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## Biophysical Parameters

In addition to regional variations in weather and climate, geographers have also employed various biophysical parameters, such as the distribution of permafrost and vegetation communities, to define the boundaries of the North.

### Permafrost

Permafrost refers to a thermal condition observed in soils, peat, and rocks in which ground temperatures remain below 0°C for two or more consecutive years. Geographers recognize several types of permafrost:

- Continuous permafrost refers to an environment where more than 80% of the ground surface is underlain by permafrost. The southern limit of continuous permafrost corresponds closely to a mean annual isotherm (which is derived from air temperatures) of -8°C.
- Discontinuous permafrost refers to an environment where 30–80% of the ground surface is underlain by permafrost. The southern limit of discontinuous permafrost corresponds closely to a mean annual isotherm of -1°C.
- Sporadic permafrost refers to an environment where less than 30% of the ground surface is underlain by permafrost. There is no commonly acknowledged thermal criteria for the southern boundary of sporadic permafrost. The presence of sporadic permafrost is often dependent on the presence of organic soils that help preserve the permafrost under milder climates.

Continuous permafrost is associated with the Arctic and Polar zones, while discontinuous permafrost is associated with the Subarctic zone.

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### Student Activity

1. How are regional climates defined?
2. What two air masses most affect precipitation, and where do they originate?
3. What categories of climate do the three letters in the Köppen-Geiger Climate System represent?
4. How is the Köppen-Geiger Climate System different from the Thornthwaite System?



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5. How would you classify the climate in which you live with the Köppen-Geiger Climate System?
  6. What does PE stand for?
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### Terrestrial and Marine Biomes

Ecologists and biogeographers have examined the influence of air masses and water masses on the distribution of *biomes* to define the boundaries of the circumpolar North. Biomes are large, stable *ecosystems* characterized by specific plant and animal communities. The term *ecosystem* refers to any self-sustaining association of plants and animals and their physical environment.

Biological activity in terrestrial environments is influenced directly by air temperatures and the availability of liquid water and soil nutrients; hence the quantity of energy available to melt snow and ice, thaw permafrost, and warm the soil and air is important.

The Boreal Forest biome occupies the Subarctic zone of North America and extensive areas of Asia and Europe. This biome is characterized by a closed-canopy, mixed-forest vegetation consisting largely of deciduous broadleaf trees (e.g., aspen, birch, and poplar) and evergreen needleleaf trees (e.g., fir, pine, and spruce). The understory vegetation is dominated by shrubs, herbs, and mosses. This vegetation cover is within this biome gradually replaced northwards by open lichen woodland as the climate becomes more rigorous. In open lichen woodlands, trees are spaced widely apart and the understory vegetation is dominated by mosses and lichens. The Tundra biome occupies the Arctic and Polar zones of North America. This biome is characterized by shrubs, grasses, sedges, mosses, and lichen; trees are absent.

The boundaries of terrestrial biomes are commonly correlated with climatological phenomena. The boundary separating Boreal Forest and Tundra biomes corresponds closely to the boundary separating continuous and discontinuous permafrost terrain (i.e.,  $-8^{\circ}\text{C}$  mean annual isotherm). The northernmost extent of the Boreal Forest biome is represented by the *treeline* and corresponds closely to the  $10^{\circ}\text{C}$  mean July isotherm (see fig. 1.1).

Biological activity in marine environments is influenced directly by water temperatures and salinities, and the availability of plant nutrients; hence the quantity of energy available to melt snow and ice and to warm ocean waters is important.



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The marine Arctic zone is characterized by the permanent cover of multi-year sea ice and surface waters exhibiting relatively low salinities and temperatures approaching the freezing point of sea water (approximately  $-2^{\circ}\text{C}$ ). The marine Subarctic zone is characterized by the seasonal cover of annual sea ice and the mixing of cold, low-salinity surface water derived from the Arctic Ocean with surface waters exhibiting relatively warm temperatures (i.e., above  $0^{\circ}\text{C}$ ) and high-salinity surface water derived from the North Pacific and North Atlantic oceans (see fig. 1.1). Note that the boundary separating Subarctic and Arctic environments on land does not correspond with the boundary in the marine environment.

