Some Historical Notes on Ecological Sensibilities in Modern Western Culture

A revised version of a lecture given in the School of Economics of the University of Hyderabad in 2014
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In Western culture since *ca*.1800, ecological sensibilities, though hardly dominant, have cropped up now and then in one way and another. This essay will include succinct descriptions of some examples illustrating various points of concern (highlighted in bold-face font).

• In 1798, Thomas Malthus, a top English economist of the generation after Adam Smith, had said that "*The power* [i.e. rate] *of* [**human**] ***population*** [**increase**] *is so superior to the power of the earth to produce subsistence for man, that premature death must in some shape or other visit the human race."* He said it would happen by means of "*war*, *pestilence*, [and] *famine*". (The number of humans at that time was about one thousand million.)

• In 1804, William Blake published a powerful poem (though only 16 lines long) contrasting *(a)* the working conditions in the English cotton mills and the air pollution which their coal-burning steam engines were causing, with *(b)* a utopian concept of a green "new Jerusalem" in England where, he imagined, Jesus had supposedly once visited. Some lines from the poem are: "*And did the Countenance Divine* / *Shine forth upon our* ***clouded hills****?* / *And was Jerusalem buildèd here* / *Among these dark* ***Satanic mills****?"*. (A musical setting of this poem is beloved today in England. Many Brits want it to be the national anthem.)

• In 1797, a French hydraulic engineer, Jean Antoine Fabre, published a book explaining (among other things) how streams flowing fast on micro-watersheds become **torrents** ravaging fertile valley floors.

• In 1841, another French engineer, Alexandre Charles Surell, published a hydrological study of "Torrents in the High Alps", blaming them for the **denudification of land** on unstable sedimentary slopes.

• In 1857, a leading British philosopher and economist, John Stuart Mill, advocated a "stationary state" of society – that is, with stable amounts of human population and of capital stock. He said this would be compatible with moral and social progress; he thought **the economy could become better without becoming bigger**. (He did not think about whether a human population, even if stable in size and per-capita production, might in due course deplete the stock of *non-renewable* natural resources such as the fossil fuels.)

• In 1865 another British economist, William Stanley Jevons, declared in a famous book, *The Coal Question*, that because the coal **mines** would one day come to be **exhausted**, "*We have to make the momentous choice between brief greatness and longer continued mediocrity*."

• In 1864, George Perkins Marsh in the USA published a splendid book, *Man and Nature*, about various menacing aspects of "**misuse**" **of the environment** (e.g. **deforestation**), and analyzing its causes and prescribing reforms.

Concern about deforestation can be traced back in Western culture to Hans Carl von Carlowitz's *Sylvicultura oeconomica* (1713), Jean-Baptiste Colbert's *Grande Ordonnance* (issued in 1669 in behalf of Louis XIV) for a "*réformation des forêts*" to ensure the supply of wood for making ships, John Evelyn's *Sylva* (1664, commissioned by the Royal Society at the request of the "principal officers and commissioners of the navy"), and even the following poetic lines of Walther von der Vogelweide (*ca*.1200; pardon me for going back so far):

Alas, where have	*Owe war sind verswunden*
all my years disappeared to?...	*aliu miniu jar?...*
The people and the land with which	*Liut unde land, dar inn ich*
I was brought up since childhood –	*von kinde bin erzogen,*
they have become strange to me,	*die sind mir froemde waren*,
as if it were all a lie.	*reht als ez si gelogen.*
Those who were my playmates,	*Die mine gespilen waren,*
they are tired and old.	*Die sint traege und alt.*
The fields are ploughed up;	*Bereitet ist daz velt,*
the woods are cut down.	*verhouwen ist der walt.*

• In 1866, Ernst Haeckel, a German zoologist and evolutionist, coined the term "ecology" (***Ökologie***). He defined it as "*the entire science of the **relations of the organism to the environment**, whereby we can in a broader sense take account of all of its 'conditions of existence'*". (This is not a concept of an eco-system.)

• In 1867, Karl Marx said that "*Capitalist production, by collecting the* [human] *population in great centers, disturbs the* [**transformative**] ***circulation of matter*** (***Stoffwechsel***)[1] *between Man and the soil, preventing the return to the soil of its constituent elements consumed by Man in the form of food and clothing; hence it violates the conditions necessary to lasting soil fertility.... Progress in increasing the fertility of the soil for a given time is a progress toward ruining the lasting sources of that fertility*."

In 1868 he remarked (after reading a certain scientific book about plants) that agriculture, "*when it progresses spontaneously and is not consciously controlled ... leaves **deserts** behind it, as happened long ago **in Persia, Mesopotamia etc**.*" Other contemporary German economists had also observed this historical fact.

• In 1872, the first US national park, Yellowstone National Park (*ca*.9000 km^2 in the northwest corner of the state of Wyoming) was established.

• In 1877 a German zoologist, Karl Möbius, described in detail, in a study of oysters and oyster farming, the pattern of interactions between the various kinds of organisms cohabiting an oyster bank, and introduced the concept of a **biotic community** (i.e. with a fairly uniform composition of biological species in a geographical locality of a certain size); his term for such a community was "**biocenose**".

• In 1883, a Russian geologist and geographer, V.V. Dokuchaev, founded modern **soil science** by showing that geographical variations in soil type could be explained in relation not only to original geological factors (to which the "parent material" of a given soil is due), but also to subsequent climatic and topographic factors, as well as to the amount of time available for pedogenesis (soil formation) to operate.

• In 1890, John Muir, a Scottish emigrant to the USA, got the national government to establish Yosemite National Park in California. In 1912 he founded the Sierra Club to defend the park against "development". In 1908-13 he led an unsuccessful "preservationist" **campaign to prevent the construction of a big dam** in a valley, just north of the park, to provide water for San Francisco (which was the port for immigrants participating in the California Gold Rush of 1849-55; its population grew from 500 in 1847 to 350,000 in 1900).

• In the early 1880s, a Ukrainian doctor, Sergei Podolinsky, proposed that **economics** be **assessed in terms of energy** rather than of money, and suggested that physical and ecological laws would determine **natural limits of economic growth**.

• In 1898, the most eminent British chemist, Sir William Crookes, declared that because of **population increase** – the total was now more than 1½ thousand million – and because wheat is (he said) the only "fit and proper [cereal] food for the development of muscle and brains", artificial "*fixation*" *of nitrogen* [to improve wheat crop yields] *is vital to the progress of civilized humanity.... The chemist ... must come to our rescue. It is through the laboratory that starvation may ultimately be turned into plenty*." (The fixation, i.e. combining nitrogen chemically with oxygen to get nitrates for artificial fertiliser, was achieved on an industrial scale in the 20th century, and that achievement enabled the human population to increase fivefold.)

• In 1885, an Austrian geologist, Eduard Suess, coined the term "**biosphere**" (**Biosphäre**) and noted that this part of the planet is to be found in a certain zone "at the surface of the lithosphere".

• In 1886, a French geologist, Maurice de Tribolet, published a book-length account of the **extinction of animal species** since the emergence of Humankind, *Les animaux disparus depuis l'apparition de l'homme*.

• In 1904 a German geographer, Ernst Friedrich, surveyed environmentally destructive economic practices, in a famous article on the "essence and geographical extent of **robber economics**" (**Raubwirtschaft**).

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1. This term is often translated into English as "social metabolism", but that seems to me to be a subtly incorrect translation inasmuch as metabolism is a property of biological organisms and it would be quite misleading to call a human society a biological organism. Herman Daly (see below) agrees, and has told me: "*As you point out, not all systems are organisms, so I see no reason to call the economy an organism.... I do not use the term 'social metabolism'*[,] *because I think of metabolism as something physical, not social. An organism, it seems to me, has a higher degree of unity and purposiveness than a system like an economy, and, unlike an economy, an organism is alive*."

• In 1905, Nathaniel Shaler, a geologist who was the Dean of Sciences at Harvard University, published a book, *Man and the Earth*, expressing concern about **exhaustion of mineral resources** because of increasing human consumption. (By now the USA had a great system of railways.)

• In 1906, a Swedish physical chemist, Svante Arrhenius, whose publications had included in 1896 the pioneering article (40 pages long) on the **greenhouse effect** (which he regarded as beneficial suggested that "*we may* [thus] *hope to enjoy … better climates, especially as regards the colder regions of the earth, …* [and] *the earth will bring forth much more abundant crops than at present, for the benefit of rapidly propagating mankind*."

