economic growth (as measured by the average annual growth rates of real GNP and of real GNP per capita), it is clear that the urbanward migrants were simply responding to economic opportunity; the waves of urban growth in the United States were sympathetic and somewhat lagged responses to waves of economic growth (Fig. 7.4). Each burst of economic growth called forth a rush of urbanward migrants and raised the level of urbanization.

It was the Soviet economist Nikolai Kondratiev who first drew attention to the 55-year-long-wave phenomenon (Kondratiev 1935; like all such ideas, this one had antecedents, for example van Gelderen 1913). As enriched by growth theorists such as Schumpeter (1939), the theory of long waves centers on the role of key innovations that become the leading sectors in growth. In the eyes of these theorists, clusters of innovations produce accelerated expansion until markets are saturated; there is then a recessionary turning point, acceleration turns to deceleration, and deceleration turns to stagnation and collapse in a depression. Venture capitalists then look for new sources of profit, investing in new technologies that become the leaders for the next wave of growth. The span from depression to depression averages some 55 years.

Following this argument, the late-eighteenth-century growth that was Britain's alone (the "first Kondratiev") was sparked by innovations in the water-powered textile industries. Britain's second wave of growth (the "second Kondratiev") was coal-based and steam-powered, marked by mechanization of the textile factories, initial railroadization, and the growth of the iron industry. It was in this wave that Britain became the "workshop of the world" and the center of the Atlantic economy. Around 1830, jerry-builders hit upon an ingenious house design that could save both land and building materials and that produced increasing urban concentration - the back-to-back house. Built in double rows under a single roof, with a standpipe for water supply at the end of the streets and a couple of earth closets devoid of privacy for each 150 people, this design could cram large numbers of houses into small spaces, without either sunlight or ventilation. The result was "...the despair of medical officers... (with) a mortality rate greater by 15 or 20 percent... the absence of a general system of sewerage, the imperfect conditions of the streets and roads, the confined courts, the open middens and cesspools, stagnant ditches and insufficient water supply" (F. Tillyard, quoted in Aldridge 1915).

It was apparent that the new urbanization was creating unhealthy environments - environments that persisted long into the twentieth century and were responsible for the growth of the modern public health and urban planning professions. Even in 1913 in Birmingham

200,000 people were housed in 42,366 buildings of the back-to-back type already long condemned or injurious to health because of lack of ventilation. In the worst six wards, from 51 percent to 76 percent were back-to-backs. Even more serious was the fact that 42,020 houses had no separate water supply, no sinks, no drains, and 58,026 no separate w.c., the closets being communal and exposed in the courts. This meant that over a quarter of a million people lived in insanitary conditions. The real objection to back-to-back houses lies not so much in their method of construction as in the degrading and disgusting condition of their out-buildings, which frequently made decency impossible and inevitably tended to undermine the health and morals of the tenants (Bourneville Village Trust 1941: 16-16).

There was lagged emulation of both the best and the worst of Britain's second-Kondratiev growth, in which factory chimneys and smoky atmospheres were the mark of progress. Victorian England became the hub of a worldwide economy. Liverpool and Manchester became the first noncapital cities in the world ever to rival in size the capital cities of the world empires. Railroadization and both industrial and urban growth diffused outward, finally reaching the world's furthest peripheries late in the twentieth century (Berry, Conkling, and Ray 1987: 415-16).

As the Victorian boom began in Britain, the first wave of United States industrial and urban growth also took place, but it was predominantly water-powered (Fig. 7.5; Borchert 1967); this was the epoch in which the northeastern mill towns grew. Only toward the end did the railroads and the iron industries expand. It was not until after the Civil War that the locus of initiative shifted to the United States and to continental Europe as the leading growth regions (Fig. 7.6). Urban growth rates in Britain slowed down, and were further depressed by the magnitude of emigration. It was the third Kondratiev that was the principal epoch of coal-based steam power in the United States (later supplemented by gas and electricity), of steel rails and ships, and of the growth of the chemical industry. New steel-frame technologies enabled urban densities to be increased by going upward at the same time that the balloon frame enabled rapid construction of workers' housing further outward. New communications technologies enabled the head office to be separated from the factory floor, and the office skyscraper core of the modern central business district was born. Large-scale mass production gave rise to the essence of urbanization, "a process of population concentration" (Tisdale 1942), characterized by increasing size of cities, increasing population densities, and the increasing heterogeneity of their immigrant populations. 
the present century is the concentration of population in cities" (Weber 1899:1). Chandler's statistics reveal a fivefold increase in the cities exceeding 125,000 population and an eightfold increase of those exceeding 500,000 between 1800 and 1900 (Table 7-2). The ancient Asian urban hierarchies of 1800 were replaced by a map dominated by major cities within Northern-hemisphere industrial regions, linked by overseas gateways to colonial empires (Fig. 7.7).

