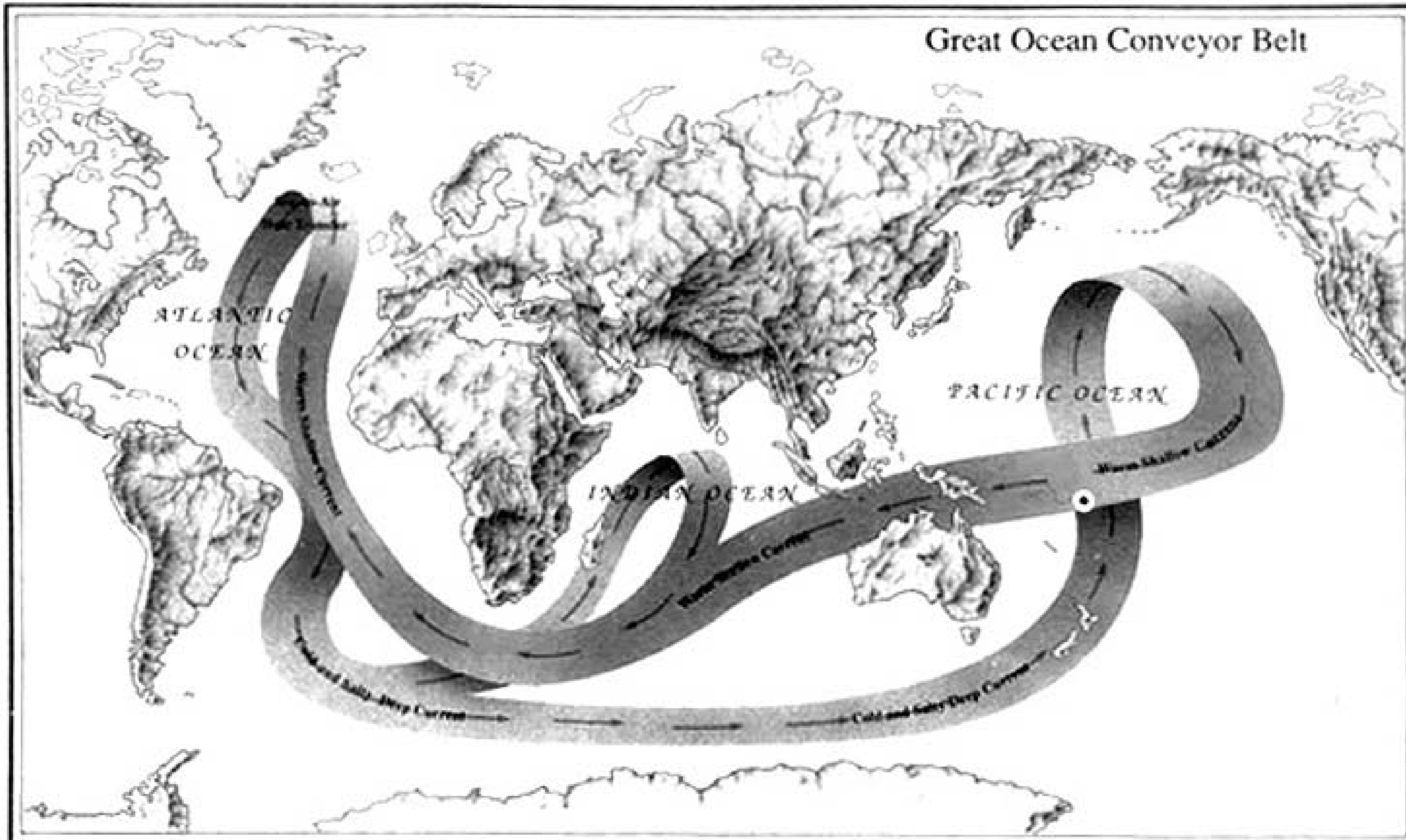


Fig. 10-11 Schematic of the ocean "conveyor belt" from Broecker (1991). (Reproduced with permission of the illustrator, Joe Le Monnier.)

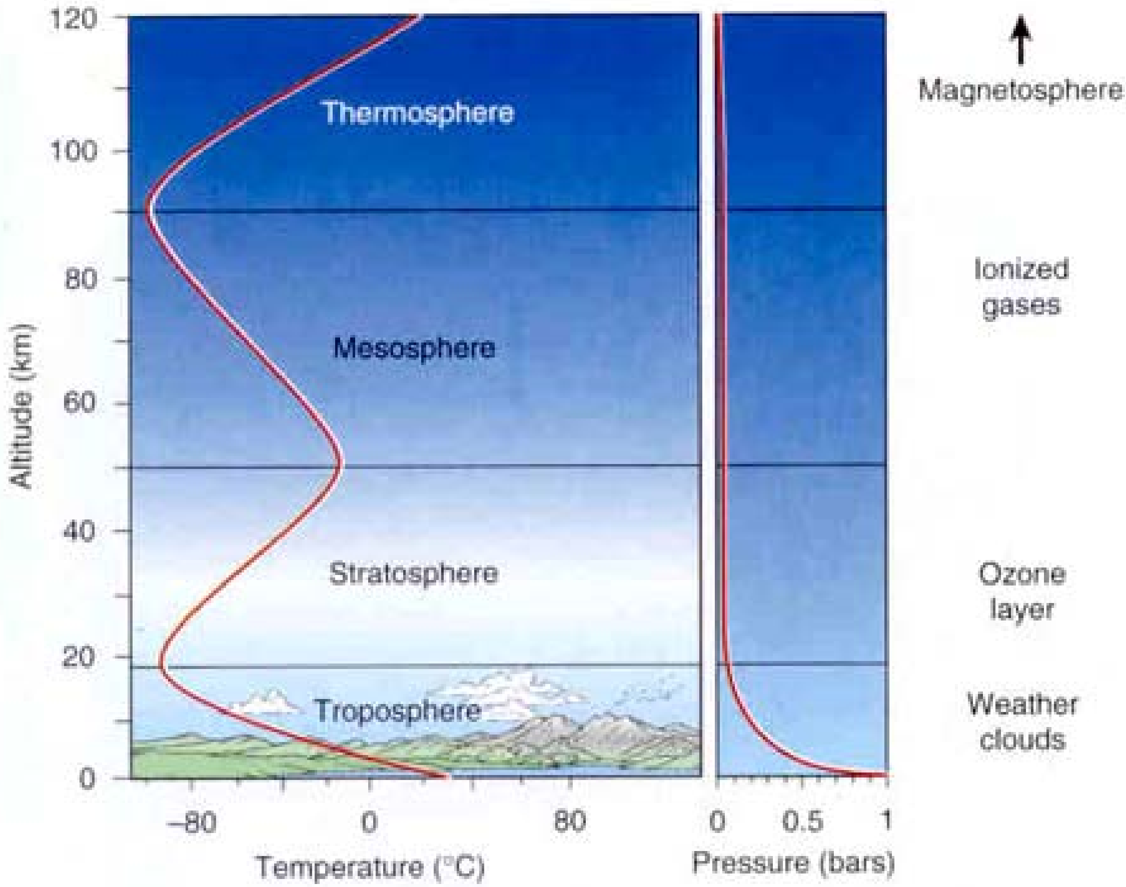


FIGURE 9.3 The main layers of Earth's atmosphere are defined according to their temperature gradients (left). Earth's weather systems develop in the troposphere. This profile shows mean temperatures at 15° N. The atmospheric pressure decreases regularly with height (right).