• In 1912, the professor at St. Petersburg University of forestry, G.F. Morozov, applied Dokuchaev's soil science and Möbius's concept of biotic communities to the study of forests. He advocated rational **forest management** as a professional discipline with a theoretical basis in scientific forestry.

• In 1915, an eminent Scottish biologist and town-planner, Patrick Geddes, argued that physical geography, market economics and anthropology are interrelated in such a way that there ought to be a science of **human interaction with regional natural environments**.

• In 1920, the professor of economics at Cambridge University, A.C. Pigou, introduced the term "externality" into economic theory, in his book *The Economics of Welfare*. (An externality is an effect of an economic activity on one or more people who have not participated in the contractual arrangement of the parties involved (for instance as capitalist and labourer) in that economic activity.) Pigou proposed that **negative environmental externalities** – due for instance to "*farming operations so conducted as to exhaust the **fertility of the soil***", and to overfishing threatening the **survival of** certain **species of edible fish** – should be curtailed by means of governmental taxes and/or subsidies, since the government "*is the **trustee for unborn generations*** [of humans] *as well for its present citizens*".

• In 1922, a zoologist at Oxford, Alexander Carr-Saunders, published a neo-Malthusian (and racist) book, *The Population Problem: A Study of Human Evolution*, which included an account of how human overpopulation has **cascading effects** on plant and animal life around the world.

• In 1924, Rudolf Steiner, a German mystic who was at that time in the process of founding the Anthroposophical Society, gave a set of lectures addressing the problem of **decline in soil fertility**. (He proposed a system of "biodynamic" agriculture marshalling various techniques to harness "astral" and "ethereal" spiritual forces allegedly causing domesticated plants to flourish.)

• In 1931 and 1940, a British agronomist with a proper understanding of organic chemistry, Albert Howard, published two book-length accounts, *The Waste Products of Agriculture* and *An Agricultural Testament*, of his findings from agricultural experiments which he had conducted in India since 1903 and from careful study of published agronomic research and of ancient and worldwide current farming practices. In the introduction to the second book, he asked, "*Can mankind regulate its affairs so that its chief possession – the **fertility of the soil** – is preserved?*" and declared that "*On the answer to this question the **future of civilization** depends.*"

• In 1940, a British aristocrat, Walter James (Baron Northbourne), coined the term "**organic farming**" in his book, *Look to the Land*. He said that "the farm itself must have a biological completeness … must be organic in more senses than one", so that "the soil and the microorganisms in it together with the plants growing on it form an organic whole", that a farm relying on "imported fertility … cannot be self-sufficient nor an organic whole", and that "in the long run, the results of attempting to substitute chemical farming for organic farming will very probably prove far more deleterious than has yet become clear."

Now let me describe some 20th-century writers who integrated market-economic theory and nascent ecological-economic theory more intricately than those earlier writers had done it:

• Frederick Soddy (1877-1956). As a chemist, he was a Nobel Prize laureate in 1922. As an economist, he was distressed by what was happening after World War I. He said: *"We have to find out how it comes about that science, which, without economic exhaustion, provided the sinews of war for the most colossal and destructive conflict in history* [he meant World War I]*, ... has not yet abolished poverty and degrading conditions of living from our midst in the piping times of peace."*

His concept of "**virtual wealth**" was practically the same as James Tobin's concept (1965) of "fiduciary issue", and his main proposal for reform was made (though for a different kind of reason) by two top economists of the 1920s in the USA, Irving Fisher and Frank Knight. He worried about the fact that there is no limit to the amount of money which can be borrowed, from banks practicing fractional-reserve banking, in order to spend it on **destroying nonrenewable natural capital** and/or on **using up renewable natural capital faster than it can be renewed**. This is the main point of his 1926 book, *Wealth, Virtual Wealth and Debt: The Solution of the Economic Paradox.* He said: "*Debts are subject to the laws of mathematics rather than* [to the laws of] *physics. Unlike* [material] *wealth, which is subject to the* ***laws of thermodynamics****, debts do not rot with old age and are not consumed in the process of living. On the contrary, they grow* [causing the money supply to grow] *at so much percent per annum, by the well-known mathematical laws of simple and compound interest.… It is this underlying* ***confusion between*** [**material**] ***wealth and*** [**aggregate**] ***debt*** *that has made such a tragedy of the scientific era.*"

Here is a good example of his crankiness as a writer on economics: *"Orthodox economics has never yet been anything but the class economics of the owners of debts. If its writers ever attempted any wider social applications, they made them-selves simply ridiculous, as when one* [of them] *solemnly looked forward to the millennium* [i.e. paradise on Earth] *arriving through the accumulation of so much* [monetary] *capital that everyone would be well off and comfortable, presumably by living on the interest of their mutual indebtednesses.*"

• J. C. Kumarappa (1892-1960). We may regard him as a Westerner by virtue of his religion (Christian) and his Western higher education (certification in London as a chartered accountant; North American undergraduate and graduate degrees in economics).

In his book ***Economy of Permanence*** he said "*The world possesses a certain stock or reservoir of such materials as coal, petroleum* [and] *ores …* [of] *iron, copper, gold, etc. These, being available in fixed quantities, may be said to be 'transient', while the current of flowing water in a river or the constantly growing timber of a forest may be considered 'permanent' as their stock is inexhaustible in the service of man if only the flow or increase is taken advantage of.... Basing our life pattern on the economy of permanence paves the way for world peace, while the other* [kind of economy, based on **dwindling sources of consumable energy and raw materials**,] *leads to disharmony,* ***unhealthy competition****, enmity and world wars.*"

He advocated **careful** uses of **technology**: *"The main trouble with man arises out of the fact that he is endowed with a 'free will' and possesses a wide field for its play. By exercising this gift in the proper way he can consciously bring about a much greater coöperation and* ***coördination of Nature's units*** *than any other living being. Conversely, by using it wrongly he can create quite a* ***disturbance in the economy of Nature****, and in the end destroy himself."*

Material reckonings are characteristic of ecological economics. Kumarappa reckoned that 77,700 acres of land (66,600 in crops, plus some for "seed and waste") could provide 100,000 people with a balanced vegetarian diet of some 2850 calories per day:

	per capita			
	ounces daily	calories daily	pounds annually	*acres cultivated*
cereals	16	1600	365	43,400
beans & peas	2	200	45½	5,400
molasses	2	200	45½	1,200
nuts	1	145	23	2,600
edible oils	½	255	11½	3,000
butter	½	-	11½	-
milk	12	240	274	-
vegetables	8	48	182½	1,600
potatoes & tubers	4	100	91	1,000
fruits	4	52	91	900
cotton			12½	7,500

In his book *Gandhian Economic Thought* he distinguished between "**home industry**" such as cooking etc. for members of the same household, "**village industry**" for distribution and consumption mainly within the same village, and "**cottage industry**" producing commodities the consumption of which might take

place anywhere. He said village industry offers more **efficiency transportation-wise** and in terms of transaction costs, than do mass-production factories.

He had more regard for chemistry and biology than market economists do. He urged (for instance) that government send out "**soil doctors**" to analyze local soils and advise farmers as to how much of this and that chemical to apply by way of artificial fertilizer as a carefully dosed adjunct to ample natural fertilizer. (It was not done, alas.) And note in the following passage the alertness to important nutritional (biochemical) factors together with the concern for reducing transportation costs "[*P*]*addy,if it has to be transported in bulk to great distances, involves great expense because of the space required and the weight of its natural covering. To avoid this difficulty paddy is subjected to mill processing which leaves the rice grains in a highly polished condition. Polished rice in a country where there is malnutrition is a veritable menace. It is pure starch. It lacks the nutritive elements of bran, pericarp, germ and other fats and minerals which have been taken out* [and discarded] *in the mill processing*."