Britain's urban map was dominated in 1900 by nine major cities and a constellation of smaller industrial towns:

- London 8,380,000
- Manchester 1,335,000
- Birmingham 1,248,000
- Glasgow 1,015,000
- Liverpool 941,000
- Newcastle 615,000
- Leeds 430,000
- Sheffield 402,000
- Edinburgh 460,000

Eight urban complexes marked out Germany's industrial heartland:

- Berlin 2,707,000
- Hamburg 895,000
- Ruhrgebiet 766,000
- Dresden 540,000
- Leipzig 532,000
- Munich 499,000
- Cologne 437,000
- Breslau 427,000

Paris (3,330,000) still dominated France, but Lyon (508,000) and Marseille (410,000) had grown. Barcelona (552,000) now rivaled Madrid (539,000) in Spain, and Italy's first wave of industrialization had seen the rise of Milan (491,000), alongside Naples (563,000) and Rome (438,000). And instead of small mercantile centers on the eastern seaboard of North America in 1800, there now was the northeastern manufacturing belt marked out by major urban centers:

- New York 4,242,000
- Chicago 1,717,000
- Philadelphia 1,418,000
- Boston 1,075,000
- St. Louis 614,000
- Pittsburgh 562,000
- Baltimore 508,000
- Cincinnati 417,000

Standing in a dependent relationship to this heartland, radiating out across the national landscape, were resource-dominant regional hinterlands. But whereas within the United States the resources of the hinterlands had been brought within the nation's boundaries during the course of the nineteenth century by purchase and conquest, many of Europe's resource hinterlands were parts of overseas empires, and major cities had grown at the points of colonial penetration. To be sure, San Francisco (439,000) was a gateway to the West, but in the zones of active European settlement in the
Southern Hemisphere, comparable gateway cities included Buenos Aires (806,000), Rio de Janeiro (744,000), Melbourne (485,000), and Sydney (478,000). Cairo's growth (595,000) reflected the flow of world commerce through the Suez Canal. Calcutta (1,085,000), Bombay (780,000), and Madras (505,000) were the gateways through which British Imperial domination of India was exercised, and even though Peking (1,100,000) remained China's largest city, external influence through Tientsin (700,000), Shanghai (619,000), Canton (585,000), and Hankow (480,000) dictated the dissolution of that imperial system. The balance of the world's urban map in 1900 was the more familiar one of the centers of the world empires: Europe's other capitals had grown [St. Petersburg (1,439,000), Moscow (1,112,000), Constantinople (900,000), Warsaw (724,000), Brussels (561,000), Amsterdam (510,000), and Copenhagen (462,000)]; and Tokyo (1,497,000) and Osaka (970,000) were still dominant in Japan; but there was a great gulf between them and lesser cities within their regions.

As impressive as these numbers may be, the change had not yet produced any truly urbanized societies, save perhaps Great Britain. Only 43 cities in the world exceeded 500,000 population in 1900, although 16 of them were now more than a million. Barely ten nations had more than 25% of their populations living in urban centers of more than 10,000 people in 1900 (Great Britain, Belgium, the Netherlands, Germany, France, the United States, Turkey-in-Europe, plus Australia, Argentina, and Uruguay) – a level of urbanization that was surpassed in 1965 by all but a few of the very poorest of the world's nations (Figs. 7.8 and 7.9).

What was significant about late-nineteenth-century growth was not that it urbanized the world, but that it produced a new scale and texture of world empires: the heartland (core) and hinterland (periphery) pattern of regional specialization in which multiechelon hierarchies of urban places played the critical structuring role. In the United States this involved the concentration of big cities in the northeastern manufacturing belt, the great heartland nucleation of industry and the national market, the focus of large-scale national-serving industry, the seedbed of new industry responding to the dynamic structure of national final demand, and the center of high levels of urbanization (percent).

Figure 7.7 The world cities in A.D. 1900.

Figure 7.8 Increases in the level of urbanization in the world's more- and less-developed regions, 1800–2000.
Figure 7.9 World urbanization levels in 1985.
of per capita income. Standing in a dependent relationship to the heartland, radiating out across the national landscape were developed resource-dependent regional hinterlands specializing in the production of raw materials and intermediate outputs for which the heartland reached out to satisfy the input requirements of its great manufacturing places. In the hinterlands, resource endowment was a critical determinant of the particular cumulative advantage of the region and hence its growth potential. In each case, the two conditions of regional growth were set by the heartland. It was the lever for successive development of newer peripheral regions by reaching out to them as its input requirements expanded, and it thereby fostered specialization of regional roles in the national economy. The heartland experienced cumulative urban-industrial specialization, while each of the hinterlands found its comparative advantage based on narrow and intensive specialization in a few resource subsectors—diversifying only when the extent of specialization enabled the hinterland region to pass through that threshold scale of market necessary to support profitable local enterprise. Flows of raw materials inward and finished products outward articulated the whole. Large cities grew at the center of each region, at the top of each regional hierarchy—centers of activity and of innovation, focal points of the transport and communications networks, locations of superior accessibility, at which firms could most easily reap economies of scale and at which industrial complexes could obtain economies of localization and urbanization, encouraging labor specialization and efficiency in the provision of services.