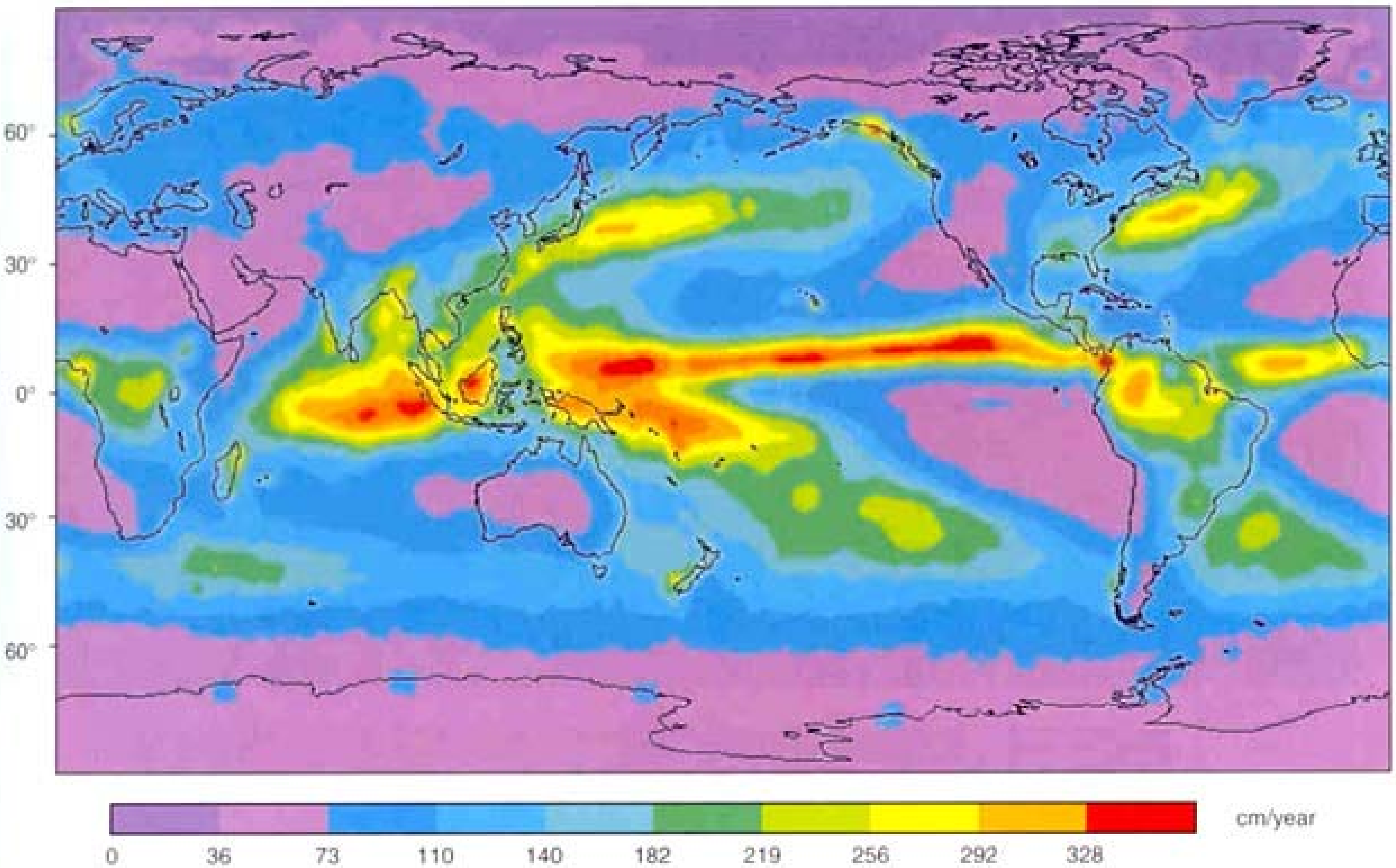


FIGURE 9.5 **Precipitation is greatest near the equator,** where warm, moisture-laden air rises, then cools at high altitude, and becomes supersaturated with water that falls as rain. This phenomenon causes the tropical rain forests. Dry regions lie in subtropical belts north and south of the equator, because here dry air descends, becomes heated, and can then absorb more water vapor. Such conditions cause evaporation to predominate over precipitation and a desert climate to exist. *(Data from Global Precipitation Climatology Project, NOAA)*

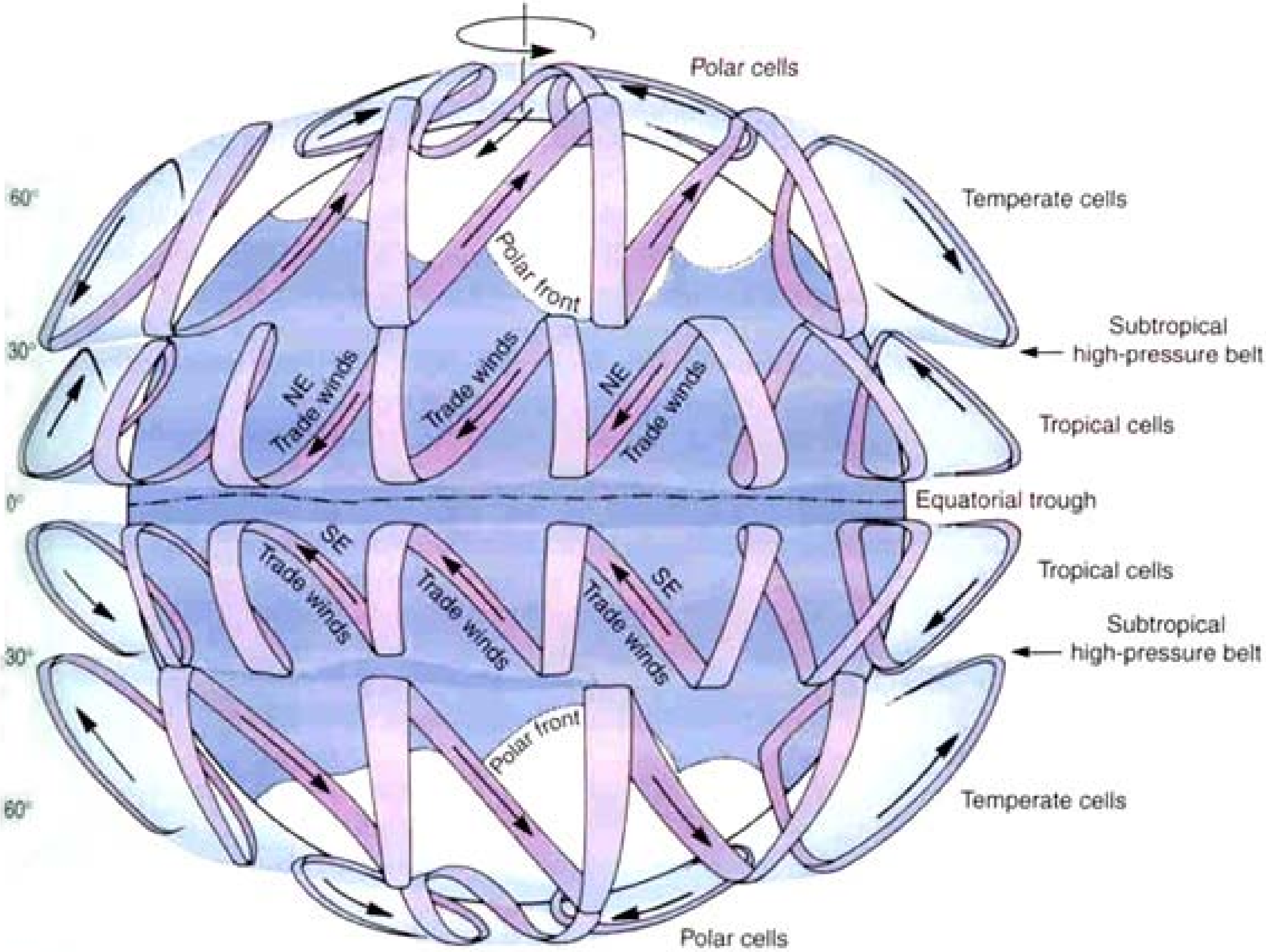
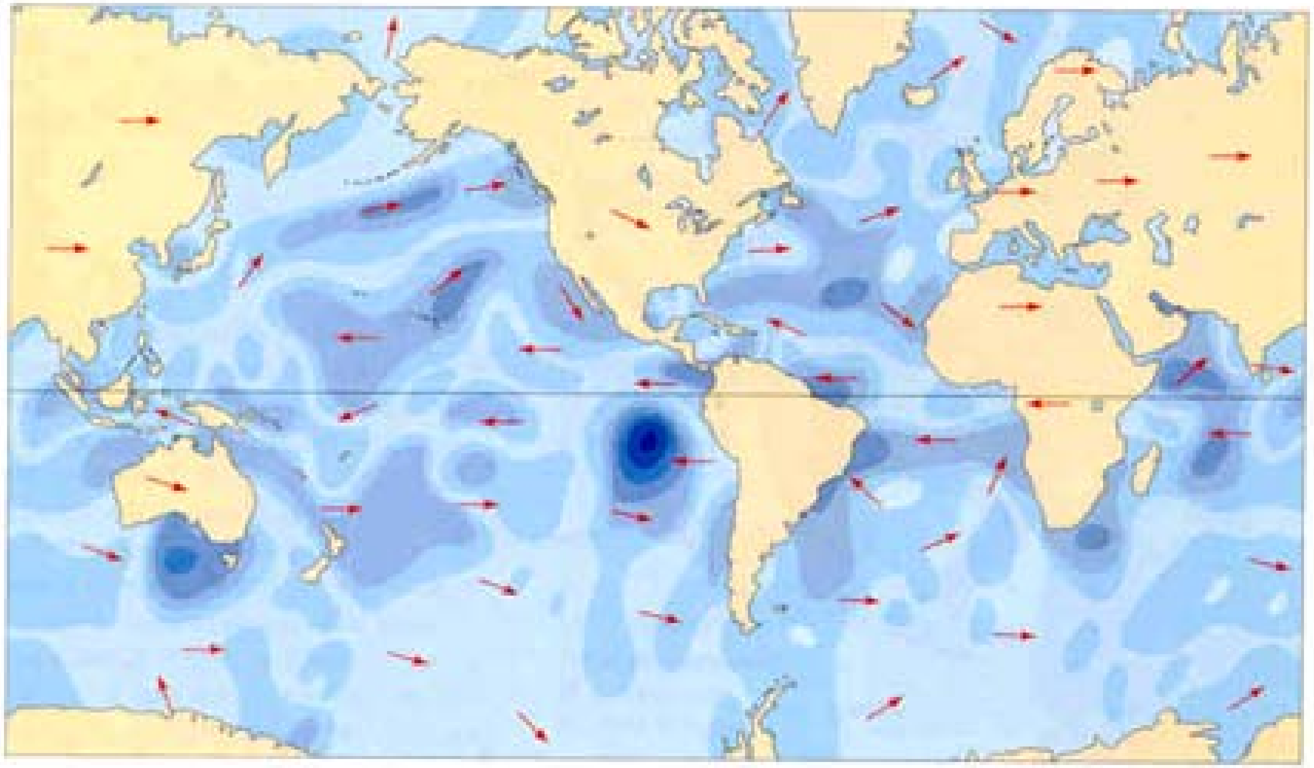