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### Student Activity

1. Which terrestrial classification system for determining northern borders is most relevant to vegetation?
  2. What are the differences in water composition in the marine Arctic and marine Subarctic zones?
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### The Nordic Index

It is apparent, then, that using various criteria to delimit the boundary of the circumpolar North has yielded not a single comprehensive boundary, but many different boundaries. Louis-Edmond Hamelin, a Canadian geographer, recognized the complexity of the situation and proposed the comprehensive *Nordic Index* based on a combination of biological, physical, demographic, and economic development criteria in order to reflect the natural and human-modified characteristics of northern environments. The index is based on the calculation of *polar units* (*valeurs polaire*) for each of ten criteria (see table 1.1).

**Table 1.1** Criteria for the calculation of the Nordic Index

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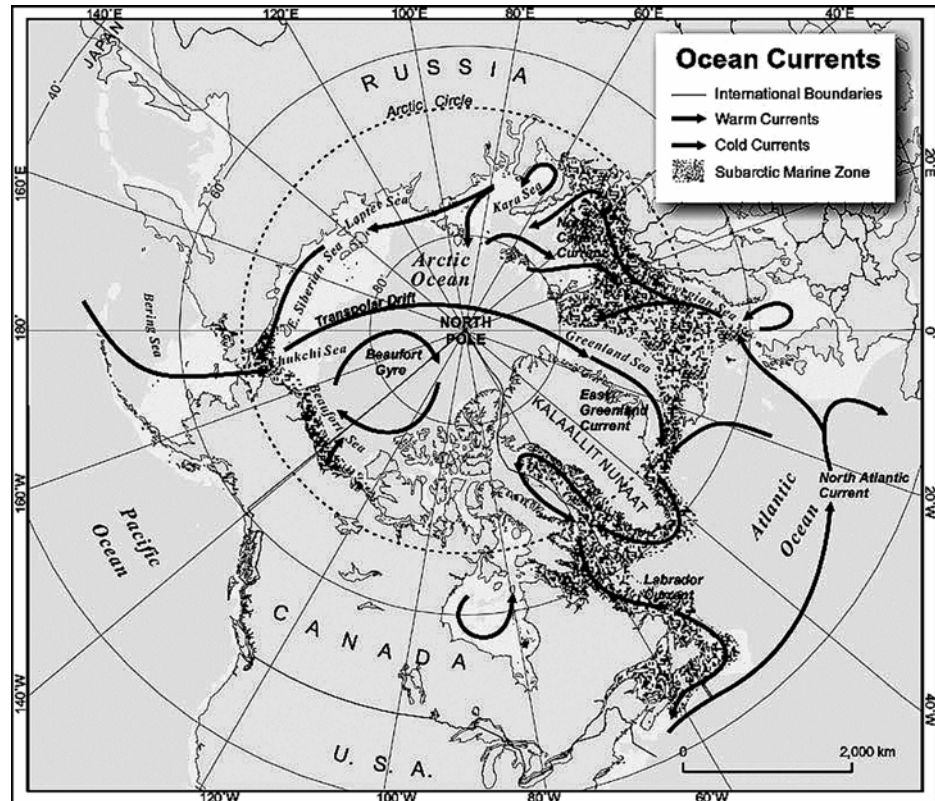
1. Latitude
  2. Summer heat (number of days above  $5.6^{\circ}\text{C}$ )
  3. Annual cold (number of days below  $0^{\circ}\text{C}$ )
  4. Types of ice: permafrost, sea ice, glaciers, and snow cover
  5. Total annual precipitation
  6. Natural vegetation: rock, tundra, open lichen woodland, boreal forest
  7. Accessibility by means other than air: water transport, winter highways, pipelines
  8. Air service: charter, regular
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9. Resident population: total population, population density