I agree with Dr. T. J. Jacob's assessment of Kumarappa as "one of the tallest and most original thinkers in the Indian independence struggle". So, why didn't Nehru pay more heed to him in the 1950s? Two reasons were that *(1)* the AIVIA was in fact not brilliantly successful (Kumarappa was not a brilliant administrator), and *(2)* he was often rather sharp-tongued. But a bigger reason was that Nehru, whose university studies in England had been in physics, chemistry and biology, believed – mistakenly – that orthodox economic theories, which guided the architect of the Five-Year Plan (P.C. Mahalanobis), were scientific and therefore the Plan would succeed. It is, however, notable that Nehru toward the end of his life saw clearly that the Five-Year Plans had not represented a successful "tryst with destiny". On several occasions in the 1960s (he died in 1964) he said that Gandhian economics would have worked better. A Gandhian octogenarian in Madurai, K. M. Natarajan, has, for instance, recently told me that he heard Nehru declare, in a talk given in December 1963 in Tamil Nadu, that implementation of the Plans had failed to abolish unemployment, poverty and hunger in India, and that India could have done better by going "the Gandhian way" in economics.

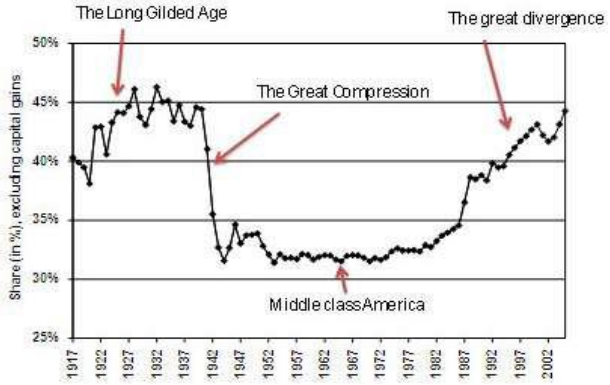
• E. F. Schumacher (1911-77). He was a brilliant market- and welfare-economist – and had been praised very highly as such by Keynes, who arranged for him to become the top economic advisor to the post-war socialised British coal industry – before becoming also an ecological economist. (His father had been the economics professor in Berlin.) In 1945 he told his wife: *"In England we are fighting for a system of government and economic administration that is based on the notion that every human being matters. We are fighting against ... **callousness towards the ordinary man**."*

In 1955, while on a three-month leave of absence from the Coal Board to advise the government of Burma, he decided (*before* Nehru reached, as we have seen, a similar conclusion with regard to India) that "*Gandhi* [had] *laid the foundation for a* [superior] *system of economics…. A civilization based on renewable resources, such as the products of forestry and agriculture, is by this fact alone superior to one built on non-renewable resources, such as oil, coal, metal, etc.*" He recommended that "*short-distance transportation should receive every encouragement, but **long hauls should be discouraged**.*"

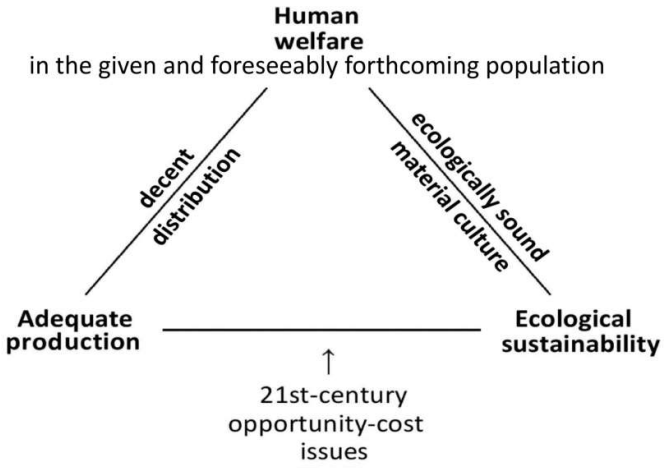
His book *Small is Beautiful: Economics as if People Mattered* (published in 1973, soon after his article entitled "The Economics of Permanence") had an impact on enlightened public opinion in England and the USA for a few years. He understood that *"Mankind ... in the last hundred years has ... broken into Nature's larder and now is emptying it out at a breath-taking speed.... Modern man ... talks of a battle with Nature, forgetting that if he won the battle, he would find himself on the losing side....* [The] ***primary factors** in the economy* [are] ***food and fuel**."* (N.B.: Not capital and labour.)

In a section on the "proper use of land" he cited several paragraphs of a discussion, from a book entitled ***Topsoil** and Civilisation* (which two ecologists, Tom Dale and Vernon Carter, had published in 1955), of the fact that "Civilised man has **despoiled** most of the **lands** on which he has lived for long", and commented: "*The 'ecological problem', it seems, is not as new as it is frequently made out to be. Yet there are two decisive* [modern] *differences*: *The earth is now much more densely populated than it was in earlier times and there are, generally speaking, **no new lands to move to**; and the **rate of change*** [i.e. of degradation of topsoil] *has **enormously accelerated**, particularly during the last quarter of a century*."

Now here is some food for thought: According to a recently published *History of World Agriculture*, "25 'glorious years' of sustained [economic] growth" in the affluent countries were "from the end of World War Two to the beginning of the 1970s". And, Paul Krugman (an eminent neo-Keynesian economist) has made the following graph showing that that was a time of *mitigated* inequality in the USA (which we may take as having been in this regard a model affluent country). The graph is of percentages of the money that the very rich had:



The percentages declined from *(a)* some 45% during the "Gilded Age" from the mid-1920s through the '30s to *(b)* some 32%-33% in the '50s, '60s and '70s, when the wage earners were therefore getting a reasonably fair deal (partly because the trade unions were strong). Those latter decades were, however, the very time when, according to Schumacher (who was exceptionally good at assessing statistics), the rate of environmental degradation accelerated "enormously". The take-away point for us is that now, in the 21st century, a reasonably fair distribution of the goods produced is not Humankind's *only* macroeconomic concern; there are two others as well: *(1)* to produce enough properly nutritious food etc. for the more than ten times as many people as were living 250 years ago; and *(2)* to do it in an ecologically sustainable way. I have made a diagram about this; it includes the phrase, "opportunity cost"[2] in view of the likelihood that further increases in production will entail ecological degradations, whereas every measure taken to mitigate the degradations may entail some short-term sacrifice of productivity:



(In other words: It will not be good enough merely to avoid dishing out the pie in such a way that a few people get giant slices while some of the others get mere crumbs; we also have to bake a pie that's big enough to feed the whole party; *and*, we have to take care not to let it get spoilt before the party's over.)

I should mention here that natural scientists in Russia in the first half of the 20th century contributed to the development of ecological sensibilities in modern culture.[3] The following examples of such scientists seem to me particularly notable:

2. Whenever you have a choice between alternatives such that if you take one of them you give up the opportunity to take the other one, if you take either one of them the foregone opportunity of taking the other one can be regarded as a kind of cost.

3. An account by John Bellamy Foster, an eminent Communist academic in the USA, is accessible at https://monthlyreview.org/-2015/06/01/late-soviet-ecology-and-the-planetary-crisis/.

• Vladimir Vernadsky (Влади́мир Верна́дский; 1863-1945). A professor of crystallography and mineralogy, he pioneered the ecological sciences of **geochemistry** (in various projects and writings in the late 19th and early 20th centuries) and then **biogeochemistry**. From Paris in 1922 he sent to scientific institutions in several countries a "Plea for the Establishment of a Biogeochemical Laboratory". The USSR responded positively and in 1926 he set up in Leningrad a biogeochemical research institute and published a book, *Биосфера* ("The Biosphere"), in which he said that "*the* [living] *matter of the biosphere collects and redistributes solar energy, and converts it ultimately into free energy capable of doing* [physical] *work*[4] *on Earth.... A new character is imparted to the planet by this powerful cosmic force. The* [solar] *radiations that pour upon the Earth cause the biosphere to take on properties unknown to lifeless planetary surfaces* [i.e. on other planets]*, and thus to transform the face of the Earth…. In its life, its death, and its decomposition, an organism circulates its atoms through the biosphere over and over again.*" He regarded the biosphere as the greatest single geological force on Earth, and estimated that it moves, processes and recycles several billion tons of mass per year.

