THE CONTRADICTIONS OF PROGRESS: REFLECTIONS ON THE HISTORY OF SCIENCE AND THE DISCOURSE OF DEVELOPMENT*

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INTRODUCTION

Fifteen years ago, historians of science and technology were asked to consider a remarkable proposition. While generations of scholars had canvassed the scientific and industrial transformations of early modern Europe, and many had charted European overseas encounters since the age of Columbus and Magellan, few had attempted to explain the processes of transmission, diffusion, and absorption by which Western science and technology had spread from Europe to the rest of the world.[1] This was all the more surprising given the importance, particularly in what constituted the sub-tropical world of former European colonies and informal empires, that scholars and governments have accorded science and technology as routes to material development, and as agencies for reducing the 'gap' between the scientific, industrial world and regions less developed, industrially backward, and poor.[2]

Today, a growing literature deals with the history of Western expansion and its attendant consequences. However, in certain respects, this history has been pursued in three complementary but rarely affiliated discourses, along parallel and rarely intersecting paths. For political, social and imperial historians, this development has revolved around motives, methods, and means that prompted, accompanied and survived the 'Expansion of Europe' into the non-Western world. For historians of science and technology, the process has emphasised certain 'tools of empire', traditions of frontier inventiveness, and the transfer of cultural institutions. For economic historians, the same process has been seen as functional to an evolving world system of commerce and trade, with a range of associated opportunities and dependencies. To bring these three worldviews into thematic convergence may be viewed as one of the most important tasks awaiting 'development studies' today.[3]

To make a case is easy; but it is less easy to make it popular. Even where historians agree on pressing priorities, epistemological positions inevitably influence interpretative preferences. Over thirty years ago,

* This paper forms part of a contribution to the work of the International Council for Science Policy Studies. I am grateful for the valuable comments of Dr Jan Annerstedt and for the assistance of Mrs Elizabeth Short.

Michel Foucault distinguished between two principal historiographical traditions.[4] General history, as he perceived it, traditionally found its rationale in the association of periods, places and themes, in patterns of ideas, individuals and institutions, and in the unfolding of peoples, nations and world systems.[5] In this respect, the historian's proper work lies in revealing continuities, charting lineages, and showing relationships between domains and structures. This perspective Foucault contrasted with that of the history of science, which stressed the importance less of continuity and stability, and more of radical change — epistemic 'ruptures' and paradigm shifts.[6] The growth of scientific ideas inspires the language of revolutions and cognitive transformations, universal in their implication. For their part, historians of technology, for all their differences, have been similarly absorbed by the adventitious history of novelty, innovation, and success, 'bigness', and change.[7] Such generalisations, of course, fare unevenly in practice: political, religious, and economic histories have revolutionary episodes; and the history of science repeatedly announces intellectual orthodoxies that are stable, conservative, and continuous. But the point remains: a distance has separated the writing of history of Europe's expansion from the historiography of Western science and technology.

These traditional distances readily expose certain 'contradictions of progress' that have been implicit in both liberal and Marxist historiographies, and in the assumptions of development. The successful transmission of scientific ideas and institutions has conferred legitimacy on the belief that the path to successful development lies through imitation of the West, principally through industrialisation, a process which depends upon identifying and eliminating obstacles to the Western scientific *mentalité*. However, we know that the history of Western science is deeply imbricated in Western culture, and reflects traditions deriving from particular views of Man's place in Nature.[8] To assume that the value-system of Western science is above criticism is flawed in principle, and difficult in practice.[9] The transmission of Western technologies to the non-Western world has frequently imposed irrevocable and lasting damage on 'pre-contact' cultures and environments. What applies to the cultural response of Islam can be applied equally to the exotic cultures of Oceania, where contact with the West all too often proved 'fatal'.[10] Can we construct an historiography of development that survives the disenchantment of the modern world?

THE WORLD OF EUROPE OVERSEAS: PROMETHEUS UNBOUND

In certain respects, the history of European expansion and Western science share a common past. Until recently, both were written largely by Westerners, or by the Western-educated, writing from Western points of view. European historians stressed the projection of institutions,

strategies, and ambitions. Equally, the history of Western science reflected a governing, and at the same time, limiting, Eurocentrism. This depicted modern science as a trajectory of Western progress, its guiding genius inspired by the Hellenistic heritage, sustained by the wealth of Mediterranean civilisation, thence codified by the schoolmen of the Middle Ages, refreshed by the Renaissance, and transformed by the scientific revolution of the 17th century.[11]

Along the way, according to the received view, science was emancipated from its legacy of magic, mysticism, and folk belief, and gradually united with experiment and mechanism until, by the end of the 19th century, it was combined first with craft-based, then science-based technology. Its application was celebrated by industry, and supported by governments which, by the end of the Second World War, acquired through science the means of disposing dominion over nature and mankind. This story, in more or less general form, powerfully contrasted the unique development of the West with the barbarism and retarded development of the rest. Its success was underlined by a history of conquest. In modern dress, it created a play of two industrial worlds, and a Third World of backwardness.[12]

The last fifteen years have brought many alterations to this oversimplified picture. On the one hand, we are no longer confident in applying easy categories of 'developed' and 'underdeveloped' to differing places. The economies of post-communist Eastern Europe, the 'tigers' of South East Asia, the ancient cultures of India and China, and the impoverished majorities of sub-Saharan Africa share few analytical similarities, while the 'development' histories of North Asia and South America have little in common. Attempts at theoretical unity attempting to draw lessons from the West for the modernisation of newly decolonised nations, gave way before the 'dependency theorists' of the 1960s and 1970s, who reasoned that Western economic history might well be irrelevant to the rest of the world.[13] Since then, theories of 'self-sufficiency', once a universal panacea, have been replaced by rational management plans for 'sustainable development'. In the year of Columbus and the summit at Rio, there is talk of 'green imperialism', and a newer history that reads European discovery as invasion. Certainly there remains a legacy of dependency upon Western tools and capital; whether this can ever be altered without revolutionary change in capitalist society remains an untested proposition.