FIGURE 9.8 **Atmospheric circulation** and prevailing wind patterns are generated by the uneven distribution of solar radiation in combination with Earth's rotation. In the equatorial regions, air is intensely heated; the heating reduces its density, and the air rises. At higher altitudes, this air cools, becomes denser, and descends, forming the subtropical high-pressure belts (deserts) on either side of the equator. Near the surface, this air then moves back toward the equator to complete the cycle, causing trade winds. In the Northern Hemisphere, this air is deflected by Earth's rotation to flow southwestward. (In the Southern Hemisphere, flow is northwestward.) Temperate cells form a complementary spiral, creating strong west-to-east winds. Cold polar air tends to wedge itself toward the lower latitudes and forms polar fronts.



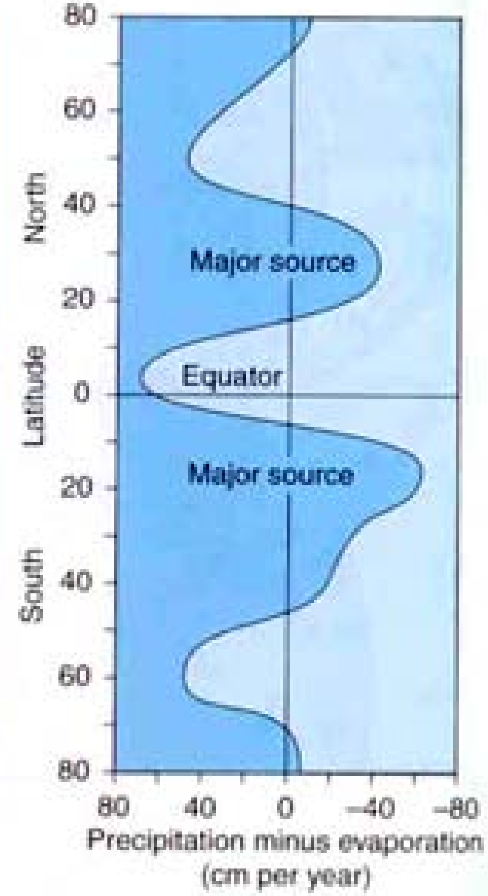


FIGURE 9.9 **Evaporation creates major sources** of water for the hydrologic system. Darkest areas are where evaporation exceeds precipitation, moving great volumes of moisture into the air. These areas are the main sources of water for the global hydrologic system. Light areas are where precipitation dominates, returning water from the atmosphere to the surface. Arrows show the direction of water movement in the atmosphere as caused by prevailing winds. The graph on the right shows that the two major sources of water for the hydrologic system are the oceans between 10° and 40° north and south of the equator. The equatorial oceans and the high-latitude oceans do not supply significant water to the global system. (*Modified from J. P. Peixit and M. A. Kettani*)

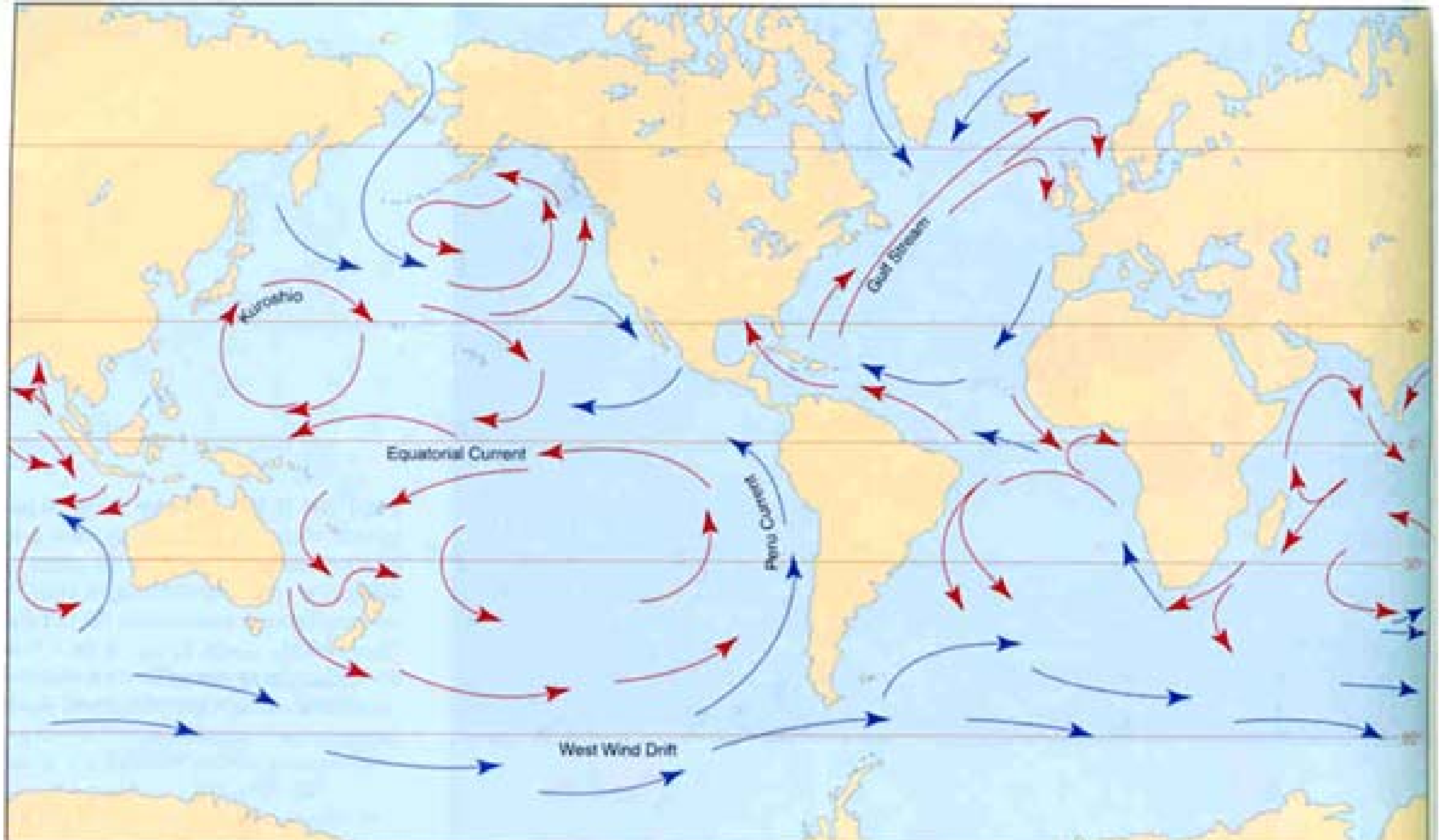


FIGURE 9.13 **Surface currents of the oceans** are driven by prevailing winds, which are in turn caused by the uneven heating of Earth's surface illustrated in Figure 9.6. Most of the currents have crudely circular patterns. Warm (red) and cold (blue) currents are shown.