• Vladimir Sukachev (Влади́мир Сукачёв; the surname is also transcribed as "Sukaczev"; 1880-1967). Trained in forestry, he became a leader in the scientific study of plants with wood in them (trees etc.) in their natural environments (Lenin was impressed by his book (1929) on the formation, development and properties of swamps), and in the 1940s promoted a biogeographical concept for which he coined the term биогеоценоз (transcribed as "biogeocoenosis" or "**biogeocenose**"), defined as follows: "*A biogeocenose is a combination, on a specific area of the earth's surface, of homogeneous natural phenomena (atmosphere, mineral strata, vegetable, animal, and microbiotic life, soil, and water conditions), possessing its own specific type of interaction of these components and a definite type of interchange of their matter and energy among themselves and with other natural phenomena, and representing an internally contradictory dialectical unity, being* [therefore] *in constant movement and development*." He said that "*interaction among the components constantly disrupts the established relationships"* and that the "*continuous interaction of all the components among themselves and with surrounding natural objects means that each biogeocenose is a dynamic phenomenon, constantly moving, changing, and developing.*" This outlook led to a governmental programme of nature-reserves (заповедники; **zapovedniki**) for long-term study of the ecological dynamics of theoretically pristine (i.e. unaffected by human agency) biogeocenoses. At certain moments in their history the zapovedniki amounted, in all, to nearly 1½% of the territory of the nation. There was also, on the other hand, the "Great Stalin Plan for the Transformation of Nature", whereby tracts of new woods (of which a million acres' worth is said to have survived) were deliberately created between 1948 and 1953. (I should, however, mention also the contrary trend under Khrushchev in the later 1950s and '60s, when 33 million hectares of Siberia were plowed up for agriculture, resulting in *(a)* an economic fiasco of rotting food as transportation infrastructure to deliver the harvests to cities was inadequate) and in due time *(b)* Siberian dust bowls, and meanwhile two rivers feeding into the Aral Sea were diverted to provide irrigation for cotton farming, thus causing that sea, which in the 1960s was the fourth largest lake (68,000 km^2) on Earth, to be reduced, by 1997, to a tenth of its former size.)

• Vladimir Stanchinsky (1882-1941 or '42; the surname is also transcribed as "Stanchinskii"), an ornithologist and geographically oriented zoologist. He published in 1927 a book on **food-chain energetics**, according to which the biosphere's total mass depends on how much solar radiation it can appropriate and transform at various **trophic levels,** i.e. successive levels in the food chain. He cited the Second Law of Thermodynamics[5] to explain why the total mass of the organisms higher on the trophic ladder is less than that of those which they eat. He edited for a while a journal on ecology, but then the Soviet authorities imprisoned him in the mid-1930s and again (this time fatally) in 1941.

In the West meanwhile:

• In 1927, Charles S. Elton, a 27-year-old English zoologist, published a book, *Animal Ecology*, discussing **ecological niche**, the sizes of various animals' food items, the resulting food chains, and a theoretical "**pyramid of numbers**" outlining the structure of ecosystems in terms of feeding relationships. In 1932 he

4. "Exergy" is nowadays an accepted term in English for this. See Note 9 below.

5. See the second paragraph of Note 9.

established at Oxford a center for the collection of data on fluctuations in animal populations, and became the founding editor of the *Journal of Animal Ecology.*

• In 1935, Arthur Tansley, Professor of Botany at Oxford University, introduced the term "**ecosystem**" for a biotic community along with its physical environment (i.e. its "biotope").

• Also in the mid-1930s, Prof. Aldo Leopold of the University of Wisconsin promoted the science of "**wild-life management**". He called for a "**land ethic**" in regard to "soils, waters, plants, and animals". He said it would "change the role of *Homo Sapiens* from conqueror of the land-community to plain member and citizen of it".

• In 1944, Karl Polanyi, a Hungarian economist and historian who had migrated to North America, proposed, in an acclaimed book, *The Great Transformation*, a "substantive" concept of economic activity as "**provisioning**" – i.e. as society meeting its material needs **from natural resources**.

• In 1948 two best-selling books about **soil erosion**, *Our Plundered Planet* and *Road to Survival*, were published in the USA. Albert Einstein and Eleanor Roosevelt[6] endorsed one of them; the other one had a preface written by an eminent financier who called for a "favorable **biophysical relationship with the earth**".

• In 1949 a British disciple of Mahatma Gandhi (named Madeleine Slade in England but "Mirabehn" in India) declared that "The tragedy today is that educated and moneyed classes are altogether out of touch with the vital fundamentals of existence – our Mother Earth and the animal and vegetable population which she sustains. This world of Nature's planning is ruthlessly plundered, despoiled and disorganized by man whenever he gets the chance. By his science and machinery he may get huge returns for a time, but ultimately will come desolation. We have got to **study Nature's balance**, and develop our lives within her laws, if we are to survive as a physically healthy and morally decent species."

• In 1950, William Kapp, a German-American economics professor, published a book, *Social Costs of Private Enterprise* (a later version is entitled *Social Costs of Business Enterprise*), arguing in detail that **externalities**[7] **often have pervasive social costs**, some of them due to environmental degradation and all of them due meanwhile to the structure and incentives of free markets.

• In 1952 a German-born economics professor at the University of California, Siegfried von Ciriacy-Wantrup, proposed that renewable vital natural resources (such as soil and certain kinds of plants and animals) should not be reduced below a "**safe minimum standard**" **of conservation** (to be determined for each such resource) whereby the loss would be likely to become irreversible.

• Also in 1952, the metaphor of **the Earth** as **a** "**spaceship**" was invented in the USA by the Democratic Party's candidate for president, Adlai Stevenson. (The election was won by the Republican candidate, General Eisenhower, who had been the military leader of the Allies in World War II.)

• In 1953, a biologist at the University of Georgia (USA), Eugene Odum, published an influential textbook, *Fundamentals of **Ecology***. (Subsequent editions were co-authored by his brother, Howard T. Odum, who had studied at Yale under George Hutchinson[8] and who devised a concept of "emergy" for exergy expended by Nature in the past and allegedly "remembered" by the exergy present in various different ways today.[9] (It is a mistaken idea. Exergy has no memory.)

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6. Eleanor Roosevelt was the widow of the most successful 20th-century American politician (Franklin D. Roosevelt, who had been elected four times to the presidency) and had been for many years the most prominent American champion of human rights, proactively and indefatigably opposing racial bias and gender bias. The Universal Declaration of Human Rights was created at her insistence.

7. See the entry (above) for 1920.

8. See the entry (below) for 1957.

9. Exergy is energy that makes (or *can* make) objects move. If a car goes 50 km upon burning up a litre of gas, that level of efficiency in terms of exergy is the same regardless of the price per litre of gas. If you have studied physics and are at home with the concept of entropy but not with the term "exergy", let me assure you that it does mean the same thing as "available energy" or "free energy" (and so the unit of measure can readily be kilowatt hours). If you haven't studied physics you may wonder whether there is any energy that doesn't do work (in the physicist's sense of the term). There is. Here are two examples: *(1)* If you try to lift a bucket of water but can't get it off the ground, you haven't accomplished any physical work – no matter you much energy you put into the effort – because it didn't budge. (And by the way, the amount of work done by lifting 5 kilos 2 metres would be the same as the amount done by lifting 10 kilos 1 metre.) *(2)* The heat in the air which makes us uncomfortable in

• Also in 1953, Bertrand Russell understood that "*We have good reason to be concerned when **soils** are **exhausted by unwise cultivation**. We are* [meanwhile] *far too careless of the world's **mineral resources**…. This is a more serious matter than is sometimes thought.*"

• In 1956, M. King Hubbert, a geophysicist employed in Texas by the Shell Oil Company, predicted accurately the year (1970) when "**peak** [rate of] **production**" from oil wells in the USA would occur. He saw great possibilities in nuclear in solar energy. He said that *if* "foresight can be exercised" and *if* "the cultural lag can be sufficiently reduced between [*a*] the ... behavior patterns which we [affluent people] have inherited from our recent past and [*b*] the action requirements which are necessitated", then the long-term outcomes might not be drastically Malthusian, but that any "serious **overshooting** of the world population above a manageable level" would entail "a temporary state of chaos".

• Also in 1956, the University of Chicago published a 1200-page book (based on a conference held in 1955 at Princeton University) about "Man's Role in **Changing** the **Face of the Earth**". One of the remarks in it was that "*if all the nations of the world should acquire the same standard of living as our own* [in the USA]*, the resulting* [human-]*world need for materials* [of economic value, supplied by Nature] *would be six times present consumption*".