While economic historians ponder the present, historians of science are looking afresh at the world of 'Europe overseas' that has become post-colonial within our lifetime. Their new knowledge has materially shaped the way in which many now view their discipline. Science has featured as an agent of European colonialism, and as a residual feature of post-colonial nation-states, but it remains to be seen how far we can discriminate between the 'surface effects' of institutional transfer, and what may be deeper, organic requirements for scientific creativity and technological innovation. In this respect, historical scholarship on China,

South Asia, and the Middle East holds great, if unrealised potential. Needham's magisterial work[14] and a growing corpus of scholarship on India,[15] commands attention for the long history of innovation and enterprise that preceded, and survived, occidental contact. Similarly, the contributions of Arabic and Persian culture to natural knowledge are increasingly well documented.[16] Yet, this knowledge has not greatly altered received opinion about the importance of modern science and technology, nor has it greatly qualified the near-universal acceptance of Western technological development. The ideologies of Western science and technology remain triumphant, not least in the Persian Gulf. Baconian knowledge manifestly 'works'; and where it apparently fails, the fault is too easily attributed to the opposition of the ill-educated, uninformed, or obstinate.

For this reason, it has been fairly easy for historians of science and European expansion to work with a generalised concept of a superior 'core culture',[17] radiating its influence from 'epicentres' of Western intellectual, inventive and entrepreneurial talent. The notion of a stable 'metropolitan' Europe of capitals and courts, extending first from the Mediterranean world to the Atlantic,[18] thence to a discontinuous 'periphery' of unknown peoples and uncharted regions, afforded a convenient framework for explaining Western expansion beyond the boundaries of continental Europe, thence beyond the New World of the Americas, into Asia, Africa and the Pacific.[19] In canvassing causes, the influences of commerce, religion and politics remain pivotal. Europe,it is said, was 'pulled by the magnetic force of the periphery'.[20] Certainly, from Marco Polo onwards, European encounters with the non-Western world brought tales of wonder, curiosity, and reverence for civilisations more ancient than those of Rome or Byzantium. From exotic cultures east of the Urals and south of the Hindu Kush there was much to learn, and much to gain, by study and trade.[21]

Following the fall of Christian Constantinople to the Ottomans in 1453, forcing European traders to seek sea routes to the spices and silks of Asia and the Indies, challenges arose to enterprise and innovation. The voyages of Vasco da Gama and his successors gave Europe a mighty 'swing to the East'.[22] With the Treaties of Tordesillas and Zaragoza, Spain and Portugal divided the world. Columbus and Magellan claimed for the metropolis sovereign possession of vast lands, unknown oceans, exotic islands, and native souls, with enormous consequences for the destiny of mankind.[23] For the next three centuries, reflecting the mixed ambitions of commerce, strategy and national prestige, the Netherlands, France, England, and finally Germany followed their example, creating what became the capitalist world economy.[24]

Against this trajectory of political and economic ambition appeared another, less well charted history of scientific and technological engagement. The material culture of the East fascinated Europe. Fabled India and China captured an interest which those civilisations in turn valued lightly, and reciprocated rarely. The Middle East, the Ottoman

empire, Persia, and Islam excited deep curiosity, but different passions. Perhaps memories of occupation were too close;[25] perhaps Arab contributions to Western learning, already so deeply assimilated in Renaissance scholarship, were difficult to distinguish.[26] Certainly, despite historians' efforts,[27] the vast realm of Islamic natural philosophy remained under-represented in the West until recent times.[28]

Where they travelled to the East, early European explorers left few references to the virtues of their own weapons, tools or techniques. Equally, few could well appreciate the industrial arts and sciences of the East, or the methods of manufacturing porcelains, chemicals or fabrics. Christianity, rather than technology, was the message borne on their flags and swords. But in one decisive technology, Europeans held an edge over the East — in the shape of the long-haul, square-rigged, deep draft, armed merchantmen, evolving steadily from the galleons of Hapsburg Spain, to the caravels of Portugal.[29] These were the 'black ships' that landed off Nagasaki, and first brought Japan consciousness of the West.[30]

At first, the scientific revolution culminating in Europe during the 17th century failed to challenge the balance of opposites — between East and West, capitalism and feudalism, religion and politics.[31] In time, however, a Baconian vision of an 'empire of nature', accessible to Everyman, overwhelmed the traditional knowledge of the Renaissance *magi*.[32] When joined to the Cartesian imperative to objectify, and thus understand nature, the Baconian imperative to subdue nature, to order and control, comprised a manifesto that appealed to intellectual colonisation.[33] That appeal, to compute and complete the natural compass of the world, took Europeans round the Horn, and past the Cape of Good Hope.

For over a century, Western armed transport expanded Europe's horizons overseas, while their maps and charts recorded opportunities for trade and settlement. By the 18th century, the Spanish had posted the coastlines of South America, while the French and the English competed for the islands of the Caribbean and the Pacific.[34] Before Bougainville and Cook, and well after, naval expeditions returned from Pacific archipelagos with pen sketches of the 'natural man' of Oceania, 'primitive' exemplars of natural virtues long lost to sophisticated Europe. For the *philosophes* of the Enlightenment, the Pacific became a symbol of Paradise. If, by contrast, Africa and the Caribbean held less attraction for the European mind, they were commended more to European trade, and to businessmen in the practical world of cocoa, sugar, teak, and slaves.[35]

Historians record that, from about the 1760s, came a shift in European attitudes towards the non-Western world, driven by the accumulating wealth of the agricultural and industrial revolutions, and foreshadowing systematic overseas investment and strategic control.[36] Where once the material culture and antiquity of the non-Western world had evoked wonder and praise, now science and technology, instruments of

enterprise and statecraft, became symbols of superiority, key elements in the 'idea of progress' and the 'civilising mission' of Europe.[37] Baconian applications of knowledge through technology became fundamental 'measures of human worth and potential' and, as such the justification for European hegemony.[38] Even where science was revered as a quest for transcendent, universal truth, that quest, and that truth, were taught as a European prerogative, mediated through Christianity, and manifested in the mechanical world view. With Western science and technology as a 'gauge' of abilities, came a hierarchial view of race and culture, and self-fulfilling rationale that placed Europeans on top. The instruments of Western culture would, apparently, explain the realities of the universe more convincingly than the philosophies of any other people or society, of any other race or time.