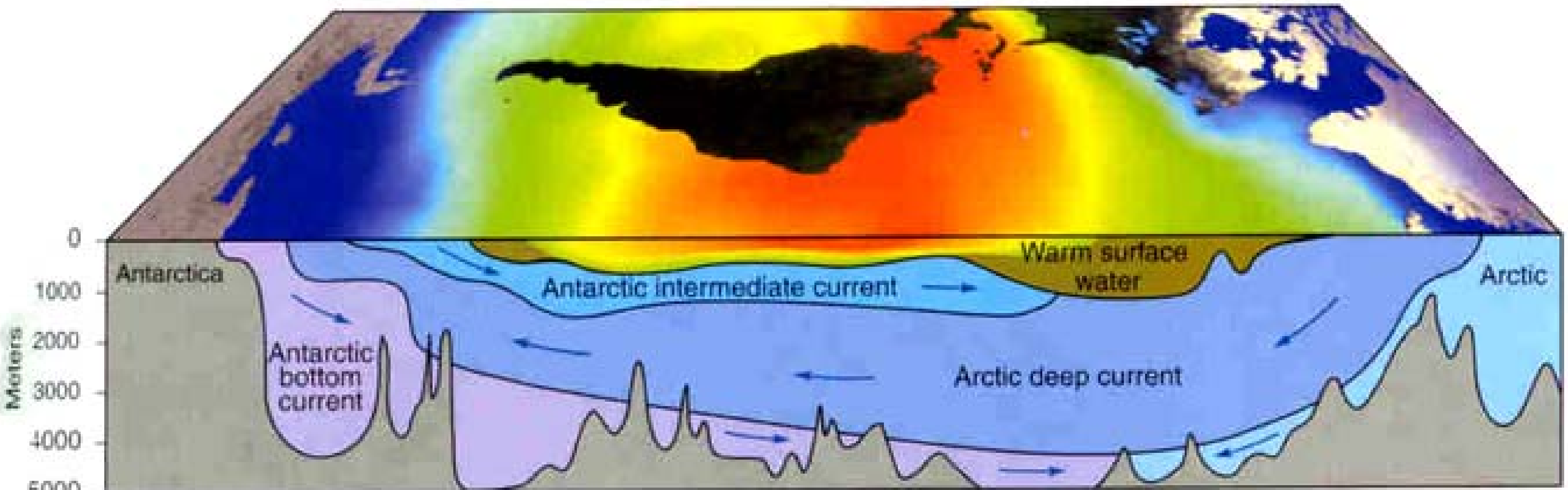


FIGURE 9.15 **Deep circulation of the ocean** is driven by density differences caused by temperature differences and to a lesser extent by differences in salinity. The coldest bottom water in the Atlantic Ocean tumbles down the margins of Antarctica and flows northward, reaching points as much as 40° N of the equator (the latitude of New York and Portugal). Cold waters of the north also sink toward the ocean floor and flow southward.

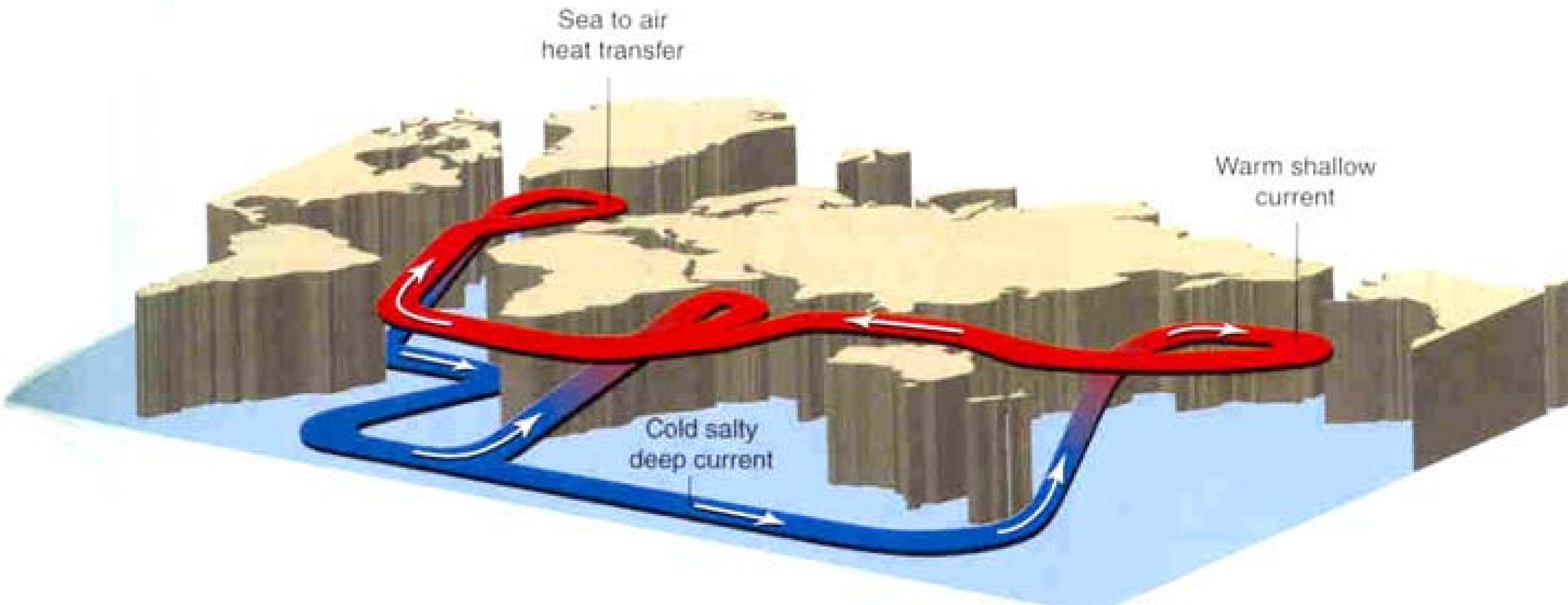


FIGURE 9.19 The global pattern of ocean circulation can be likened to a huge conveyor belt that carries surface water to great depths and then back again. Deep-water circulation (blue arrows) originates in the North Atlantic by the sinking of cold surface waters north of Iceland. This water flows southward at depth along the western side of the ocean basin and into the South Atlantic Ocean. Along the shores of Antarctica, it is joined by more cold sinking water and then flows eastward into the deep basins of the Indian and Pacific oceans. Diffuse upwelling in all of the oceans returns some of this water to the surface. In addition, a warm surface current from the Pacific (red arrows) may return water to the North Atlantic. *(Modified from NOAA)*

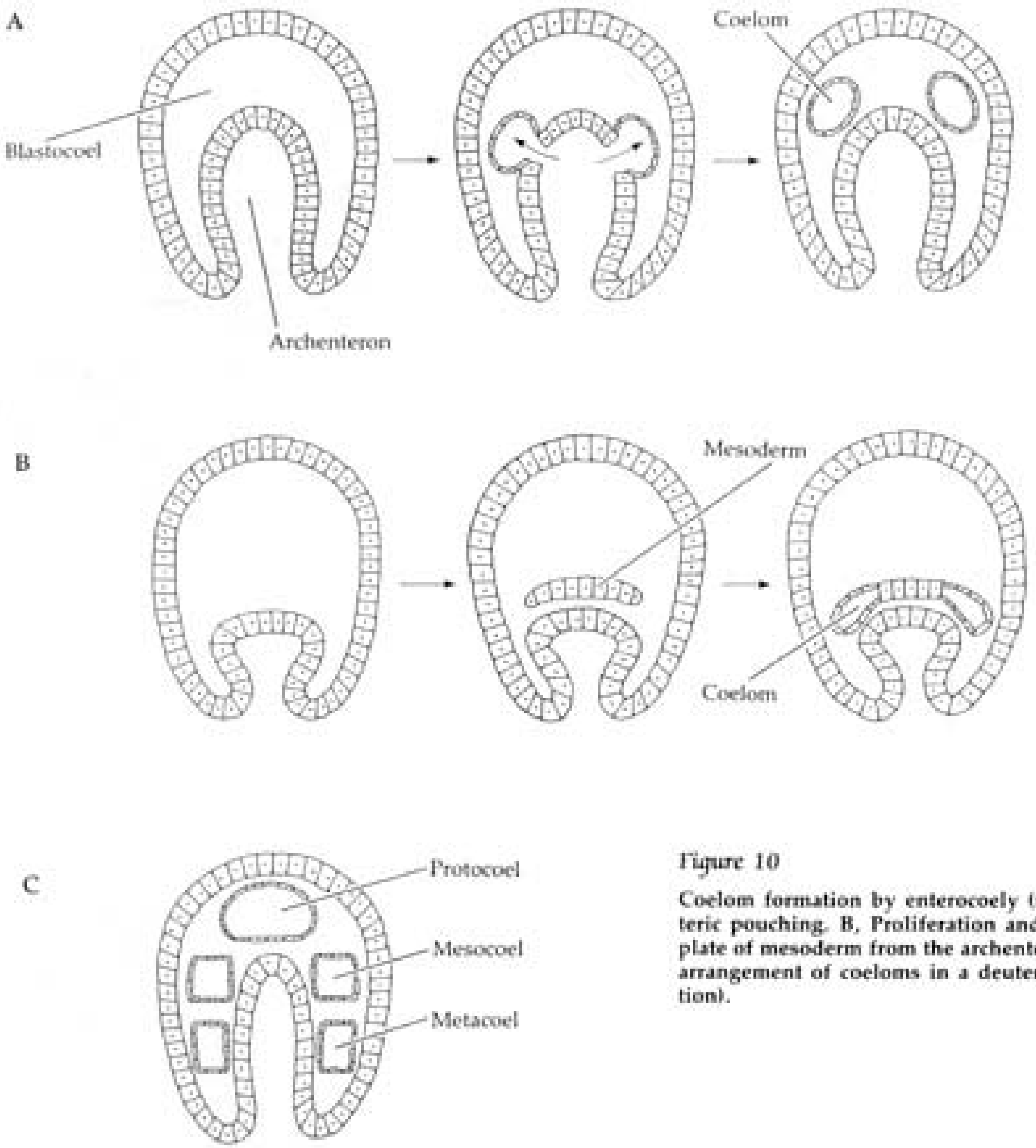


Figure 10

Coelom formation by enterocoely (frontal sections). A, Archenteric pouching. B, Proliferation and subsequent hollowing of a plate of mesoderm from the archenteron. C, The typical tripartite arrangement of coeloms in a deuterostome embryo (frontal section).