10. Degree of economic activity: subsistence, resource extraction only, etc.

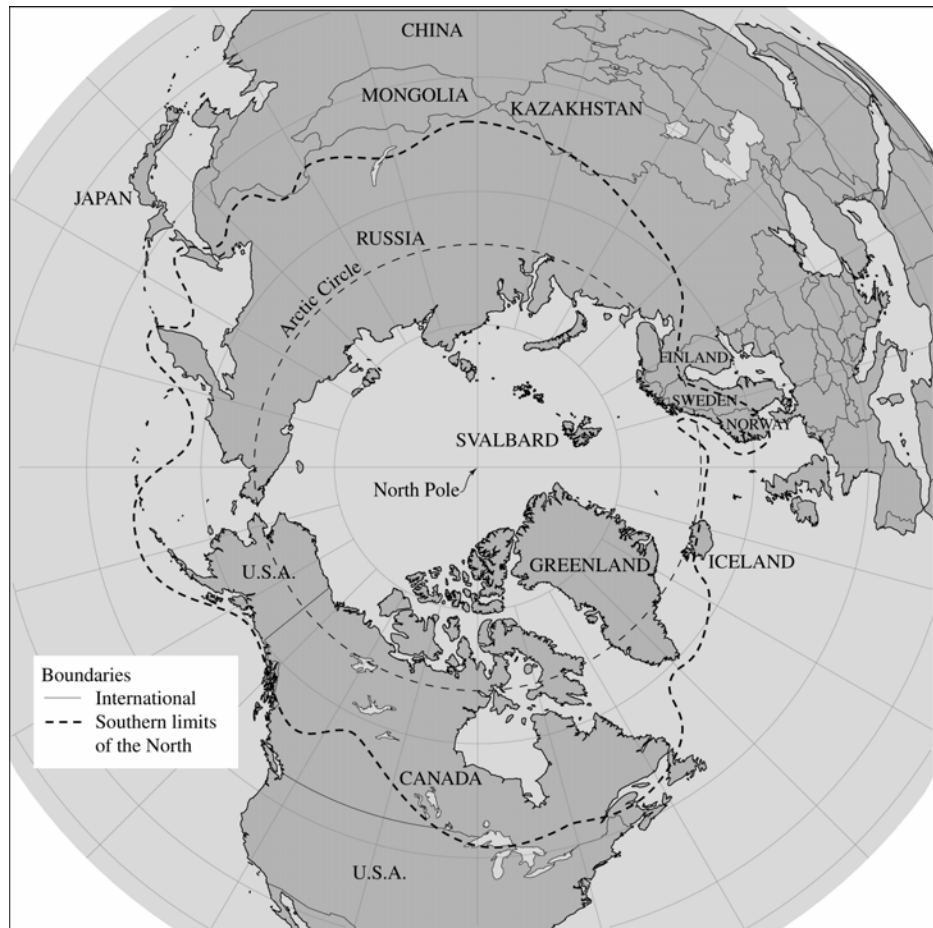


**Fig. 1.9** Map of the circumpolar North illustrating the treeline, marking the boundary on the continents between the Boreal Forest biome of the Subarctic region and the Tundra biome of the Arctic region, as well as the boundary in the oceans between the Arctic and Subarctic marine zones. Note that the boundary separating Subarctic and Arctic regions on land does not correspond with the boundary in the marine environment.

Each of the criteria is assigned a maximum value of 100 polar units. The sum of the ten individual values gives the total degree of *nordicity* for the location under consideration. The maximum value of the Nordic Index is 1000 polar units and would correspond to the North Pole. Using the criteria for the Nordic Index, Hamelin established the southern boundary of the circumpolar North as an isoline of 200 polar units (see fig. 1.9).



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**Source of Projection:** Azimuthal Equidistant. Latitude of Origin 90° N, Central Meridian 90° W.

**Fig. 1.10** Map illustrating the boundary of the nordic world as defined by the Nordic Index of Hamelin

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### Student Activity

1. How many criteria comprise the Nordic Index?
  2. Which of these criteria relate to human activity?
  3. How many different boundaries for defining the Arctic are there?
  4. Which boundary is most relevant to you? Why?
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### Summary

No simple definition exists to define the North in a way that is relevant to all areas of scientific inquiry. To define the concept of nordicity, various disciplines in the natural and social sciences have posited criteria based on Earth-Sun relationships, variations in climate parameters such as temperature and precipitation, the mixing of water masses in the oceans, and the nature of socio-economic development of regions and communities. None of these criteria has proven entirely satisfactory. The Canadian geographer Louis-Edmond Hamelin has made a unique contribution to the study of the concept of nordicity through the development of a quantitative measure that he refers to as the Nordic Index. This index is based on a combination of biological, physical, demographic, and economic development criteria in order to reflect the natural and human-modified characteristics of northern environments.