Given this perspective, by the middle of the 19th century, Western science and technology had come to underwrite an imperialist ideology, reflecting belief in an innate cultural superiority, and claiming the right to rule by virtue of its superior grasp of natural knowledge. Science and technology afforded 'tools of empire'; quinine and gunboats enabled penetration, conquest, and ultimately, colonial consolidation.[39] In Asia, India, Africa, Australasia, and South America, historians trace the results, whether in terms of formal occupation, plantation, and settlement, or in continuing, informal commercial influence.[40] Envelopment was pushed by the financial centres of London and the Netherlands, and spurred by European strategic and diplomatic rivalries.[41] For indigenous peoples, articles of Western supremacy and their companion texts produced wealth unevenly derived and unequally distributed.[42] Western technologies, governed by mercantilist capitalism and free enterprise, invoked mastery, secured control,[43] and made autonomy subject to the 'civilising mission'.

For five centuries, Western influence grew and triumphed. How has history explained the fact? Three concepts are central to understanding how science and technology helped shape and direct that influence. These are optimism, order, and the appeal of universal rationality, combined in the applications of 'useful' knowledge. Europe's early voyages of discovery and exploration were adventures framed by promise. Sixteenth-century Europe entered the world in a sustained burst of optimism, a keen willingness to surmount the risks and dangers of profitable trade. By 1620, that optimism, with all its attendant risks and gains, was codified in the spirit of Francis Bacon's *Novum Organum.* Voyaging beyond the legendary 'Pillars of Hercules', whose image was reproduced on the title page of Bacon's *Great Instauration*, first Iberia, then the Low Countries, France and England carved enclaves in the Americas, and made their way to Africa and the East Indies. With contact, came experience of new-found natural and human artifacts. Some were of economic value, others, not.[44] But all enlarged Europe's command over nature's diversity. In a spirit of systematic enquiry, epitomised by Linnaeus and Humboldt, came a thirst for more complete

knowledge of the world's surface and skies, its inhabitants and their material culture.[45] To reduce diversity to universal order, to create systems of understanding, became the goal of knowledge. Through the application of systems, came order and, with order, control.

From the mid-18th century, Europeans overseas collected, counted, mapped and named plants, animals, places and peoples. Voyages of discovery informed European debates, filled out European 'centres of calculation' in Paris and London,[46] rivalling one another in prestige and influence. From natural order followed economic ownership and economic competition. By the third quarter of the 19th century, Europe had imbued the world with a universal rationality based on technology, and employing the three *carrefour* technologies of Europe — steam power, the railway, and the telegraph.[47] By the end of the century, these means and methods had united the tropics and the poles, and extended its missionary regime to the Pacific. In the process, native populations were tolerated, accommodated, or displaced. Theories of racial superiority, legitimised by Christianity and social Darwinism, reinforced social barriers, and taught that primitive customs, like 'primitive' peoples, would ultimately wither away.[48] What few benefits science could offer them were limited by the interests of rule.

Meanwhile, from the late-18th century, beginning in the American colonies of Spain and England, and continuing in India, South Africa, and Australasia, a new form of 'engagement' began to appear. The cardinal elements of European systematic discovery, informing a 'scientific imperialism' directed from the metropolis, gradually found their counterpart in an unfolding history of 'colonial science', mediated from the periphery. For two hundred years, metropolitan institutions had projected European theories onto the world, requisitioning in return objects, animals and plants for European museums, zoos and gardens.[49] With European settlement and colonisation, came the mimetic culture of European science. Academies, mining schools and hospitals reflected 'memorised' cultures, carried from Europe, and shaped by colonial hardship, isolation and distance.[50] By the end of the 19th century, and the new age of imperialism, many colonies had acquired universities, museums, observatories and laboratories. In several there were the beginnings of new 'scientific communities', with distinct features of their own.[51]

At first, the features of this 'colonial science' were distinctly imperial, fashioned by influences Dutch, French, Spanish, Portuguese or British, according to case. But in North and South America, Australasia, and South Africa, colonial nationalism soon enlisted science in shaping colonial identity. Sending settlers to mission stations in Alta California, for example, the Spanish in 1790 listed several ethnic categories. *Españols,* born Spaniards, were distinguished as such from *europeos,* born in Mexico. In the southern hemisphere, where British science had proved midwife to the 'invention of Australia,' the equivalent of 'europeos' were 'transplanted Britons'. This concept implied the

movement of European baggage and the assumptions of a metropolitan order; but it also identified Europe as fashioning and controlling its new world overseas. From Vancouver to Van Diemen's Land, and from Cairo to Capetown, 'attenuated Europeans' began to create a synthesis between the local and cosmopolitan.