Box One

Protostomes and Deuterostomes

Developmental differences between protostomes and deuterostomes and some representative eucoelomate taxa

PROTOSTOMIA	DEUTEROSTOMIA
Spiral cleavage	Radial cleavage
Blastopore becomes the mouth	Blastopore does not become the mouth (often becomes the anus)
Mesoderm derived from mesentoblast (usually the 4d cell)	Mesoderm arises from wall of archenteron
Schizocoelous coelom formation	Enterocoelous coelom formation
Annelida, Mollusca, Arthropoda, Nemertea, Sipuncula, Echiura	Echinodermata, Hemichordata, Chordata

Note: Some authors include certain noncoelomate taxa in these listings; for example, the flatworms demonstrate all the features of the Protostomia except the formation of the coelom.

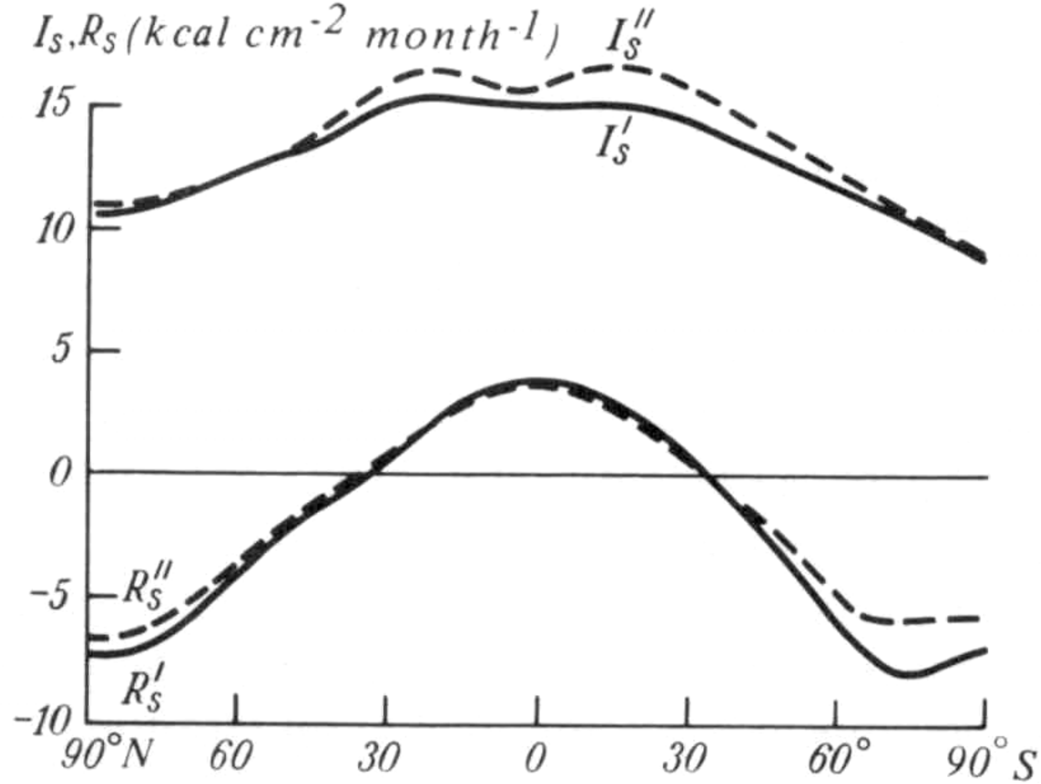


Fig. 3.6 Dependence of the earth–atmosphere system radiation balance and outgoing radiation on latitude.

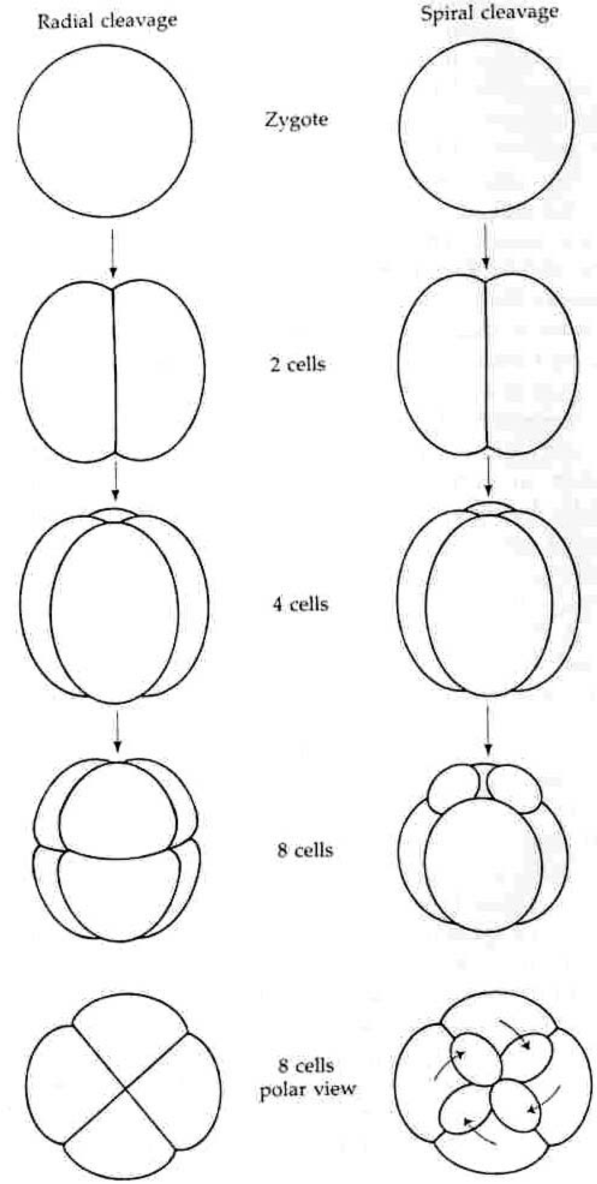


Figure 4

Comparison of radial versus spiral cleavage through the 8-cell stage. During radial cleavage, the cleavage planes all pass either perpendicular or parallel to the animal–vegetal axis of the embryo. Spiral cleavage involves a tilting of the mitotic spindles, commencing with the division from four to eight cells. The resulting cleavage planes are neither perpendicular nor parallel to the axis. The polar views of the resulting 8-cell stages illustrate the differences in blastomere orientation.

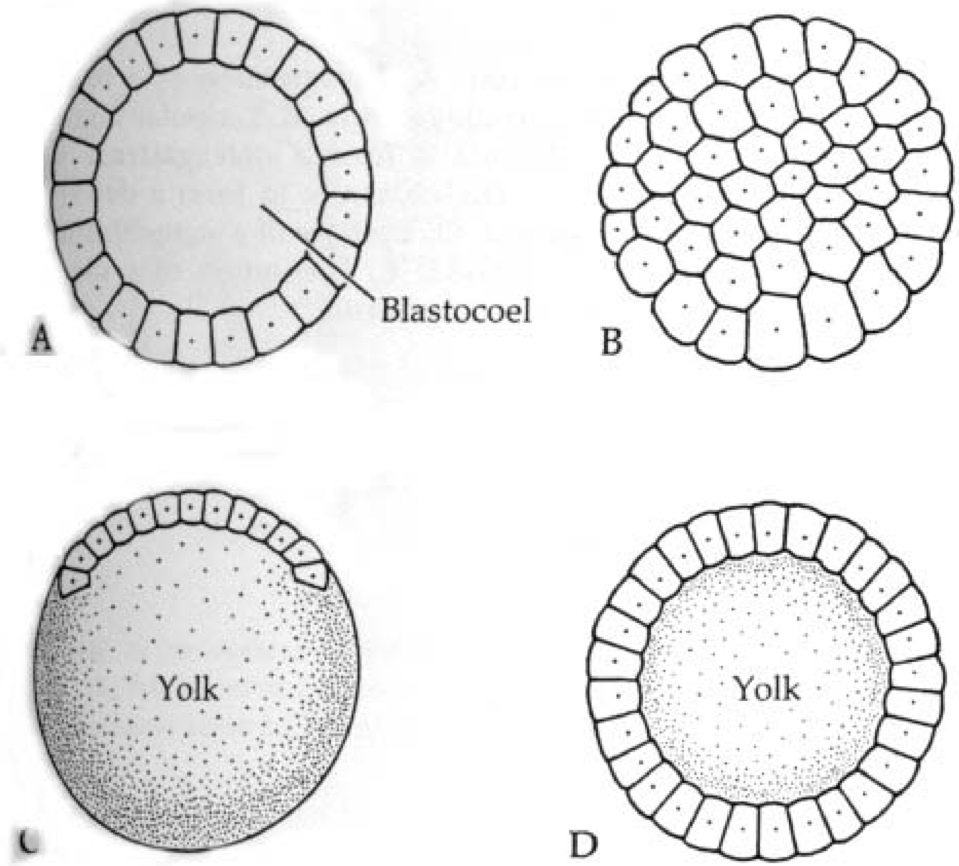


Figure 6

Types of blastulae. These diagrams represent sections along the animal–vegetal axis. A, Coeloblastula. The blastomeres form a hollow sphere with a wall one cell layer thick. B, Stereoblastula. Cleavage results in a solid ball of blastomeres. C, Discoblastula. Cleavage has produced a cap of blastomeres that lies at the animal pole, above a solid mass of yolk. D, Periblastula. Blastomeres form a single cell layer enclosing an inner yolky mass.