• In 1957, G. Evelyn Hutchinson, a Yale University professor of zoology (and former student of Charles Elton), published the first volume of a magisterial, four-volume *Treatise on **Limnology***.[10]

• In 1958, Charles Elton published *The Ecology of Invasions by Animals and Plants*, establishing "**invasion ecology**" as a branch of biogeographical study.

• In 1962, a "green anarchist", Murray Bookchin, published in New York a book entitled "Our Synthetic Environment", including chapters entitled "Urban Life and Health", "The Problem of **Chemicals in Food**", "Environment and **Cancer**", and "**Radiation** and Human Health".

• Also in 1962, Rachel Carson, a marine biologist employed by the US government, questioned, in a best-selling book, *Silent Spring*, the ecological safety of DDT and of certain other chemical **pesticides**. (She deliberately evoked **uncertainty** in remarks like "No one knows whether the same effect will be seen in human beings" and "*The whole concept of **genetic damage** by something in the environment is also relatively new, and is little understood except by the geneticists, whose advice is too seldom sought.*"[11])

• In 1966, an eminent British journalist and economist, Barbara Ward, published a book entitled "**Spaceship Earth**". She then co-authored, for the U.N. Conference on the Human Environment (Stockholm, 1972: see below), a report entitled "Only One Earth: The Care and Maintenance of a Small Planet". She said that "*The **careful husbandry** of the Earth is sine qua non for the survival of the human species and for the creation of decent ways of life for all the people of the world.*"

• In 1967, a professor at the London School of Economics, Edward Mishan, argued at length, in *The Costs of Economic Growth*, that **GNP** is **a mismeasure in regard to human welfare**, and that some of the bad "externalities" of economic expansion had to do with the natural environment.

• In 1968, Paul R. Ehrlich, a biologist at Stanford University (in California), published an influential neo-Malthusian book entitled "The **Population Bomb**", predicting – incorrectly – that hundreds of millions of people would starve to death in the 1970s.

April (even if no work is being done at the moment) is due to the "thermal energy" of molecules zig-zagging aimlessly here and there and bumping into each other. *They* aren't getting any work done; they're just making us sweat.

A salient difference between energy and exergy is that whereas energy cannot be destroyed but can only be transformed from one kind to another (electrical energy, the energy of a waterfall, and chemical energy that is released in an explosion are examples of different kinds of energy), every such transformative process entails some loss of exergy. This latter fact is the famous "Second Law of Thermodynamics". An example of it is that a car doesn´t just *go* while burning up its fuel, it also gets hot, and that resulting heat – inside cars and perhaps making the city too warm for comfort – represents a net loss of exergy. The total *amount* of energy is always the same. (This is the *First* Law of Thermodynamics.) The difference between the exergy and the other energy is *qualitative*: Can or can it not do work?

10. Limnology is the scientific study of inland aquatic ecosystems.

11. The structure of DNA molecules had been discovered in 1953.

• In 1969, Edward Goldsmith founded in Britain a journal, *The Ecologist*, which in due time helped to make well known the **World Bank's role** in "financing the destruction of our planet".

• In the 1960s and '70s, Mikhail Budyko, a distinguished USSR climatologist, compiled an atlas of the global **heat-balance system**, wrote a **paleoclimatic analysis** of the history of big changes in the biosphere associated with changes of climate, described in some detail the history of **anthropogenic climate-change**, and warned that **ice-albedo feedback** (i.e. with more and more of the ice and snow on the surface of the Earth melting and hence less and less reflection of sunlight back into outer space) would accelerate global warming. He noted that socio-economic characteristics of the capitalist system hinder the long-term rational utilization of natural resources and render it difficult to rely on planned undertakings against environmental pollution.

• In 1969-70 the idea of an annual "**Earth Day**" celebration was proposed at a UNESCO Conference in San Francisco and was established in the USA as a government-sponsored national celebration each year on John Muir's birthday, April 22nd. (It is celebrated nowadays in more than 190 countries.)

• President Richard Nixon of the USA said in his 1970 "State of the Union" Address that "the great question of the seventies" would be "*'Shall we make our peace with nature and begin to make **reparations for the damage** we have done to our air, to our land, and to our water?' ...It has become a common cause of all the people.... It is of course a particular concern to young Americans because they more than we will reap the grim consequences of our failure to act on programs which are needed now if we are to prevent disaster later.... [But] the price tag on **pollution control** is high. Through our years of past carelessness we incurred a debt to nature and now that debt is being called.... We can no longer afford to consider air and water common property, free to be abused by anyone without regard to the consequences. Instead, we should begin now to treat them as scarce resources, which we are no more free to contaminate than we are free to throw garbage into our neighbor's yard. This requires **regulations**. It also requires that, to the extent possible, the price[s] of goods should be made to include the costs of producing and disposing them without damage to the environment."*[12]

President Nixon signed into law a "Clean Air Act", a "Clean Water Act", an "Endangered Species Act" and an "Environmental Policy Act" establishing the **EPA**, the Environmental Protection Agency.

• In 1971, a biology professor in St Louis (Missouri), Barry Commoner, declared in a best-selling book, *Closing the Circle*, that "*everything is connected to everything else*" (by which he meant that there is **just one ecosphere for all living organisms**) and so "*everything must go somewhere*" (by which he meant that there is no "away" on Earth into which things can be "thrown away").

In 1990, he would lament that "*It's not just the environmental movement that has failed … since the first Earth Day. The government programs have also failed. The approach strategy taken by the Environmental Protection Agency and all the state environmental regulatory groups … hasn't worked…. [T]here's been little improvement in the environment, and certain things* [about it] *have gotten worse*." After citing relevant statistics he concluded that "*When a pollutant is attacked at its point of origin, it can be eliminated. Once produced, it's too late*."

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12. In strategic opposition to such thinking, Lewis F. Powell, a lawyer specializing in corporate mergers and acquisitions and a board member of the Philip Morris cigarette company, sent in 1971 a confidential 6,400-word memorandum, entitled "*Attack on American Free Enterprise System*", to the chairman of the "education committee" of the U.S. Chamber of Commerce (one of the most powerful NGOs in the world), saying that a "*primary responsibility of corporate management*" is to influence public opinion and legal institutions and that "*Strength* [in that regard] *lies in organization, in careful long-range planning and implementation, in consistency of action over an indefinite period of years, in the scale of financing available only through joint effort, and the political power available only through united action and national organizations*." He said the need of the hour was to "recruit" lawyers of "the greatest skill" to represent business interests before the Supreme Court. "*Under our constitutional system … the judiciary may be the most important instrument for social, economic and political change*." He himself then served on that court from 1972 until 1987. His memo of 1971 led to the formation in 1972 of "Business Roundtable", a high-gear lobbying organization whose members included, by 1977, most of the richest 200 corporations in the USA. Then came various right-wing political think tanks, "public interest" law firms, etc., including the U.S. Chamber of Commerce's National Litigation Center, which has, ever since John Roberts became in 2006 the Chief Justice of the U.S. Supreme Court, won more than two thirds of the cases that it has argued before that court.

• In the 1970s, Charles Hall (a research scientist at the Brookhaven National Laboratory and then at the Woods Hole Marine Biological Laboratory) began to use the acronyms "**EROI**" (for "Energy Return On Investment") and "**EROEI**" (for "Energy Returned On Energy Invested"). In these tags, the word "energy" refers to *commodified* energy, and the concern is to reckon the ratio between *(a)* a certain amount of it brought to market by a given technique and *(b)* the amount of commodified energy that has been or has to be expended in order to do that:

$$\text{EROI} = \frac{\text{Energy returned to society}}{\text{Energy required to get that energy}}$$

• In 1972, in a report entitled "The **Limits to Growth**" (which the "Club of Rome", funded by the chairman of the largest Italian automobile manufacturing company, FIAT, had commissioned in 1968), Donella Meadows *et al.* used the results of some MIT computer modeling to argue that if current economic trends were maintained, then "*The limits to* [economic] *growth on this planet* [would] *be reached sometime in the next hundred years,* [but that] *to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future"* would be possible. (The report was translated into dozens of languages. Twelve million copies have been sold.)

• Also in 1972, there was (in Stockholm) a U.N. "Conference on the Human Environment" (i.e. a conference about the environment in which Humankind lives and will go on living). (Indira Gandhi delivered there a speech citing the "Hymn to Earth" from the *Atharva Veda* and calling for "modern man" to be "conscious of his **responsibility**" **to the Earth**.[13])

• In 1973, a Norwegian philosopher, Arne Naess, coined the term "**deep ecology**", for an outlook based on the precept that all living things have value independent of their usefulness to other living things.