For generations, their intellectual models remained European, their education, European, and their lives shaped by the architecture they imported from overseas. From the late-18th century in the new United States, however, and by the late-19th century in Canada, Australasia and South America, their position began to change, and with changes, came many that are still incomplete. As colonial science matured, so the 'metropolis' moved, importing models, retaining forms, but changing content. If North Americans adopted a British model for their Association for the Advancement of Science in 1846, so Australians sought 'federation' by a similar, intercolonial framework in 1888; Latin American nations, leading Spain, followed suit.[52] Other institutional models were borrowed in name only. 'Royal Societies' in Canada and Australia pledged fealty to their parent body in London, but served different purposes,[53] while colonial universities, if imitating European disciplines and traditions, soon reflected regional needs.[54] The 'periphery' began to boast its own 'centres of calculation' and its own strategies.

If similar patterns obtained in many of the 'settler colonies,' the colonies of 'plantation and conquest' in Africa, the Indian subcontinent, the Far East and the Caribbean fared differently. Here, Europeans established learned societies — the Asiatic Society of Bengal, established in 1784, was one of the earliest in the East — but these remained European creations, for European curiosity. Such societies formed a thin veneer of scientific culture, granting respectability to expatriate Europeans. Sometimes, these fashioned a view of 'high science', particularly in mathematics and astronomy; but in botany, zoology, and anthropology, they frequently commissioned research on local traditions, local sources. The Royal Society of Mauritius loyally reflected its Anglo-French heritage, for example, by publishing in both languages. The empires responded, with practices varying within and between the imperial spheres of Britain, France, Germany and the Netherlands.[55] British institutions favoured the creation of self-regulating colonial offspring; France, which traditionally favoured specialist expeditions, eventually created special agencies for colonial science and medicine,[56] covering by the mantle of metropolitan science her most distant possessions. Germany and the Netherlands sent imperial servants directly to Africa, the Pacific and the East Indies. By the end of the century, the United States, just entering the ranks of imperial powers, was still to find its own solution.

By 1900, European governments, which had long used science and technology as instruments of cultivation and control, found uses for scientific knowledge as agents of management and 'efficiency'.[57]

Doctrines of racial obligation flourished and were summoned to explain the missionary presence of Europe in Africa and Asia.[58] While the economics of imperialism gained celebrity in debates stimulated by J.A Hobson and V. Lenin,[59] the imperial order continued to turn on the careful use of colonies as reservoirs of natural resources and markets for manufactured goods. Colonial 'development' meant ways of improving the return on capital investment.[60]

In the meantime, Western scholars became custodians of 'backward cultures', reducing religious belief and human artifact to index categories in the museums and archives of Europe.[61] There, Confucian, Buddhist and Islamic traditions were studied, absorbed, or filed away by the educated West; while in Africa and the Pacific, evolutionary anthropology and social Darwinism relegated the rich totemic systems of Micronesia, Polynesia, and the Pacific Northwest to the library shelves of 'primitive belief'.[62] In the act of preserving non-Western cultures, it is argued, Europe conveniently rendered them irrelevant to rule. Such a fate awaited the ancient hydraulic civilisations of the Indus, Mesopotamia and China, their supreme achievements reduced to mechanical illustrations of 'failure' to progress, the unquestioned product of dogmatic theocracy and oriental despotism.[63]

From the late 19th century, expressions of cultural resistance were evident throughout the colonial world, of which the Boxer Rebellion was among the better known. But it was the experience of the First World War that severely exposed Europe to the consequences of relying upon colonial resources and routes of trade. Until 1914, Britain maintained by far the largest economic network in the world, based on her empire. Although colonial trade was never as large as her trade with North America and Europe, the empire enabled Britain to 'evade' competition from rising industrial Germany and the United States, arguably contributing to her weakened manufacturing position in the decades ahead.[64] The 'imperialism of free trade', in which the transmission of science and technology played a central role, involved costs to the giver, as well as to the recipient.[65] The First World War temporarily masked tensions between the demands of international competition and protected markets; but afterwards, as economic depression ensued, the imperial system neared collapse. By the close of the Second World War, no colonial power in Western Europe, except Britain, was capable of defending an empire either on economic or strategic grounds; and even the British case could not long reserve judgement. The Leviathans of the United States and the Soviet Union, the new 'key centres',[66] saw science and technology, which the war had raised to an exponent of power, as the hallmark of superpower status. A similar vision encouraged post-war optimism that in science — and perhaps only science — lay the world's best hope for peace, even if in peaceful competition. All nations would be served by diffusing science, and by investing in scientific and economic development.

In this way, by the early 1950s, the interests of historians of science, imperial historians, and strategists of development, had reason to converge.[67] Perhaps no two events foreshadowed that convergence better than the contemporaneous creation of the United Nations (together with the FAO, WHO and UNESCO, its specialist agencies for science applied to development), and the Royal Society's Empire Scientific Conference of 1946.[68] If science and technology were to play a commanding role in UN development, so, too, the British Commonwealth promised that the benefits of science and technology would flow to that vast spectrum of under-developed nations which, from India to Jamaica, shared the heritage of Empire.

DECOLONISATION AND DEVELOPMENT: 'METROPOLIS AND PERIPHERY'

By the 1960s, the history of Western imperial expansion, and the history of scientific and technological engagement, had proceeded in counterpoint for two hundred years. With what Harold Macmillan called the 'winds of change' impelling the decolonisation of the empires of France, Belgium, Britain and Portugal, talk was no longer of imperial development, but of 'modernisation' among the 'new nations' of the post-colonial world, particularly in Africa.[69]

The modernisation of these new nations was to occur through industrialisation, and by means of the development of new national scientific communities, educated at the 'centre'.[70] Historical cases were sought to show how 'take off' might occur. Some followed later economic fashion in contemplating Japan; others took up India, Africa, and South America, in asking how industrialisation had met success in some contexts, delays in others, and denial in most. Such enquiries produced findings which, in retrospect, were not revolutionary. It could be generally agreed that colonialism had hindered the advancement of colonial peoples, 'setting in motion a process of underdevelopment that political independence [did] not necessarily terminate.'[71]