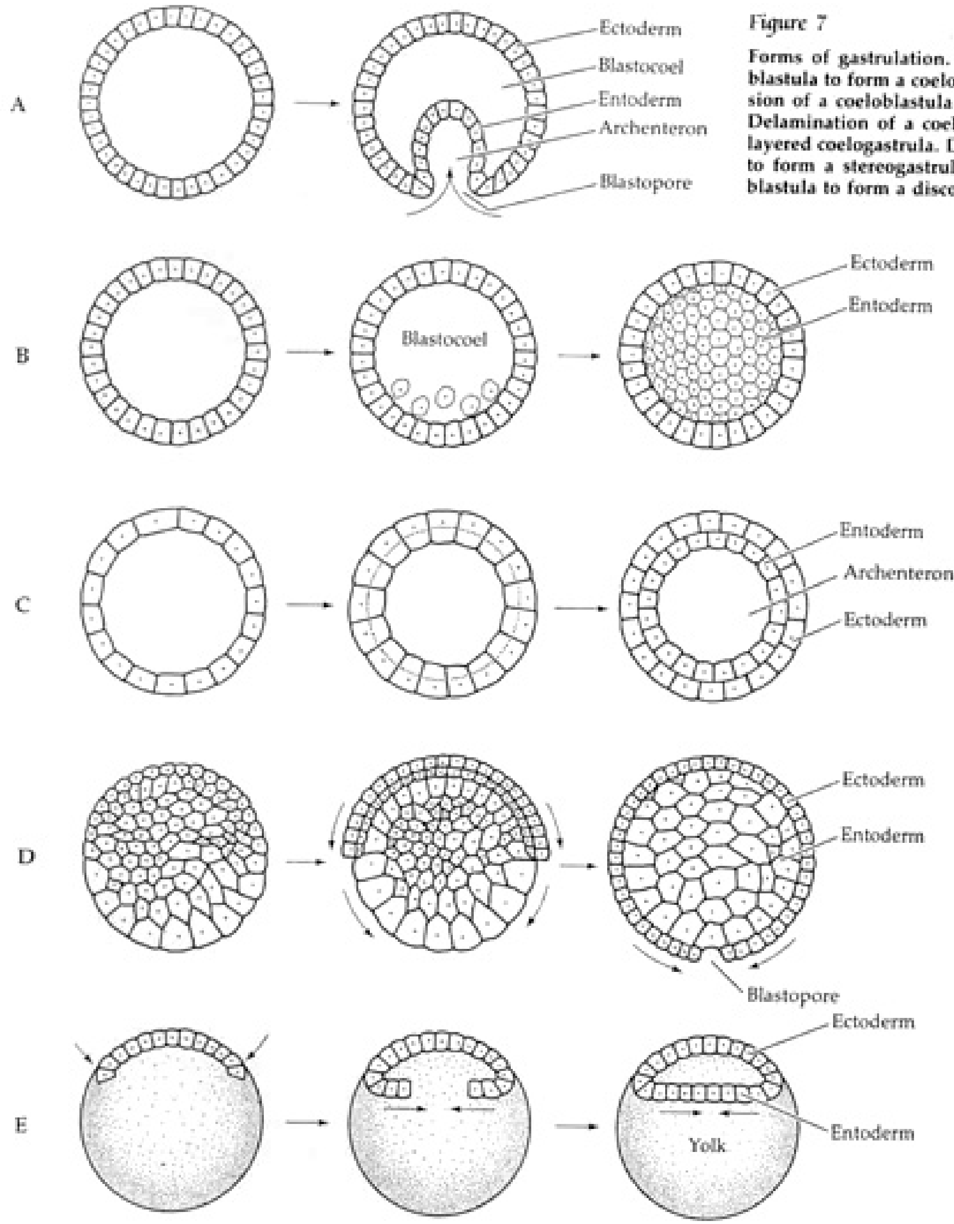
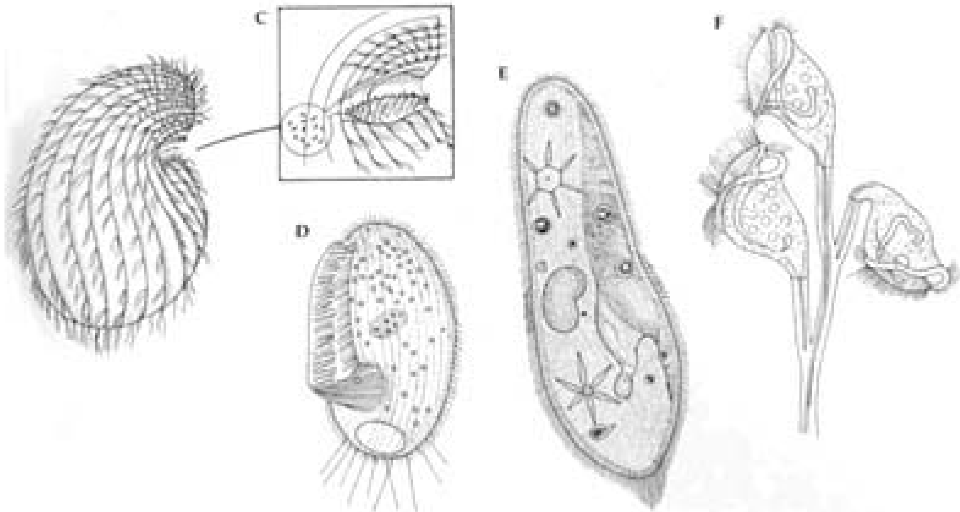
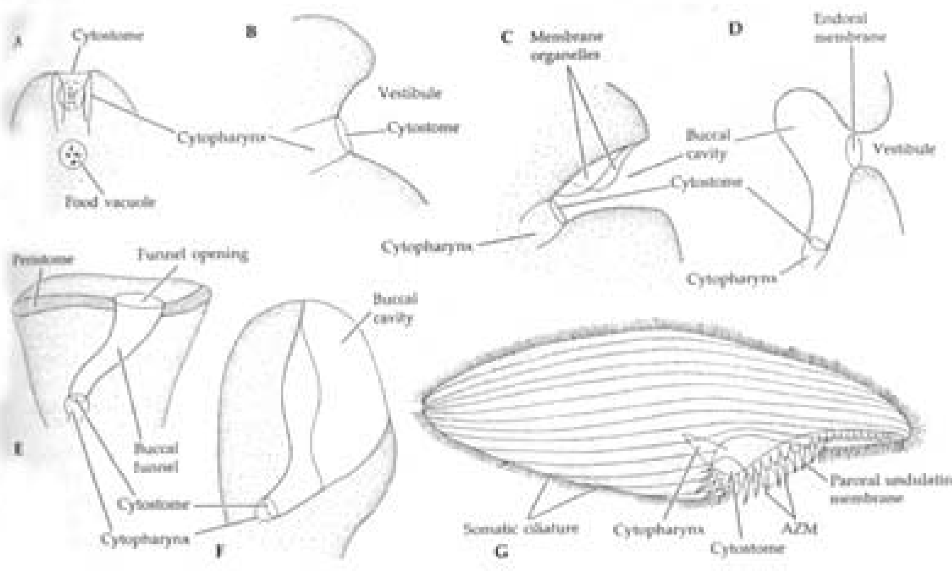
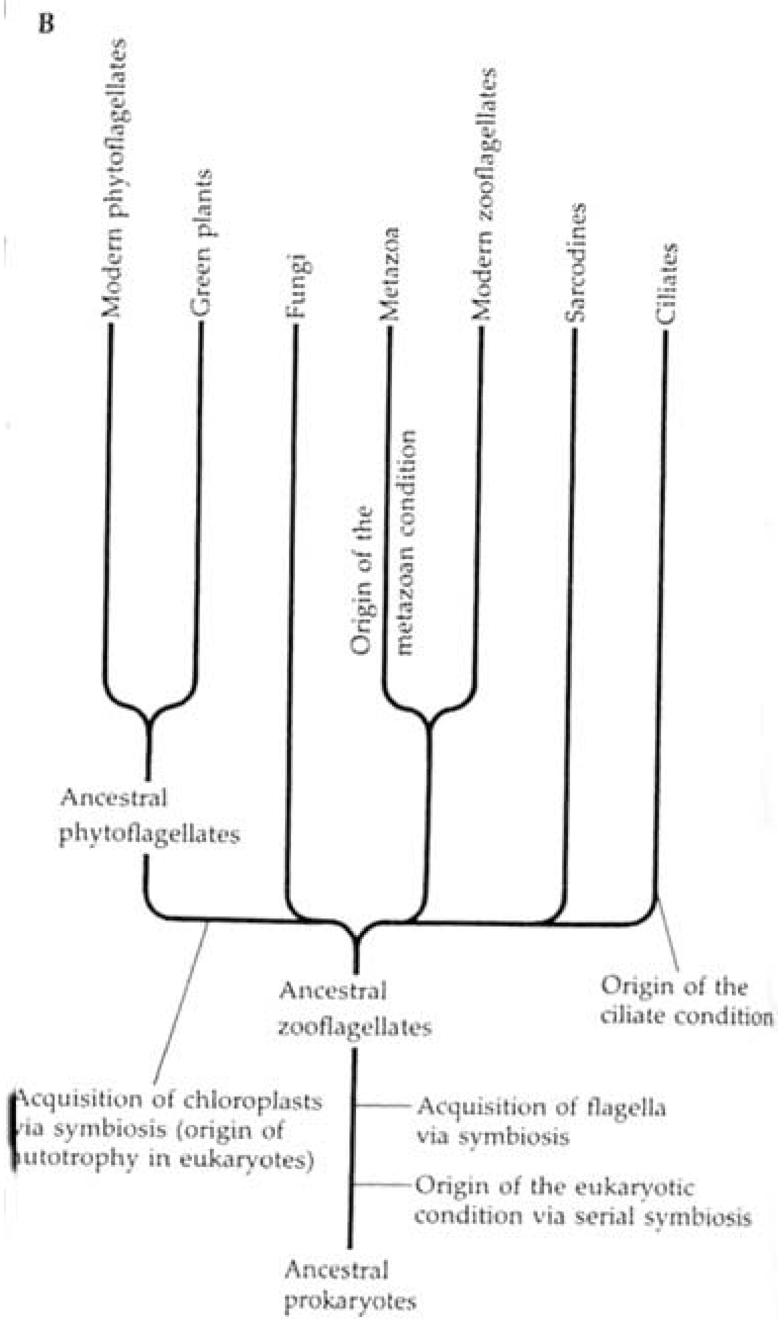