• In 1974 a French writer, Françoise d'Eaubonne, coined the term "**eco-feminism**". She blamed environmental degradation on social inequality between men and women, and discerned a patriarchal "criminal and warrior-like" logic in industrialized agriculture.

• Also in 1974, an Australian philosopher, John Passmore, argued, in a book entitled "Man's **Responsibility for Nature**", that it was urgent for Humankind to stop its *unconstrained* exploitation of the biosphere.

• In 1975, Peter Singer, an Australian-born moral philosopher, published the first edition of a seminal book entitled *Animal Liberation: A New Ethics for Our Treatment of Animals*. He has focused on (among other things) the appallingly **cruel suffering caused by** "**factory-farming**".

• In 1979 James Lovelock, a British inventor, published a book, *The Quest for Gaia*, popularizing his (mistaken) theory of the **Earth as an organism**. (He neglected that all organisms – but not the Earth – ingest and emit significant amounts of substances.)

• Also in 1979, the "**Permaculture** Institute" in Tasmania began to issue publications.

Lots more evidence could be cited as to a crescendo in the 1970s of awareness, in Western culture, of environmental issues. "**Green**" **political parties** were founded in Australia, New Zealand, Switzerland, Britain, Belgium, and – most successfully – Germany where *Die Grünen* adopted in 1980 their four "ideological pillars" of social justice, **ecological wisdom**, grassroots democracy and nonviolence.

There has meanwhile been, however, a lavishly funded worldwide movement *against* ecological economics.[14] The Club-of-Rome report, for instance, was attacked by myriad trolls (as well as by some eminent academics – for instance Robert Solow, who in 1974 trumped it with his intuitive personal imagination: "*The* [human] *world has been exhausting its exhaustible resources since the first caveman chipped a flint, and I imagine the process will go on for a long, long time*"). In 1980-81, Ronald Reagan, as candidate for the US presidency and then as President, declared that trees cause more pollution than automobiles do, and

13. If you have studied chemistry and astronomy, you know that there is really no current threat to Planet Earth. It will persist until the Sun becomes a much older star and swells up and engulfs it. A realistic current concern is the threat meanwhile to Humankind's chances of surviving for an indefinite number of generations.

14. (See the last two sentences of Note 12.) Two relatively early book-length studies of this were Andrew Rowell´s *Green Backlash: Global Subversion of the Environmental Movement* (Routledge, 1996) and Sharon Beder's, *Global Spin: The Corporate Assault on Environmentalism* (White River Junction, Vermont, USA, and Totnes, Devonshire, UK, 1997/98).

that "*Eighty percent of air pollution comes not from chimneys and auto exhaust pipes, but from plants and trees.*" The "International Union for Conservation of Nature and Natural Resources" promulgated in 1980 the self-contradictory term "sustainable development" – self-contradictory inasmuch as most businessmen and economists mean, by "development", more production (whereas every national government wants a bigger GNP so that it can collect more revenues without raising the rate of taxation). And so on, as you undoubtedly know.

An ironic aspect of this tragic – as is now beginning to become clear – chapter of human history is that environmental responsibility became characteristic of Communist government in the USSR under Gorbachev in late 1980s. Severely polluting methods of production were curtailed, river-diversion projects were cancelled, etc. This was due in part to the influence of one of his top advisors, Ivan T. Frolov, who had written philosophically probing books entitled *Global Problems and the Future of Mankind* and *Man, Science, Humanism: A New Synthesis*, and who advocated "moving away from the illusion of anthropocentrism and rejecting the traditional hegemonistic relationship [of modern Humankind] to Nature".[15]

I could describe in detail, as an interesting example of non-Communist Western economic thinking in the 1990s, the ideas of David W. Pearce, an economics professor in London and a government consultant there. While discussing responsibly the concept of an economy sustainable in relation to an evolving natural environment, he posited, nevertheless, that "*For all we know, it may be perfectly possible* [for Humankind] *to dispense with natural environments in favour of an encapsulated world of plastic and microchips.*" (If he really meant that, then his understanding of nutrition and agronomy was incredibly weak.) But let me, instead of dwelling on bizarre cultural byways, revert to my series of 20th-century academic theorists who seem to me to have prepared a basis for modern ecological economics with due attention to the prospect of galloping (alas) environmental degradation.[16]

• Kenneth Boulding (1910-93). He was a founder of **systems-analysis** and served as president of the American Economic Association, the American Association for the Advancement of Science (which publishes the journal, *Science*), etc. He said (in 1965) that "*Primitive men, and to a large extent also men of the early civilizations, imagined themselves to be living on a virtually illimitable plane. There was almost always somewhere beyond the known limits of human habitation ... someplace else to go when things got too difficult either by reason of the deterioration of the natural environment or a deterioration of the social structure in places where people happened to live.... The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past.... I am tempted to call the open economy the 'cowboy economy', the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour, which is characteristic of open societies. The closed economy of the future might similarly be called the 'space-man' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in* ***a cyclical ecological system****."*

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15. An eminent USSR economist from Siberia, Pavel G. Oldak, suggested in 1985 that the kinds of economic-growth calculations which are standardized in neoclassical economic theory should be replaced with an approach focusing on "gross social wealth" as the basis for socio-economic decisions, taking into account not only the accumulated capital (in the classical economists' sense of that term) of the nation, but also the condition of its natural resources, as well as the health of the population, the services available to them, and the condition of the "knowledge sector". A similar suggestion is made in Sir Partha Dasgupta's article, "The Nature of Economic Development and the Economic Development of Nature", in vol.XLVIII, No.51 (21 December 2013) of *Economic & Political Weekly.*

16. A grotesque example of an eminent market-economist recognizing implicitly that environmental pollution was beginning to get out of hand toward the end of the 20th century is suggestion made by Lawrence Summers to the staff of the World Bank, in 1991 when he was its chief economist, that the Bank should encourage "*MORE migration* [his capital letters] *of the dirty industries to the LDCs*", i.e. to the "Less Developed Countries". A good reason for doing this would be, he said, that "*The measurement of the costs of health-impairing pollution depends on the foregone earnings from increased morbidity and mortality. From this point of view a given amount of health-impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wages. I think the economic logic behind dumping a load of toxic waste in the lowest-wage country is impeccable and we should face up to that.*" Years later he claimed that the suggestion had merely been a joke and that he hadn't written it himself but had merely subscribed to it. In reality, however, France has adopted the suggestion in regard to the radioactive waste from the nuclear-fission power plants which are providing most of its commodified energy, and that kind of thing is done by well-off people in many countries in regard to various kinds of noxious waste materials.

He also said (in 1973) that "*The troubles of the 20th century are not unlike those of adolescence – rapid growth beyond the ability of organizations to manage, uncontrollable emotion, and a … search for identity. Out of adolescence, however, comes* [**spiritual**] ***maturity**, in which physical growth with all its attendant difficulties comes to an end, but in which growth continues in knowledge, in spirit, in community, and in love; it is to this that we look forward as a human race. This goal, once seen with our eyes, will draw our faltering feet toward it*."