In orchestrating the transfer of technology and science, strategists of development drew deeply upon the language of science. Thus, physics was appropriated for 'transmission' and 'irradiation', chemistry, for 'diffusion', and biology for 'transplantation'. With this discursive formation, in Foucault's phrase, came a formalised language of metaphorical 'rims' and spokes, of hubs and wheels, all entailing a Eurocentric model, in which the world revolved around the post-Renaissance West, and drew its inspiration from liberal Western democracies. 'Core cultures' were no longer the ancient civilisations of the Fertile Crescent, let alone the drift valleys of East Africa, but universities, research institutes and multinational corporations, or the modern cities of London, Paris and New York — or, more problematically, Los Angeles. Symmetry might have argued (but, given Cold War tendencies, did not) for similar 'cores' in Moscow and Peking.

Just as political ideology helped shape the economics of development, so it shaped the sociology of science. Latin American scholars were notably critical of this oversimplified vision of development, and stressed the difficulties inherent in absorbing what the West could offer. Industrialisation through technology transfer and the building of local scientific infrastructure was likely to depend upon the resolution of cultural questions far more complex than economists had imagined. The continuing economic and political dependence of Latin America upon its northern neighbour were sharply paralleled by the position in which Latin American scientists found themselves. Political turmoil, autocratic ministries, and universities closed for months made for uneasy participation in the 'republic of letters'.[72]

During the late 1960s and early 1970s, three historians of science -- Derek de Solla Price, Abdur Rahman and George Basalla -- helped to crystallise thinking about the history of science in the process of development. Price, with personal experience of teaching in the post-colonial Third World, was interested in means by which ancient culture and 'new' nations could advantageously appropriate Western science and technology, and benefit from membership in the international scientific community.[73] Rahman, consistently concerned with the plight of scientists in the Third World, took inspiration from Needham, and began to create an archaeology of Indian knowledge systems.[74] Through such work lay one path to cultural self-confidence, ideally preserving the organic continuities of intellectual tradition against the discontinuities of Western science.[75]

The work of Price and Rahman rotated pivotally through the dimensions of dependency and domination, and the history of the diffusion of Western scientific culture. In the political climate of the 1960s, such issues became the subtext of dissent.[76] Among historians of science, however, the politics of dependency and underdevelopment were less prominent than the pragmatics of diffusion. In 1967, an influential article by George Basalla, published in *Science,* set out not to criticise Western science, but to see how it had been transmitted, or resisted, and implicitly to match its transmission with the history of national development. Basalla proposed a three-phase, evolutionary model to describe the trajectory of Western science as it travelled to the non-Western world. During the first phase, a typical 'non-scientific' society — whether China, India, Australasia or pre-Columbian America — provided the West with what Foucault might have called the 'positives' of science, the new objective evidence of nature in diversity. Classification and codification would follow, along patterns familiar to students of imperial expansion. Next would emerge what Basalla called a 'colonial' or dependent science, an enterprise that is small, lacking independent vision or finance, and existing principally to supply the metropolis with facts and field workers. Given appropriate circumstances, the development of a local scientific community could be accelerated, as in the United States, or retarded, as in Latin America. Ultimately, however, a sense of nationalism, or at least national purpose, comes to pervade the colonial community; national institutions are

created, and a third phase, of 'independent' science, ensues. In this, a phase of maturity in the political economy of science, a country's scientists are trained and rewarded by their own leadership, and recognised as 'national-members' of the international scientific community. To achieve this scientific maturity, a country, according to Basalla, must overcome traditional, cultural and religious resistances to the Western scientific enterprise; it must accord prestige to its scientists, and establish appropriate organisations for their self-regulating conduct. Latterly, a 'proper technological base must be created' to transform their ideas into a form of — presumably beneficial — material culture.

Basalla's model harmonised well with theories of modernisation. It usefully summarised what many development theorists believed, and offered to legitimise, by the use of history, optimistic outcomes that linear development models had promised. In its catholicity, it underwrote the popular 'take off' theory of economic development associated with such leading neo-classical economists as W.W. Rostow; and, if it failed to treat the dynamics of under-development, it offered an apparently 'scientific' alternative to Marxism (if at the cost of substituting an unself-conscious Hegelianism of its own). It did not escape notice that, while apparently intended for new countries with nascent scientific traditions, the model seemed to 'fit' particularly well the historical experience of the USA, Japan and the USSR.[77]

Within the last ten years, historians have come to view the model as problematic.[78] Australians have been among the most sustained critics; but these are now joined by scholars from Canada, Mexico, and Ireland, and few today would take the model as a literal description.[79] It assumes that science is everywhere 'value-neutral', and so understates the significance of intellectual hegemonies; it neglects the cultural significance of traditional knowledge, and avoids mention of critical, if at times 'anti-scientific', traditions of dissent. In positing a linear sequence of events, it falls prey to a species of determinism, apparently blind to the cultural, historical and economic context of the process of diffusion itself. It lacks a geopolitical dimension, and ignores the dynamics of 'absorption'. It limits itself to Western thought, and neglects traditional knowledge, or sources of local creativity in craft, technology or design. It 'abstracts' science from both primary and secondary industry, and ignores the factors on which a technological base depends. By its illustrations, it appears intended for non-Western developing countries; yet, especially in India and Asia, it has been repeatedly falsified. At worst, it reflects what might be called a 'sonambulist historicism', dangerous insofar as its assumptions remain unexamined.[80]