Figure 7

Forms of gastrulation. A, Invagination of a coeloblastula to form a coelogastrula. B, Unipolar ingression of a coeloblastula to form a stereogastrula. C, Delamination of a coeloblastula to form a double-layered coelogastrula. D, Epiboly of a stereoblastula to form a stereogastrula. E, Involution of a discoblastula to form a discogastrula.


C
D
E
F

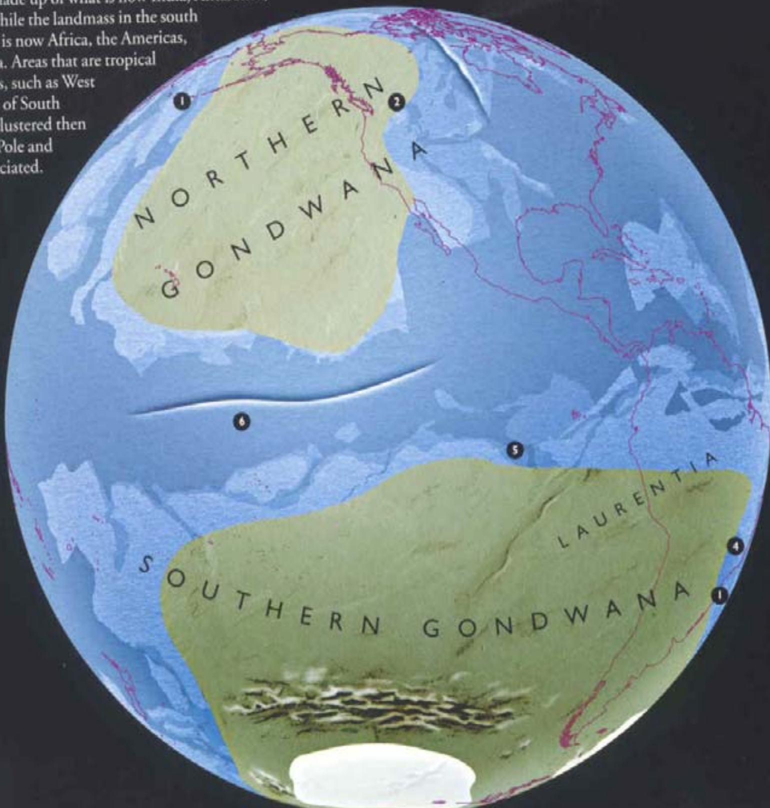

A
Cytostome
Cytopharynx
Food vacuole
B
Vestibule
Cytostome
C
Membrane organelles
Buccal cavity
Cytostome
Cytopharynx
D
Endoral membrane
Vestibule
Cytopharynx
Peristome
Funnel opening
Buccal funnel
Cytostome
Cytopharynx
E
Buccal cavity
F
Somatic ciliature
Cytopharynx
Cytostome
AZM
Paroral undulating membrane
G


B
Modern phytoflagellates
Green plants
Fungi
Metazoa
Modern zooflagellates
Sarcodines
Ciliates
Origin of the metazoan condition
Ancestral phytoflagellates
Ancestral zooflagellates
Origin of the ciliate condition
Acquisition of chloroplasts via symbiosis (origin of autotrophy in eukaryotes)
Acquisition of flagella via symbiosis
Origin of the eukaryotic condition via serial symbiosis
Ancestral prokaryotes

Vendian Times

Maps of the Earth some 620 million years ago, at the beginning of Vendian times and at the end of the long Precambrian era, show a planet with an unfamiliar face. Land fills much of the area now covered by the Pacific Ocean, while ancient seas fill the hemisphere where Europe, Asia, and Africa now lie. Two main continents dominate the globe: the northern one (northern Gondwana) is made up of what is now India, Antarctica, and Australia, while the landmass in the south consists of what is now Africa, the Americas, and parts of Asia. Areas that are tropical in modern times, such as West Africa and parts of South America, were clustered then near the South Pole and were heavily glaciated.

1. PASSIVE MARGINS
The coasts of what are now northwestern Australia (in northern Gondwana), northeastern North America (Laurentia), and northeastern Siberia were all "passive margins," zones forming the edges of crustal plates but without the earthquake activity associated with such regions. Extensive sediments built up on the beds of shallow seas in these locations in Vendian times.



6. DISAPPEARING OCEAN
The ocean between the northern and southern parts of what would one day become the supercontinent of Gondwana was rapidly narrowing. About 580 million years ago, the northern coast of southern Gondwana collided with the southern coast of northern Gondwana to form a landmass called Pannotia, which seems to have lasted for only a few million years.

5. WARM NAMIBIAN WATERS
Namibia, now in southwest Africa, lay in warm shallow equatorial waters for a long period during Vendian times. It is now one of the most famous localities in the world for Ediacaran fossil traces (although they are somewhat younger in age, mostly less than 600 million years old, than the times shown on this map).

2. FLINDERS RANGE, SOUTH AUSTRALIA
Australia lay in the northern hemisphere in Vendian times. It contains excellent examples of the sandstone that is typical of the period, originally laid down on a shallow, sandy seafloor swept by tidal currents. Vendian sandstone preserves the best-known fossils of the period, the Ediacarans. These soft-bodied animals were named for the Ediacara Hills in the Flinders Range of South Australia, where they were first found. They thrived in the shallow seas, anchored to the seabed or burrowed into the sand.

WHOLE WORLD PROJECTION

4. NEWFOUNDLAND
The Vendian sandstone rocks of Newfoundland are finer grained than those of Australia. The sediments may have been deposited by successive underwater avalanches called turbidity currents, possibly triggered by submarine earthquakes. *Ediacaran fossils* are also found here, at locations such as Mistaken Point.

3. CHINESE STRATA
The Nantuo Formation in southern China is made from "tillites," a mixture of mud, sand, large stones, and rock brought together and carried along by ancient glaciers. The presence of tillites in this region shows that it was glaciated in late Vendian times (20 million years after the situation shown in this map, once sea levels had fallen). How much of the world was covered by glaciers is hotly debated. Some specialists theorize that the Earth was almost completely frozen over, while others refute this claim.