### Study Questions

#### A. Multiple Choice Questions

1. Arrange these locations from greatest to least according to the “*valeurs polaire*” criteria for nordicity:  
  
**Schefferville, Quebec, 295; Rankin Inlet, Nunavut, 622; Resolute, Nunavut, 775; Bathurst Inlet, Nunavut, 812; Dawson, Yukon, 435.**
  - a. Schefferville; Dawson; Rankin Inlet; Resolute; Bathurst Inlet
  - b. Schefferville; Rankin Inlet; Resolute, Bathurst Inlet; Dawson
  - c. Bathurst Inlet; Resolute; Rankin Inlet; Dawson; Schefferville
  - d. Bathurst Inlet; Dawson; Rankin Inlet; Resolute; Schefferville
2. Which of the following statements is false?
  - a. Low Arctic environments are situated at latitudes of 60° to 75° north.
  - b. Low Arctic environments are underlain by discontinuous permafrost.
  - c. Low Arctic environments exhibit summer temperatures warmer than 5°C.
  - d. Low Arctic environments exhibit tundra vegetation.



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3. The quantity of energy received from the Sun at the Earth's surface depends on \_\_\_\_\_.
  - a. the tilt of the Earth's rotational axis
  - b. the day length period
  - c. the latitude of the location on the surface of the Earth
  - d. all of the above
  - e. only a
  - f. only c
4. The Arctic Circle is situated at \_\_\_\_\_ north \_\_\_\_\_.
  - a. 55°; latitude
  - b. 66°33'; longitude
  - c. 66°33'; latitude
  - d. 55°; longitude
  - e. 90°; latitude
5. The combination of summer temperatures less than 5°C, continuous permafrost, and tundra vegetation characterizes the \_\_\_\_\_.
  - a. High Arctic region
  - b. Low Arctic region
  - c. Subarctic region
  - d. treeline

### Answers to Multiple Choice Questions

1. c
2. b
3. d
4. c
5. a

### B. Essay Question

Discuss the role of climate in distinguishing between Subarctic and Arctic environments by using the various criteria presented in this module.



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### Glossary of Terms

biome	a large, naturally occurring community of flora and fauna adapted to the particular conditions in which they occur.
ecosystem	a biological community of interacting organisms and their physical environment.
evaporate	turn from solid or liquid into vapour.
evapotranspiration	potential evaporation; one of the components of water balance used in the Thornwaite System to describe the climate of a region. [see EVAPORATE and TRANSPIRE]
International Date Line	the imaginary line on the Earth that separates two consecutive days, lies mostly on the 180° meridian, and makes up the other half of the prime meridian.
isotherm	<b>1</b> a line on a map connecting places having the same temperature at a given time or on average over a given period. <b>2</b> a curve for changes in a physical system at a constant temperature.
meridians of longitude	imaginary lines running from the North Pole to the South Pole of the Earth; used with parallels of latitude as part of a coordinate grid system to locate the position of phenomena on the surface of the Earth.
Nordic Index	a point system used to classify natural and human-modified characteristics of northern environments according to a combination of biological, physical, demographic, and economic development criteria.
nordicity	a measure of the degree of northerness of a high-latitude place, calculated by assigning values to ten criteria, including latitude, summer heat, and annual cold.
obliquity of the ecliptic	the tilt of the Earth's rotational axis, which causes the seasonal variations of receipt of solar radiation and day length.
parallels of latitude	imaginary lines running from east to west on the Earth and spaced parallel to each other; used with parallels of latitude as part of a coordinate grid system to locate the position of phenomena on the surface of the Earth.





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permafrost	Subsoil that remains below the freezing point throughout the year, as in polar regions.
polar units	values assigned to ten criteria to define the nordicity of a place, usually in a northern environment, as part of the Nordic Index.
soil moisture deficit	a net loss of water from soil; used in the Thornthwaite System of climate classification.
transpire	(of a leaf or plant) to emit water vapour.

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