Nonetheless, the model remains highly resilient. Like any good Popperian theory, it still prompts attempts at falsification. It has called into existence a burgeoning historiography of 'colonial science', prompting historians from Argentina, Brazil and India to test its local validity.[81] It was, moreover, among the earliest attempts to hint at the

differences between metropolitan agents wearing the uniform of European cultures. To 'functionaries' from France and 'seekers' from Germany, can now be added 'educators' and curators from Britain and Holland.[82] Moreover, Basalla's scheme challenged scholars to view the processes of scientific diffusion less as a problem in Newtonian mechanics, and more as a product of environmental history, organically problematic and diverse. Ironically, the model's impact owed more to what it omitted, than to what it proposed. By indicating how the pursuit and reward of science had been manipulated from the 'centre', it cast light upon the role played by scientific institutions in the history of colonisation and decolonisation.[83] It was not, perhaps, Basalla's intention to show the 'patriot philosophers' of Philadelphia in 1776 as political incendiaries, but 'revolutionary' colonial science now seems as American as apple pie.[84] Nehru's vision of an independent science for an independent India, and national science in other 'dependent' contexts, can now refer to a long line of creditable precedents.[85]

Likewise, the Basalla model emphasised, if largely by omission, the vital role of locality and local variation in the production of knowledge. Colonial science, with its infrastructure of museums and education and its own mechanisms of reward, was not necessarily a 'passage' on the way somewhere else. Indeed, as Lafuente and Sala have shown, in the Spanish colonies an important form of professional and intellectual integrity developed historically at and within the periphery, in ways which were not dependent on the metropolis. In any case, the idea of achieving scientific 'independence', as a precondition of a 'mature nation', is as facile as the notion of seeking to be an independent economy in a global, highly interdependent economic order. Science is not a surrogate for sovereignty. Instead, it may be a currency of control.

Finally, Basalla's model reasserted the importance of movement and exchange. Experience now suggests this exchange is not uni-directional, but reciprocal, and is not confined to the 'age of discovery'. History shows how empires repeatedly 'strike back' in making or breaking European reputations. What is 'local' in biological diversity is often of cosmopolitan importance. Thus, Australasia and the Andes, the Amazon and Antarctica become international 'research sites' and data reservoirs not only for Europe and North America, but for the 'moving metropolea' of former colonies.[86] Basalla's model, by forcing its critics to take up their pens, focussed attention on the 'dialectical encounter' between knowledge systems and Western science, and the environmental impacts of this encounter.[87] From Australia, Papua New Guinea, and the Pacific, to Africa and the Americans, indigenous belief systems are cultivated as much for their environmental empathy, as for their botanical cures.

Since the 1970s, and the deepening pessimism associated with the 'discovery' of 'underdevelopment',[88] some attempt at 'greening' the Basalla model has seemed necessary. Historians have proved impatient with theories of 'intermediate' and 'appropriate' technology.[89] Sagasti

has suggested that 'reinterpreting the concept' of development will require an alternative framework, differentiating between conditions for scientific creativity, the creation of a technological base, and the engineering of a productive system, by the investment of surplusses rather than their remission overseas.[90] These pre-requisites for development lie within the programme of Basalla's critics. With their work has come the vision of a 'third civilisation', outside the parameters determined by Western science, within which the achievements of modern science can be integrated in a harmonious fashion with the cultural heritage of non-Western societies.'[91]

In the passage of years since Basalla's model seemed appropriate, we have learned three lessons. First, knowledge of the conditions in which science emerged in advanced Western societies is of limited value in suggesting how either a post-colonial country or an ancient culture can begin its own local transformation. Second, where such a transformation is sought, and where Western values confront sophisticated indigenous cultures, science and technology may uproot or discard them, deny their relevance, and create in their place an alien, discontinuous presence, not infrequently sowing seeds of division, mistrust, and inequality. Third, the history of transmission resonates in certain developing countries with the language of frustration, isolation, marginalisation, low self-esteem, 'crippled minds' and 'aborted discovery.'[92] Despite the optimism of 'self-sufficiency' and sustainable development, 'peripherality' may be for some countries a constant, and not a passing, feature of life, If so, it remains one of the deepest dilemmas left by history to the descendants of the Enlightenment.

TECHNOLOGY TRANSFER AND THE ENDS OF EMPIRE

Basalla's model did not deal with the diffusion of technology , which lies at the heart of the development process, and for this reason, his model has had little influence upon historians of technology,[93] who have independently produced many useful case studies of technological diffusion.[94] Nonetheless, there is an important meaning inherent in the model for colonial 'improvisation, adaptation' and delayed innovation.[95] With the British Empire, for example, colonial 'settler societies' were among the most rapid assimilators of new technologies, and the most adaptive advocates of science.[96] Economic relations governing transfers of technology became critical to their history. That circumstances varied appreciably between the 'settler' colonies and the colonies of conquest is not surprising. What is surprising is that the experience of different 'vectors' has been assumed to have been uniform. On the contrary, examples drawn from Australia, Canada, and India are pointing to the widely varying lessons to be learned from local entrepreneurs who sought out technologies — in many cases, American rather than British — that better suited their circumstances. In so doing, they offer important insights into the nature of the 'acculturation' process, and into the selective tendencies by which certain technologies

met rational, economic resistance. Their case studies are throwing light upon long-term shifts in trade, educational and political allegiances.[97]

For most European colonies, most of the time, technology transfers remained linear. In the sub-tropical and tropical regions that comprise most of the developing world, Western civilisation was recognised by its technologies, where the emblematic bulldozer reduced forests, levelled atolls, and mined minerals in the service of metropolitan commercial and strategic interests. Undoubtedly, missionaries, government educators and Western physicians heroically and repeatedly saved native lives. But giving the means to defeat poverty, famine, malaria, and infant mortality by conveying skills to native peoples, and accepting as valid the knowledge that people had to organise their own lives, were not, until very late in the century, part of the imperial transaction.[98] It is true that, in colonies of conquest, the Western presence slowly extended the technological infrastructure — in the form of railways and roads, telegraphs, irrigation, municipal services and public health — available to native populations.[99] But the process was measured in generations; and its outcome remains problematic. However important to Indian commerce, may have been the new discoveries of genetics and bacteriology, tropical medicine was transmitted to India principally to serve British interests.

