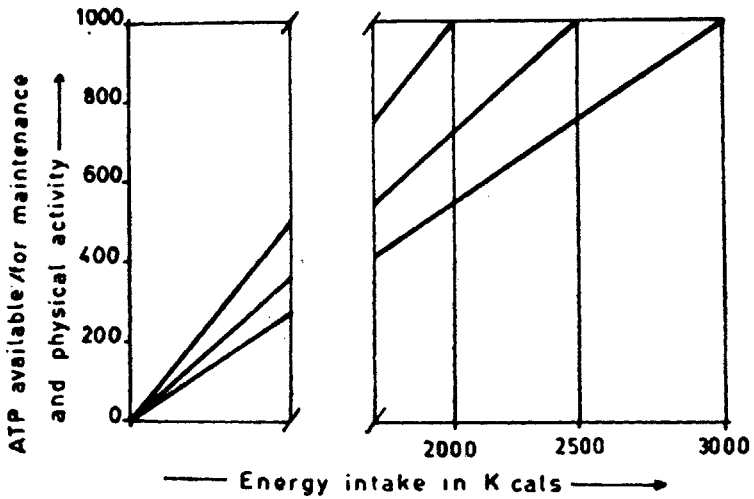

FIG. 5. Efficiency of utilization

explains why a man engaged in similar tasks from day-to-day can be in energy balance on a wide range of intakes without significant change of body weight.

It is because of this variation in efficiency with which energy is used that different responses are reported in the literature to the same increment in intake. In part, these variable responses can be traced to differences in the daily activity pattern; and in part to errors of measurement. There is a third factor and that factor is the highly individualistic response that in part is a reflection of intra-individual variation resulting from the interaction between man and environment—in this case intake. Even if therefore activity pattern were standardised and energy intake were constant, expenditure on BMR will vary in the same man from day to day as in fact all available evidence confirms. The same result is confirmed when an individual is fed excess calories or lives on restricted diet. The sum and substance of the evidence is therefore that energy requirement in man engaged in fixed pattern of activity is dynamic, self-regulated, varying from day to day with variance that is stabilised as the length of the period increases. It is this stability which gives the genetic basis for the regulation of intake over homeostatic range.

CONCLUDING REMARKS

In the title of my lecture, I have used two words. One is 'approach' and the other is 'theory'. I have done so deliberately. There is a general notion among sociologists that everything which comprises way of life is learnt and nothing of it is biologically inherited. The other view is that way of life is totally inherited. The view taken in this paper is that nature and nurture interact and that development of man has its basis in the interaction. It is the covariance between the genome and its environment which provides man with the flexibility of choice in his actions and that this flexibility in its turn leads man to generate new ways of life consistent

with the culture in which he is brought up on the one hand and with science, technology and resources on the other. 'Approach' is indicative of the role of culture, philosophy and values in changing the way of life. 'Theory' gives confidence that the results can be replicated.

The current practice in India is to identify rural problems in terms of what villagers ask for, and what is socially acceptable without being educated in the biological basis thereof for improving their living conditions. Broadly speaking, villages ask for something that is tangible, which they can use and enjoy together to improve their earnings individually and collectively. As an example, if they see the value of having a high school, it is more in terms of eventual entry to colleges and degrees *to earn a livelihood in cities* for their children when they grow up. The idea is more to escape than make the village life worth living. There is nothing wrong in asking for a tangible thing in this way. If you and I have escaped the village life, why should they not aspire for it ? Rarely, if ever, school children are brought up into thinking to look inwards as it were to appreciate the value of education for distinguishing wants from basic needs as the first step in learning the biological basis of living. I know that this is easily said than done. Yet I feel that in the absence of this approach, our efforts of village development, however useful in themselves, are bound to lack direction and end up with arbitrary decisions on priority of village problems.

I have only to recall the findings in Africa of infant deaths from the introduction of baby foods, to bring home the point I believe that Nestle's products are still being boycotted by leading universities in the United States for the part this firm played in popularising baby foods. Villagers could not be blamed for asking for the baby foods to feed their children because they like to ask for what they see you and I give to our children, little realising that giving baby foods calls for certain pre-requisites such as clean water and equipment to sterilise baby bottles that are unavailable in villages. What is true of baby foods is also true of drugs. To illustrate, villagers see an answer to scabies more in ointments and medicines than in personal cleanliness. Again, they see an answer to diarrhoea more in terms of drugs and injections than in terms of improvement of water for drinking, hygiene, public health and sanitation. What is true of nutrition products and drugs is in fact true of all symptom-oriented approaches to cure.

Past experience tells us that symptom-oriented approach surely cannot be the way to combat poverty. If anything, it will result in increased dependence of the rural population on Government programmes. It is therefore important that any effort at devising programmes for rural development should be preceded by effort to educate the children (and ourselves also in the process) around appropriate social action so that the children and their parents may see the philosophy and science at the same time in distinguishing wants from basic needs. It was in the hope that such dialogue will be encouraged and followed in school curricula that the United Nations, after failing in their earlier ventures of development, turned their attention to this basic needs approach and has declared the current decade as the 'decade of water for drinking and sanitation' in the spirit of the new approach.