• Nicholas Georgescu-Roegen (1906-94). He had sharp mathematical skills and scolded other economists for their mathematical shortcomings.[17] He is best known for his book, *The **Entropy** Law and the Economic Process* (1971), which describes the history and nature of science more perceptively (it seems to me) than does Thomas Kuhn's more famous book, *The Structure of Scientific Revolutions* (1962; the book which made the term "paradigm" fashionable). Here are two of the many bracing insights to be found in Georgescu-Roegen's book:

1: In a discussion of "**novelty by combination**" (i.e. different things combining and resulting in something new), the fact that the known "laws" of social science have little predictive power is related the fact that the "laws" of chemistry have less predictive power than do those of physics. He said, "*The rules that are now used for predicting the qualities of a substance from its chemical formula are spotty. Moreover, most of them have been established by purely empirical procedures* [rather than by theory] *and, hence, are less likely* [than are the laws of physics] *to carry much weight beyond the cases actually observed. For a chemist the behavior of a newly obtained compound may display* [therefore] *many novelties. Yet, once this chemical compound has been synthesized, the next time the chemist prepares it he will no longer be confronted by another novelty by combination: matter … is uniform. More often than not,* [however,] *this permanence is absent from the organic and superorganic domain*[s] [of reality]*. For a glaring yet simple example: In some human societies, the bride is bought, in others she brings a dowry into the new family, and in still others there is no [such] matrimonial transaction of any sort*."[18]

2: He made good use of Alfred Lotka's distinction (1956) between **endosomatic** and **exosomatic** instruments. (Lotka had founded mathematical biology in the 1920s.) "Endosomatic" means "within (or part of) the biological body"; "exosomatic" means external to it. A bird's lungs, feathers, and wings are endosomatic. Garments, houses, shovels, golf-carts, etc. are exosomatic. A related distinction is between ***(a)*** endosomatic uses of energy (i.e. within the bodies of biological organisms: for instance, the uses of chemical energy (derived from eating and breathing) to maintain a certain temperature in warm-blooded animals, and to make our muscles function) and ***(b)*** exosomatic uses of energy (i.e. by means of tools).

He published in 1972 the following recommendations: "*First, the production of all instruments of war ... should be prohibited.* [He was not an expert in political science.] *… Second, underdeveloped nations must be aided to arrive as quickly as possible at **a good** (**not luxurious**) **life**.... Third, mankind should gradually lower its population to a level that could be adequately fed ... by **organic agriculture**.... Fourth, until either the direct use of **solar energy** becomes a general convenience or controlled* [atomic] *fusion is achieved* [Dream on!]*, all waste of energy – by **overheating, overcooling, overspeeding, overlighting**, etc. – should be carefully avoided.... Fifth, we must cure ourselves of the morbid craving for extravagant gadgetry, splendidly illustrated by such a contradictory item as the golf-cart.... Sixth, we must also **get rid of fashion**.... Manufacturers will then have to **focus on durability**.... Seventh,... durable goods must be made more durable by being designed so as to be repairable.… Eighth, ... we must come to realize that an important prerequisite for a good life is a substantial amount of leisure spent in an intelligent manner."*

In the last paragraph of that essay, a sense of despair as to whether "addiction to exosomatic comfort" could be overcome led him to envisage Humankind as facing a grave predicament and a **doubtful future**: *"Perhaps, the destiny of man is to have a short, but fiery, exciting and extravagant life.... Let other species – the amoebas, for instance – which have no spiritual ambitions, inherit an earth still bathed in plenty of sunshine."*

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17. He was smarter than most of them. At Harvard University, where he had been in the same group of post-graduate students as Paul Samuelson, Paul Sweezy and John Kenneth Galbraith, *he* was the one with whom their top teacher there, Joseph Schumpeter, wished to collaborate. (But he went his own way.)

18. A bride and groom are, of course, a combination likely to produce a (human) novelty.

He pleaded for conservation, because "*With conservation we gain time, and in gaining time we make it more probable for* ***a*** [**new**] ***Prometheus*** *to arrive – if it is to arrive.*[19] *We don't know what is to come next*."

• Herman Daly (*b*.1938). He was for six years the "Senior Economist" in the "Environment Department" of the World Bank[20] – savvy about economic theory *and* about how political insiders in the USA think. He has been great at using, with ecological-economic insight, various concepts basic to neoclassical market-economics. Here are four examples:

(1, from 1977:) *"**The economy** is **a wholly owned subsidiary of the environment**, not the reverse."*

(2, from 1971:) *"**Can't Get Enough of that Wonderful Stuff**. The American people have been told by ... the President's Council of Economic Advisors that, 'If it is agreed that economic output is a good thing, it follows by definition that there is not enough of it.' ...Has the learned council forgotten about **diminishing marginal benefit** and **increasing marginal costs**?*[21] *...Growth in GNP should cease when decreasing marginal benefits become equal to increasing marginal costs. But there is* [in our "science" of market-economics] *no statistical series that attempts to measure the cost of GNP. This is growth mania, literally not counting the costs of growth. But the situation is even worse. We take the real costs of increasing GNP, as measured by the defensive expenditures incurred to protect ourselves from the unwanted side-effects, and* [we] *add these expenditures to GNP…. We* [GNP-oriented economists] *count real costs as benefits."*

(3, from 1994, in his farewell talk to the World Bank:) *"We* [in the government] *have to raise public revenue somehow, and the present system is highly distortionary in that by taxing labor and income in the face of high unemployment in nearly all countries, we are discouraging exactly what we want more of* [i.e. employment]. *The present signal to firms is to shed labor…. It would be better to **economize on throughput** because of the high external costs of its associated depletion* [of natural resources] *and pollution, and at the same time to use more labor because of the high social benefits associated with reducing unemployment.... The shift could be carried out gradually by a preannounced schedule to minimize disruption. This shift should be a key part of structural adjustment, but should be pioneered in the North. Indeed, sustainable development itself must be achieved in the North first. It is absurd to expect any sacrifice for sustainability in the South if similar measures have not first been taken in the North. The major weakness in the World Bank's ability to foster environmentally sustainable development is that it* [has] *only had leverage over the South.... Some way must be found to **push the North** also."*[20]

(4; from 2004, with Joshua Farley, in a textbook:) *"Should we tax energy and raise its price for the sake of inducing more efficient use* [of it], *or should we subsidize energy and lower its price to help the poor?* [The key is that] *one* [political] *instrument (price of energy) cannot serve two independent goals (increase efficiency, reduce poverty). We need a second instrument, say, an income policy. Then we can **tax energy for the sake of efficiency** and **distribute income** (perhaps from the tax proceeds) **to the poor for the sake of alleviating poverty**."*

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19. According to an ancient Greek myth, a titan named Prometheus stole fire from the gods on Mount Olympus and gave it to Humankind. Modern industry has been fuelled mainly by fossil fuels; a "new Prometheus" would bestow on us some other vast source of consumable energy.

20. During his stint at the World Bank, Daly and two other first-rate academic experts, Robert Goodland and Salah El Serafy, put together a volume of well-informed essays for the Bank to publish. They were hoping to "infect the World Bank's bloodstream" with environmentally savvy thinking. But "the Bank's protective white corpuscles went into action and prevented its publication [at that time] by the Bank, even though we had taken care to get protective contributions from two Nobel Laureate economists ([Jan] Tinbergen and [Trygve] Haavelmo) and a laudatory foreword by two environmental ministers from important member countries [of the Bank] (José Lutzenberger of Brazil and Emil Salim of Indonesia). In the Bank it was killed at the 'Working Paper' stage" whereby the "views and interpretations" were "not to be attributed to the World Bank". The editors got it published elsewhere as *Population, Technology, and Lifestyle*: *The Transition to Sustainability*.

21. "Marginal benefit" and "marginal cost" are *(a)* the benefit gained from, and *(b)* the cost entailed by, the next bit of consumption or production of a given commodity. The marginal benefit of the first forkful of a dish of spaghetti is greater than that of the last forkful. (This is why some people leave some on their plates.) The marginal cost of a ton of ore brought out from a mine today will be less than the marginal cost of a ton from the same mine next year when the mine is deeper (unless a significantly more efficient way of bringing it out it is meanwhile devised).

• William Rees (*b*.1943) and Mathis Wackernagel (*b*.1962). The concept of "**ecological footprint**" was first set out in 1994 in Wackernagel's Ph.D. thesis written under Rees's guidance. It is a kind of index, for ecological economics, analogous to GNP and per-capita "cost of living" in market economics. It is reckoned in terms of area (different kinds of area) on the surface of the Earth. The "ecological footprint" of a population is defined as the total area of ecologically productive land and water (cropland, pasture, forest, marsh, river, sea, etc.) that would with prevailing technologies be required in order to provide *on a continuous basis* the energy and materials consumed by that population, and to absorb its wastes. A clever aspect of the ecological-footprint index is that for each nation it can be estimated from data that have already been gathered for market economics. For instance, the pasture component of a nation's ecological footprint can be reckoned from the totals of how much money is being spent annually in that country for dairy products and from estimating, for that complex of dairy products, how much pasture (not necessarily in the same country) is needed to produce those goods.