Did science and technology spur development? Or merely mask its absence? Historians are undecided. The debate returns to the question of reception and absorption, of science certainly but also of general education and practical skills, and to the question of stimulating local creativity, issues absent from the Basalla thesis.[100] If trade in technologies came wrapped in European flags, so colonial educational policies served European ends.[101] Colonial education largely comes to us, like the story of colonial medicine, written by Western historians in Whiggish dress, who view the conquest of ignorance as analogous to the conquest of disease. In Africa, India, and the Pacific, British and French educational policies notably strove to convey knowledge of abstract principles, literature, mathematics and natural history, often with little direct relevance to the life in the region. The result was, at best, to produce able scholars who viewed the metropolis as home; at worst, to marginalise education from regional needs.[102]

Ultimately, what occurred in the reception and diffusion of science, technology, medicine and education turned as often on the administration of wider colonial policies, as on the merits of individual cases. Colonial rule involved complex matters of institutional prestige, authority, and security. Technology transfers required not only motives and means, but also opportunities; and in Africa, India and North Asia, entrepreneurs were constantly at the mercy of political ambiguity, commercial uncertainty and official ambivalence. Descriptively, historians inevitably find such situations — the 'sites' of reception — distorted by contemporary perceptions. By illustration, Headrick points to the fact that in India and Africa, colonial officials routinely imported

European experts to manage European technologies, a process that not only delayed the diffusion of machinery, but also, implicitly, the diffusion of technical skills.[103] This was done in the name of public development, and of private profit. Within the parameters of colonial rule, it made sense. Inevitably, however, the 'transfer of technology was more geographic than cultural' as a result. 'It is not surprising', he adds, 'that Asians and Africans had ambivalent feelings about Western technology. What is more remarkable is that Europeans found it so easy to believe that cultural obstacles prevented Asians and Africans from learning to operate Western machinery.'[104]

Marx had predicted that India would industrialise, and so it would, as would other post-colonial countries, but they would do so without passing through an industrial revolution of the kind Europe experienced. Their experience underlines the paradox that colonies could 'grow' without development, as foreign investment went into physical, not human, capital, and ownership and control of resources, industries and corporate structures remained in overseas hands. In this way, most post-colonial countries of Africa, Asia and the sub-continent were to become 'modern', but poor. As the world knows, however, Japan, with singular success, became both modern and rich. Historians have debated whether, or to what extent, the history of Japan before and since the Meiji Restoration in 1868 affords a 'development model' embracing a form of scientific and industrial revolution.[105] Certainly, Japan offers a 'sparkling and relevant example of relatively discontinuous and successful development in the face of severe factor and other restraints'.[106]

To construe Japan as a 'model', and if so, for whom, depends on what phenomenon is to be explained. Some historians of science and technology prefer the discontinuous 'take off', the dramatic 'revolutionary epic' of the Meiji restoration.[107] Certainly, one can point to the European visit of Prince Ito, who took from London and Glasgow the seeds of industrial culture. However, economic and social historians who dispute a single, dramatic rupture, can point to long-term demographic and economic developments occurring during the late Tokugawa.[108] What we may find is that 'Meiji technology', introduced from the West, induced rapid change, certainly of a discontinuous kind, but that it was the underlying traditions and culture of the country, together with a continuous architecture of political leadership, that transformed Japan into a 'site' of rapid technological change.[109]

Whether economic development through science and technology serves the wider interests of people in 'client' countries, resource-rich but economically poor, remains a leading question. Alvares has argued that Western models are not only inappropriate, but impossible to imitate.[110] If the underdeveloped world is to escape total dependence, it may be necessary to find a theoretical pluralism, and reject the notion of 'advanced' or 'developed' cultures. Perhaps the 'ethnosciences' — certainly local point-sources of creativity — have a key role to play in

drafting alternative development strategies. Alvares' point has been well received in the Pacific and may find adherents elsewhere.[111] Indeed, the developed world may itself need a similar acceptance of alternative pathways, less bounded, less tied to models of economic 'growth', and more responsive to social models in which sustainability has more to offer.

Elsewhere, it has been suggested that non-Western cultures, in their manifest varieties, offer science different eyes with which to behold the world.[112] As we gain purchase on the idea, this perspective may afford an epistemological 'rupture' no less significant than that between the 'two world systems' described by Galileo. Even if this does occur, however, we are well to be reminded of the continuities which underlie all human cultures, and to accept that there is likely to remain a lasting tension — ideally what Kuhn once called an 'essential tension' — between the traditional and the 'modern'. How best that tension can be harnessed to contribute to the Baconian programme — the advancement of knowledge, and the 'relief of man's estate' — remains to be seen.

CONCLUSION: REVIEWING THE BACONIAN LEGACY

On returning from the Dugum Dani tribe in the Baliem Valey of Irian Jaya in the 1960s, Robert Gardener, of Harvard's Center for Anthropological Film Research, noted with mixed feelings that

> By the year 2000, human society promises to vary little from continent to continent. Transportation and communication will link the remotest valley and farthest plateau with centres of technology. . .[and] cultures that developed in response to isolation or hardship will have disappeared.[113]

Gardener's vision foresaw a final victory for the West and for Western science. But his sentiments conveyed a double meaning. Mankind will be united through technology: in the Baconian spirit, 'what can be done, will be done'. But the process of 'development' has costs — in terms both of cultural autonomy, and economic and political independence. In fact, Gardener's prophecy is unlikely to be realised. The last thirty years have seen the 'development process' suffer repeated disappointments. Among historians, there are good reasons to ask 'why?'