The urban-industrial system that evolved within the expanding national boundaries of the United States was duplicated globally by each of Europe’s imperial powers. Each developed an economic heartland and reached out globally for resource-dependent hinterlands, in the core-periphery pattern described by V. I. Lenin’s “colonial model.”

Only imperial Russia mirrored the United States by bringing its peripheries within the frontiers of the nation-state. For Britain, France, Germany, Italy, Spain, and Portugal, the mother-country, urban-industrial cores reached out both for colonial raw materials and for safe colonial markets. Systems of imperial preference cemented the relationship, along with active European settlement of more temperate areas, from which the indigenous populations were relatively displaced. Urban-centered interconnections held the colonial networks together—networks that were to be disconnected in the twentieth century by two global wars separated by a profound depression. World War I disassembled the ancient Habsburg and Ottoman empires. World War II stemmed Germany’s ultimately unsuccessful search for Lebensraum and Japan’s attempt to create its “greater East Asia co-prosperity sphere” by military means, but the price to the victors also was a loss of empire.

The Great Depression marked another technological watershed—from coal, steam, and rail to petroleum and the internal combustion engine. The base for new rounds of urban growth was the kind of city that had emerged in the nineteenth century, built on productive power, massed population, and industrial technology, and credited with the creation of a system of social life founded on entirely new principles. “Urbanization,” wrote Tisdale (1942) “is a process of population concentration. It proceeds in two ways: the multiplication of the points of concentration and the increasing in size of individual concentrations. Just as long as cities grow in size or multiply in number, urbanization is taking place. Urbanization is a process of becoming. It implies a movement from a state of less concentration to a state of more concentration.” It was these concentrated urban environments that produced the local climatic and hydrologic alterations discussed in the section that follows.

In part, the reason for agglomeration was the concentration of large-scale production facilities at strategic points on efficient interregional transportation networks. It resulted partly from the specialization of functions that large-scale industry made possible, with external economies to be reaped within the agglomerations. But relatively poor intraregional transportation (still predominantly foot and horse until the Great Depression) meant that externalities could be captured only in the most central locations within the agglomerations. Supported by new building technologies, high-rise central business districts developed at the urban cores, surrounded by inner-city manufacturing, and then by high-density rings of workers’ housing. Only the upper classes could escape the perceived ills of the core-oriented concentrations as street railways, tramways, and the omnibus provided access to more pleasant and lower-density environs.

A new concept was needed to capture the scale of the largest agglomerations. The authors of a report issued by the United States Bureau of the Census (1932) in the 1930s wrote that “the population of the corporate city frequently gives a very inadequate idea of the population massed in and around that city, constituting the greater city. [The boundaries of] large cities in few cases limit the urban population which that city represents or of which it is the center. If we are to have a correct picture of the massing or concentration of population in extensive urban areas it is necessary to establish metropolitan districts which will show the magnitude of each of the principal population centers.” Spelling out the idea further, the Bureau of the Budget’s Committee on Metropolitan Area Definition (1967) wrote: “The general concept of a metropolitan area is one of an integrated economic and social unit with a recognized large population nucleus.”

The situation was both fluid and dynamic, however, and the form of the metropolis changed rapidly in the period of accelerating economic growth that followed World War II, facilitated by the new technologies that assumed ascendancy at this time. The concentrated industrial metropolis developed because proximity meant lower transportation and communication costs for those interdependent specialists who had to interact with each other frequently or intensively. But shortened distances meant higher densities and the costs of congestion, polluted environments, high rent, loss of privacy, and the like. The technological developments implemented in the fourth Kondratiev had the effect of reducing the constraints of geographic space and the costs of concentration. Modern transportation and communications made it possible for each succeeding generation to live farther apart, producing
first, accelerated suburbanization and urban sprawl, and later, real deconcentration. In 1902 H. G. Wells had speculated about the possibility:

Many of the railway-begotten "giant cities" will reach their maximum in the coming century [and in all probability they are destined to] decrease and disperse. [These coming cities will not be] in the old sense, cities at all; they will present a new and entirely different phase of human distribution. [Stated simply] the social history of the middle and latter third of the nineteenth century has been the history of a gigantic rush of population into the magic radius of forty miles... But now forces, at present so potent, a centripetal in their influence, bring with them the distinct promise of a centrifugal application. Great towns before this century presented rounded contours and grew as uplifts of silver; the modern Great City looks like something which has burst its intolerable envelope and spilled... the first rough expedient of far more convenient and rapid developments... We are... in the early phase of a great development of centrifugal possibilities... [A] city of one million is inexorably limited by a radius of about four miles... a horse-using city may grow out to seven or eight... [It] is too much to expect that the available area for even the common daily tolerances of the great city of year 2000... will have a radius of over one hundred miles. [The city will diffuse itself until it has taken up... many of the characteristics of what is now country. [The country will take itself many of the qualities of the city. The old antithesis... cease, the boundary lines will altogether disappear.]

These predictions were certainly realized in the United States. After 1950, growth of the service sector, increase in the number of "footloose" industries (including final processing of consumer goods using manufactured parts, and the aircraft, aerospace, and defense industries), rapid emergence of a "quaternary" sector of the economy (involved, for example, the research and development industry), expansion and interregional migration of the"non-job-oriented" population (for example, of retirees to Florida, Arizona, and California), rising governmental expenditures and overall rising real incomes, plus modern highways and the automobile—all served to produce yet another transformation of the economy and the urban system that confirmed H. G. Wells' forecasts. Not only did urban areas grow and disperse into sprawling metropolitan regions; advantages for economic growth were found during the fourth Kondratiev in former hinterland regions around the "outer rim" of the country as changing communications technology reduced the time and costs involved in previous heartland-hinterland relationships.

The changes were cumulative. First, regional growth within the context of the national pattern of heartland and hinterland brought outlying regions to threshold sizes for local production of a wide variety of goods and services. But then, they developed alternative bases of expansion as changes in the definition of urban resources made their rapid advance, free of the traditional constraints of heartland-hinterland leverage possible. Hence, the explosive metropolitan growth of the South, Southwest, and West, led by the tertiary and quaternary sectors. The outcome was that it became possible, by the end of the 1960s, to interpret the spatial structure of the United States as a pattern consisting of (1) metropolitan areas and (2) the intermetropolitan periphery. Except for thinly populated parts of the American interior, the intermetropolitan periphery included all the areas that intervened among metropolitan regions and that were the reverse image of the trend towards large scale concentrated settlement. Like a devil's mantle, the periphery developed a socio-economic profile that perversely reflects the very opposite of metropolitan reality. [Friedmann and Miller 1968]

Even by 1980, much of the United States territory was covered by the daily commuting areas of its metropolitan centers, as the farflung suburbs made possible by the automobile and by superhighway construction spread across the national landscape. The Greek planner Constantinos A. Doxiadis called these urban regions daily urban systems (Berry 1968). The coalescence of expanding metropolitan areas along the northeastern seaboard of the United States led Jean Gottmann (1961) to coin a new term for the phenomenon—megapolises—and a later author, somewhat facetiously, to call three such alleged developments "BosWash," "ChiPitts," and "SanSan." Peter Hall (1973) went on to document the extent of megapolitan development elsewhere in the world, arguing that similar processes were unfolding in every economically advanced area. It is these metropolitan regions that have been the subjects of extensive environmental analysis in the past half century, and it is from this analysis that we have been able to develop an understanding of the impacts of urbanization upon the biosphere.

Environmental Effects of Metropolitan Growth

Urban modification of the atmospheric environment can occur at three geographic scales (Berry and Horton 1974:39ff):

1. Locally, by altering in the nature of the effective surface: the replacement of the natural surface of soil, grass, and trees by the multiplicity of urban surfaces of brick, concrete, glass, and metal at different levels above the ground. These artificial materials change the nature of the reflecting and radiating surfaces, the heat exchange near the surface, and the aerodynamic roughness of the surface.

2. Regionally, by generating large amounts of heat artificially and by altering the composition of the atmosphere via emission of gaseous and solid pollutants. At certain times of the year in midlatitude cities, artificial heat input into the atmosphere by combustion and metabolic processes may approach or even exceed that derived indirectly from the sun. The heat island that results serves as a trap for pollutants.

3. Potentially, globally, through urban contributions to the sulfur budget or to CO2, and thus to the greenhouse effect, to global warming, and to sea-level changes that are likely to be of greatest consequence for major coastal cities.

Leopold (1968) records four interrelated but separable effects of local land-use changes on the hydrology: changes in peak-flow characteristics; changes in total runoff; changes in water quality; and changes in hydrologic amenities. Stream flows following rainstorms may be characterized by unit hydrographs that capture both the peakedness and the lags in the rainfall-discharge relationship (Fig. 7.10). After urbanization, runoff occurs more rapidly and with a greater peak