It is also possible to reckon how much ecologically productive surface of various types is available within each nation. The term for this in relation to national ecological footprint is "national available bio-capacity". The ecological footprint minus the available bio-capacity is the "ecological surplus or deficit". And, by dividing each of these three numbers by the number of people living in the nation, one gets corresponding per-capita estimates. Here are some of them in hectares as of the mid-1990s:

	***Ecological footprint*:**	***Available bio-capacity*:**	***Ecological surplus/deficit*:**
Australia	**9.0**	**14.0**	**5.0**
Canada	**7.7**	**9.6**	**1.9**
China[22]	**1.2**	**0.8**	**–0.4**
Germany	**5.3**	**1.9**	**–3.4**
India[22]	**0.8**	**0.5**	**–0.3**
Japan	**4.3**	**0.9**	**–3.4**
USA	**10.3**	**6.7**	**–3.6**
Earth	**2.8**	**2.0**	**–0.8**

Since the reckoning is in terms of two-dimensional surface area, it is inapplicable to aspects of depletion (for instance, of fossil fuels) or pollution (for instance, of air) which call for reckoning in terms of weight or volume. But in spite of this lack of comprehensiveness, and notwithstanding the rough nature of the estimates (though no more rough than some of those, such as for cost of living, that are commonly used in market economics), it summarizes a lot of useful information about national per-capita rates of contributing to environmental degradation.

* * *

Humankind *is* beginning nowadays to experience several kinds of galloping environmental degradation:

- Nonrenewable stocks of "natural capital" (e.g. fossil fuels and economically valuable minerals) getting exhausted.
- Flows (renewable) of "natural capital" (e.g. rivers, forests, populations of edible fish) being used up faster than they renew.
- Unfortunate dislocations of natural substances – e.g. of H_2O (glaciers melting and hence oceans flooding the shores), and of sand (dislocated into concrete, rather than conveying water laterally from rivers to agriculturally vital valleys); and, too much dispersion of strategic metals into landfills.
- Pollution (of the air, water, land, food, etc.).
- Excessively fast climate change.
- Massive extinction of biological species.
- Greater frequency of earthquakes (because of human disturbance of the planetary crust).
- Flourishing of superbacteria and of more virulent viruses (the effects of which on public health are aggravated by our crowding).

22. The ecological deficits for China and India are, of course, much higher now than they were back then.

Please note that **our relation to our material natural heritage** (which economists like to call "natural capital" in the hope that it can be made to expand like monetary capital) is **economic but *not* social**, and thus cannot be properly measured in monetary terms. Prices are subject to psychology, but our economic relation to our material natural heritage is strictly material; the Earth doesn't sign contracts and doesn't give a hoot about our incomes and expenditures and status, any more than it did about the dinosaurs. Since the economy is due to human agency, its academic study has been classified as sociological (we don't, for instance, regard birds' nest-building and beavers' dam-building as part of the economy), and yet every material part of the economy is part of the ecology, i.e. part of the material goings-on here on Earth.

We therefore need, in our 21st-century "full world", a team of economists knowledgeable in physical and chemical terms about the material events and realities which are due to human agency and are external to our bodies, somewhat as scientific doctors are knowledgeable in physical and chemical terms about the material events and realities *inside* our bodies.

Very few of today's economists are fit to help meet this need.

Let me describe briefly what three of the most eminent current professors of ecological economists *have* been doing, and then, finally, say how I think the economics profession could be gradually transformed in a way which I think needs to be done.

• Joan Martinez-Alier (*b*.1939), a professor (in Barcelona) of economics and economic history, is a leading figure in an international movement advocating, in the West, a period of economic degrowth GNP-wise for the sake of ecological sustainability and social justice. His most notable (to me) publication is an article (2012) entitled "**Environmental Justice** and **Economic Degrowth**: An Alliance between Two Movements". It has section headings like "*Socially Sustainable Economic Degrowth*", "*The Environmentalism of the Poor*", "*Against Cheap Exports and in Favor of Renewable Energy and Local People*", "*Controversies on Climate Justice*", and "*Peak Population: Love One Another More, and Do Not Multiply*".

• Robert Costanza (*b*.1950) was mentored by Herman Daly, and they were together seminal in founding, in the late 1980s, the International Society for Ecological Economics. Costanza served as its first president and, for twelve years, as the chief editor of its **journal**, ***Ecological Economics*** (free-of-charge via the web if you prefer not to pay). His writings have allegedly been cited in more than 30,000 scientific or academic publications. In 2014 he was appointed Professor of Public Policy at the Australian National University. He is upbeat and he never (as far as I know) scolds or even hints at scolding. His main theoretical interest has been in the concept of **"embodied energy"**, which a current *Dictionary of Energy* defines as "the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service".[23]

• Kozo Mayumi (*b*.1954) is an economics professor in Japan where he studied engineering as well as economics. In the mid-1980s he had studied bio-economics in the USA under Georgescu-Roegen. He is interested in "Multiple-Scale Integrated Assessment of Societal Metabolism" as a tool for analyzing the development of human society in relation to sustainability. He says that such assessment "*builds on the dynamic nature of societal metabolism, which is stabilized by autocatalytic loops operating around attractor points. This approach permits the study of trajectories of development of society.…* [It] *handles, in an integrated way, variables referring to non-equivalent descriptive domains (coming from various scientific disciplines) and data gathered at distinct hierarchical levels (national statistics, sector-specific data, household surveys)*."

A few years ago I was hoping that a few prominent economics professors might study some of the natural sciences relevant to a material understanding of galloping environmental degradation. But now I see that the hope was unrealistic and that the integrated study will have to be done instead by *students* who might later, after the ongoing flow of various kinds of catastrophic environmental events has increased to an undeniably galloping rate, be appointed to professorships of economics. Here is the gist of a proposal

23. The concept is attractive, but also vague because reckoning the extent to which "indirect" requirements should be taken into account is bound to be problematic. Suppose, for instance, a plumber comes and unclogs your sink. In an estimate of the energy "embodied" in that service, how much of the energy that was consumed to manufacture the lorry in which he drives to your home should be included, given that he can't unclog the sink without first coming there?

for “An Innovative Ph.D. Program in Ecological Economics” which I sent in 2015 to the Vice-Chancellor of the University of Hyderabad (where I was at that time the “University Chair Professor” in the School of Economics). It wasn’t implemented there, but maybe it will be in 2020 at the MGM University in Aurangabad:

“*Economists envisage two kinds of ways of assessing natural capital, but they themselves can apply only one of them. The two are called ‘weak sustainability-assessment’ and ‘strong sustainability-assessment’. The terms are inept, but the distinction is insightful. Market economists can do the ‘weak’ kind, but the ‘strong’ kind can be done only by people who have studied chemistry and this or that science making use of it, such as mineralogy, geology, biology, epidemiology, etc.*

“The ‘weak’ assessments, whereby monetary values are attributed to ‘natural capital’, can be used for settling lawsuits and in some other applications of the ‘polluter pays’ concept. (Some first-rate economists have actually made a ‘weak’ assessment of all the trees in India by calculating – this was the main factor in their assessment – how much money the lumber from all of them would fetch at current prices per kilogram. The assessment ignores the fact that in order to sell them for lumber you would have to kill them and then they wouldn’t be providing fruit or shade, performing photosynthesis, etc. Every ‘weak’ assessment of ‘natural capital’ has some such defect.) ‘Strong’ assessments, i.e. of the actual material realities (such as: how many trees of this and that kind, their ecological and economic functions, locations, conditions, vulnerabilities, etc., and whether this or that kind of tree can be substituted for by this or that other kind), are needed in order to decide what should (ideally) and can or cannot be done about such material problems as are already beginning, historically, to render ecological economics important.

“A university with a certain set of strengths and interests could teach post-graduate students who have already studied chemistry how to make various ‘strong’ assessments. A program leading to a Ph.D. in ecological economics would have to include instruction in neoclassical economics, which I reckon could be done adequately in weekly lectures in one academic year. (The revised edition of Herman Daly’s and Joshua Farley’s Ecological Economics: Principles and Applications *is a recent textbook which is well suited this kind of use and which has fewer chapters than there are weeks in the academic year.) The thesis project would include an exercise in ‘strong’ assessment, and would have two sponsors: a scientist and an economist.*

“*Neither insurable risks nor abject uncertainties are going to prevail in 21st-century ecological economics. So, the instruction at the master’s-degree level should cover how to reckon conditional probabilities.*”