We have outlined some of the ways in which historians have considered the expansion of Europe in terms of Western science and technology; and the extent to which the scholarship of development and the history of science and technology have so far failed to find a satisfactory synthesis. There remains ample scope for 'reinterpreting', in Sagasti's phrase, the concept of development as seeking organic resolution between the values of metropolitan science and those of local creativity, between Western instrumentalism and traditional knowledge.[114] On an

optimistic reading of the literature, a new agenda is emerging, suggesting lines that may offer common cause to imperial and economic historians, historians of science and technology, and students of development studies. First, the interpretative enterprise now takes as problematic the 'centre-periphery' model', and enquires instead into the 'brokerage' of European interests by agencies of science.[115] Second, without surrendering a view of Western science as conceptually (and to some extent linguistically) universal, scholarly attention is travelling away from the international, and towards the local. The details of transmission, the economics and politics of control, the arbitrage of ideas and institutions, and the propensity of the environment to determine outcomes, are all receiving closer scrutiny. With better knowledge of factors influencing diffusion across cultural frontiers[116] will come a better understanding of conditions that have biased Western development, endangered indigenous cultures, and limited the beneficial applications of science. Failures to provide adequate sanitation and housing, disease control and famine relief are being seen in local terms, as well as in terms of the inefficiencies of international finance. Third, historians of science are canvassing development in the applied sciences, with an enthusiasm once reserved for the pure sciences.[117] Contrasts in the historical reception of new technologies — railways and arsenals in India and Japan are classic cases — are being cultivated for insights into ways in which, in Charles Cooper's phrase, 'organic links' that structure successful relations between science, technology and production have been transferred, created, or denied.[118]

Finally, Western appreciation of alternative traditions is reaching beyond the commodification of artifacts. Histories of non-Western attitudes towards nature are appearing in the undergraduate syllabus, alongside studies of 'pre-contact' technological developments.[119] Accounts of the Rajput and Mughal intellectual heritage, once dismissed as 'antiquarian', are illuminating what appear as continuing traditions of inventiveness in India.[120] Until the 1980s, in Pakistan and Iran a new generation of Islamic scholars held bright promise of restoring to Western eyes a vision of Arab and Persian intellectual contributions. With the political upheavals of the last decade, that promise has been partly eclipsed, but historians await signs of its return.[121] In 1991, the Institute for the History of Arabic Science in Aleppo celebrated its sixteenth year; its work, and that of other Arab scholars may yet decant elements of their heritage, and become part of our curriculum.

Such an agenda will eventually favour non-Western scholarship, and encourage greater collaboration between scholars in the 'North' and the 'South' — where the forecast remains cloudy but hopeful.[122] Asia retains important possibilities which few Western historians beyond Needham have tested. Indeed, the next generation of Chinese historians of science may become better known for their preoccupation with learning 'how the West was Won'. North and sub-Saharan Africa has so far produced little scholarship in the history of science; and South

Africa, with its key position in the history of European expansion, has not yet found a place for the history of science in its university curricula. In Latin America, the situation is brighter, owing much to such pioneers as Marcel Roche of Venezuela and Juan-José Saldaña of Mexico.[123] Latin America now produces two important journals — *Interciencia* and *Quipu* — which bring together the history of science, technology and development, fashioning a new historiography of interdependence that looks not only to colonial and national traditions, but also to pre-Columbian Aztec, Mayan and Inca sources. In 1992, the Latin American Society for the History of Science and Technology celebrated its third International Congress. In the year of Columbus, it now looks to an Atlantic past, an American present, and also a Pacific future.[124]

All historians write for a particular present. At present, ideology has become unfashionable. Even so, it remains relevant to paraphrase Marx's commentary on Feuerbach, and to conclude our discussion where Marx began: if we wish to change the world, we must first understand it. Students of development have seen wax and wane successive models of imperialism, modernisation, dependency and self-sufficiency. Stated objectives of development — increasing participation, relieving poverty and reducing inequality — have been overtaken by policies for commercial and strategic control. Looking to the future, we require the triumph of hope over expectation. Nonetheless, understanding the transmission, assimilation and application of European science and technology remains of central importance. In understanding these processes, our generation has found renewed respect for local conditions, appropriate skills, and alternative traditions of creativity and innovation. Perhaps the next generation will afford us the capacity to comprehend their significance, and the freedom to generalise beyond them.

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111. As the word 'ethnoscience' has a specific anthropological meaning, 'traditional sciences' may be preferred. See the papers arising from the conference on the 'Science of the Pacific Island Peoples', University of the South Pacific, Suva, July 1992.
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114. In this respect, the project of Patrick Petitjean, 'Science and Empires: European Expansion and Scientific Traditions' (CNRS, Paris, from 1988), and conferences held under its auspices, are of the greatest interest.
115. R. MacLeod, 1982, *op. cit.*
116. See T.F. Glick, 'La Transferencía de las revoluciones científicas à través de la fronteras culturales', *Ciencia y Desarrollo,* Mexico, XII, 72, 1987, pp. 77-89.
117. R. Henry, 'Agriculture and the Raj', in MacLeod and Kumar (eds), *op. cit.*
118. C. Cooper, 'Science, Technology and Development', *The Economic and Social Review,* 2, 2, 1971, pp. 165-189.
119. A useful step in this direction was recently taken by the Ford Foundation, in sponsoring a conference of teachers on 'Understanding the Natural World: Science Cross-culturally Considered', Amherst, Mass., June, 1991.
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121. Sardar, *op. cit.*
122. Salam, *op. cit.*
123. See J. Saldaña, *Cross Cultural Diffusion of Science: Latin America: Cuadernos de Quipu,* México DF, Sociedad Latinoamerica de las Ciencias y la Technologia, 1988.
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