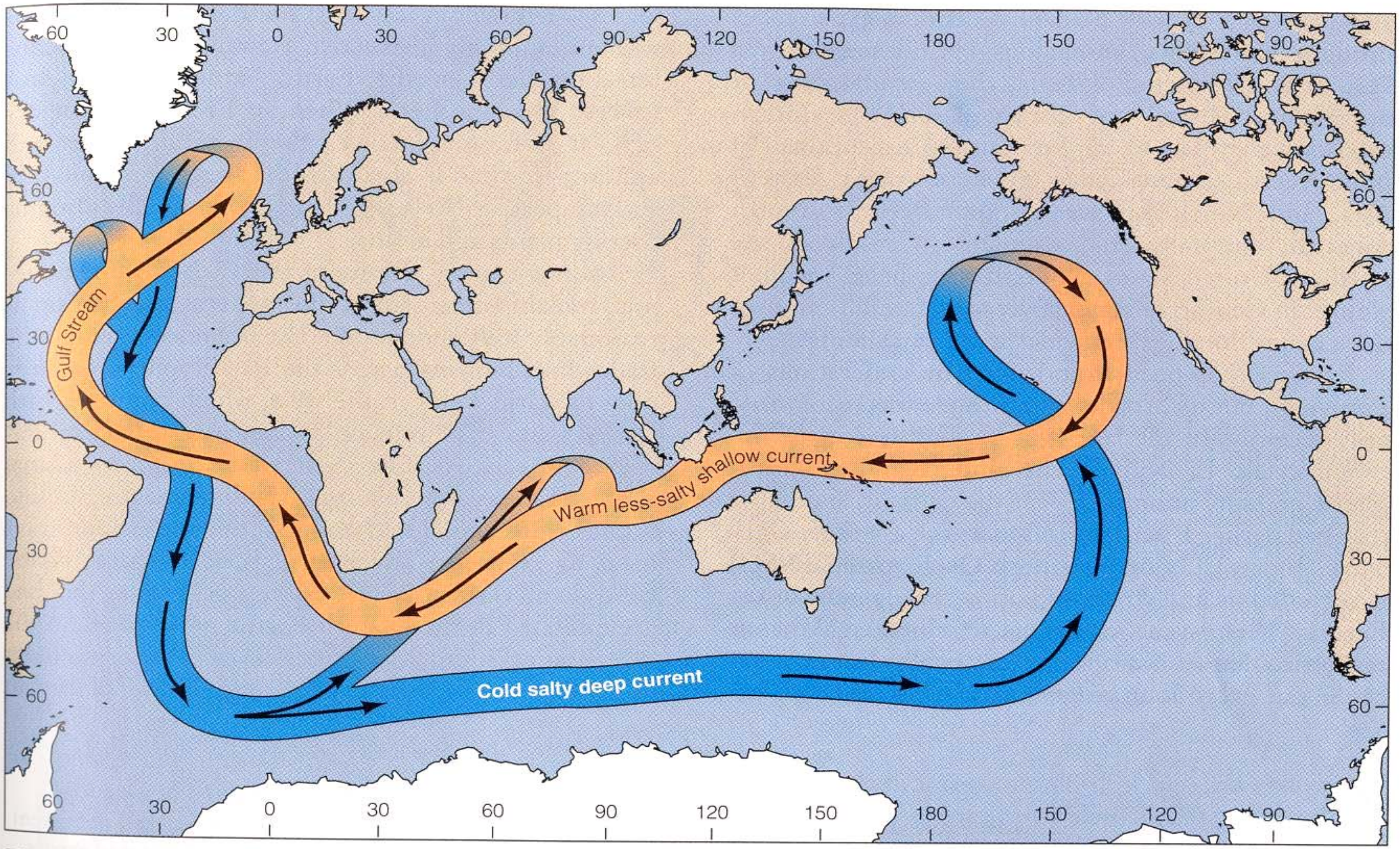


Figure 11.13 The major thermohaline circulation cells that make up the global ocean conveyor system are driven by exchange of heat and moisture between the atmosphere and ocean. Dense water forming at a number of sites in the North Atlantic spreads slowly along the ocean floor, eventually to enter both the Indian and Pacific oceans before slowly upwelling and entering shallower parts of the thermohaline circulation cells. Antarctic Bottom Water (AABW) forms adjacent to Antarctica and flows northward in fresher, colder circulation cells beneath warmer, more saline waters in the South Atlantic and South Pacific. It also flows along the Southern Ocean beneath the Antarctic Circumpolar Current to enter the southern Indian Ocean. Warm surface waters flowing into the western Atlantic and Pacific basins close the great global thermohaline cells.

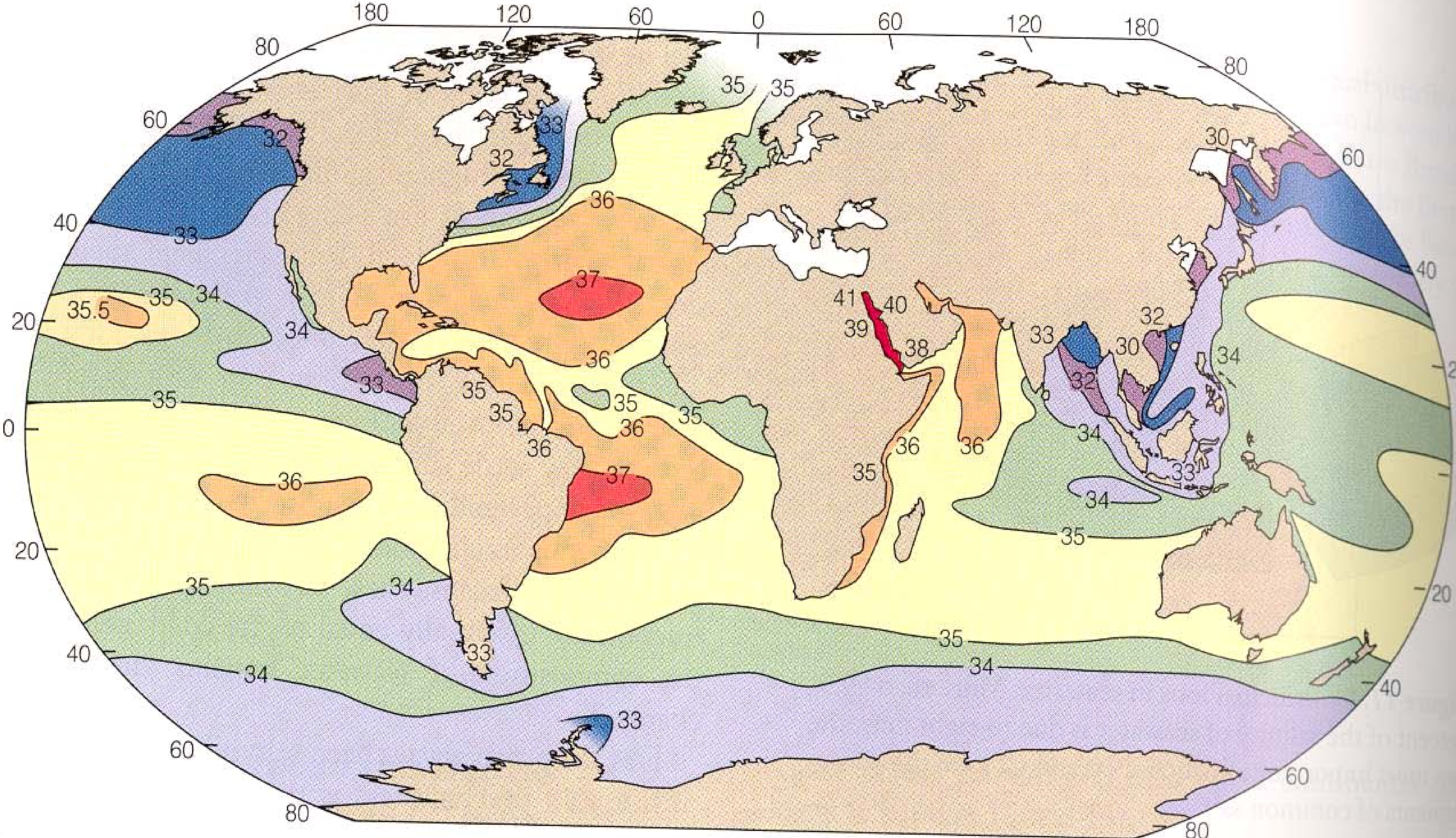


Figure 11.5 Average surface salinity of the oceans. High salinity values are found in tropical and subtropical waters where evaporation exceeds precipitation. The highest salinity has been measured in enclosed seas like the Persian Gulf, the Red Sea, and the Mediterranean Sea. Salinity values generally decrease poleward, both north and south of the equator, but low values also are found off the mouths of large rivers.