Lest I may be misunderstood, let me say that I am not against new technologies nor against nutrition intervention programmes. But surely it is our duty to enquire as to why the latter fail in the first instance. I have evaluated several of these programmes carefully. Take for instance the programme organised by CARE in the State of Kerala. It was perhaps the most extensive among the feeding programmes organised by CARE for over 10 years in 8000 and odd schools in the State. Dr Soman's evaluation of this programme leaves little doubt that it has failed. I will commend to your attention the Kerala experience described by him (Soman, 1982).

I am aware that several nutritionists have reported success in their school lunch programmes. They will be provoked if I tell them that the evaluation of their data, both the statistical design and the interpretation, leave a lot to be desired. Let us take for illustration the analysis and interpretation of the results of Narangwal project which has been reported as one of the great success stories by ICMR as to what nutrition can do to improve health of the poor. The authors have reported that the results of nutrition intervention were statistically significant. In actual fact, the gains from better diet, even after 3 years of experimentation, did not amount to more than 20 per cent of the difference in height between the U. S. and Indian children. It is one thing to be told that the difference is statistically significant, it is another to find that the difference in absolute terms is large enough to be important for policy decisions. Surely, statistical significance is not the 'be all and end all' of effort regardless of the magnitude. For more detailed comments of Narangwal project, 1 will refer you to my paper (Sukhatme, 1982).

Again, I am the last man to advocate restricting food intake. Visit Indira Community Kitchen, Pune. It has been in operation since 1976. Its employees are drawn from the poorest of the poor, but are free to eat as much as and whatever they wish from amongst the foods prepared and sold by the Kitchen. I am not even against distribution of foodgrains such as they have in Kerala and Sri Lanka, provided this is feasible. What I am agains is to serve packets of socalled nutritious foods to children from 6 months to 10 years old. While it may satisfy hunger for the time being, it can do little in initiating a process that will contribute to alleviating the basic cause of hunger. Such intervention will only increase helplessness among children. Our intervention ought therefore to be so organised that it can also initiate a self-sustaining process that will benefit the children as well as the society in which they live. The same principle governs the working of the Indira Community Kitchen. Not only are the workers of the Kitchen self reliant, but are also altruistic. They sacrifice their profits to work on no profit no loss basis. This enables the Kitchen sell its foods on the market at half the market price. The demand for its food is so heavy that food is sold within an hour or so of its arrival at the distribution centres. Although the employees number only about 300, the number of poor served from the Kitchen from its distribution centres comes to over 20,000 a day. The Kitchen illustrates the principle of how the poor can help the poor to combat poverty.

What I am pointing out is the need to avoid a clash between the interests of the individuals and the society that inevitably must arise when the poor are individually identified for help, their number are large and each one so identified is thought to be starving or living with impaired functions for lack of adequate income. The claims of society necessarily get a lower priority under this approach. When one sees beggars, it is easier to dole out a little money or offer food and earn their gratitude but this action does not have any permanent impact on improving the condition of beggars. Perhaps this analogy is too strong but man, I fear, is downgraded in this action to the status of an animal. The very method of measuring poverty line by relating poverty to the minimum energy needs of man and that too wrongly, is tantamount to putting the closk back to the pre-industrial area. Our problems are social and economic of course. However, merely calling them social is not enough. There is a need to redefine this term and in particular to recognise that the basis of social change lies in the interaction between the genetic entities in man and culture (man made environment) as illustrated earlier.

Obviously, the assumption that the genetic potential for anthropometric growth is the same for all and that Indian children are unable to achieve it for lack of adequate diet cannot be valid. It follows that Gomez classification for assessing malnutrition has little scientific basis. As Morris (1982) states there just cannot be any universal fixed standards as assumed in nutrition literature.

How then did these assumptions come to be accepted by the nutritionists when all available data contradiet them ? Again Morris has given a very incisive analysis of the problem. Suffice it to say here that work on human nutrition was influenced by early work in animal nutrition and that human nutritionists were not careful enough in extrapolating from it. They were more influenced by the growth that was achieved in animals from protein feeds, minerals and vitamins. The attractions of this approach for expanding markets and new technology were so large that the more important issues for man like reduction of infant mortality and increase in life expectation were bypassed. It was believed that once the growth in weight is assured, these other issues can be tackled through developments in drug industry. If the protein gap fiasco of the last decade has a lesson to offer it will be rewarding to redesign some of the experiments with different diets and nutrition supplements reported earlier by Aykroyd and others and verify how far the conclusions reached were valid. It will be equally instructive to study why infant mortality is lower and life expectation higher despite low food intake in Kerala. Independent surveys to examine the tall claims made by ICDS will be yet another line of fruitful research. We shall be failing in our responsibilities if in the name of development we blindly copy the western consumerist models.

I am afraid my lecture has become too long. The topic is deceptively simple and for that reason difficult to put across. On my part, I am happy that people are interested in debating the issues I am talking about. That in itself I consider most rewarding.

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