Topic 4.1

Technological Innovations from 1450 to 1750

You Will Learn To:

- Describe knowledge and scientific contributions from the Classical, Islamic, and Asian worlds that facilitated European technological developments and innovations.
- Identify new navigational tools, ship designs, and mariners' improved understandings of meteorological patterns.
- Explain how transoceanic travel and trade was impacted by the new navigational tools, ship designs, and mariners' improved understandings of meteorological patterns.

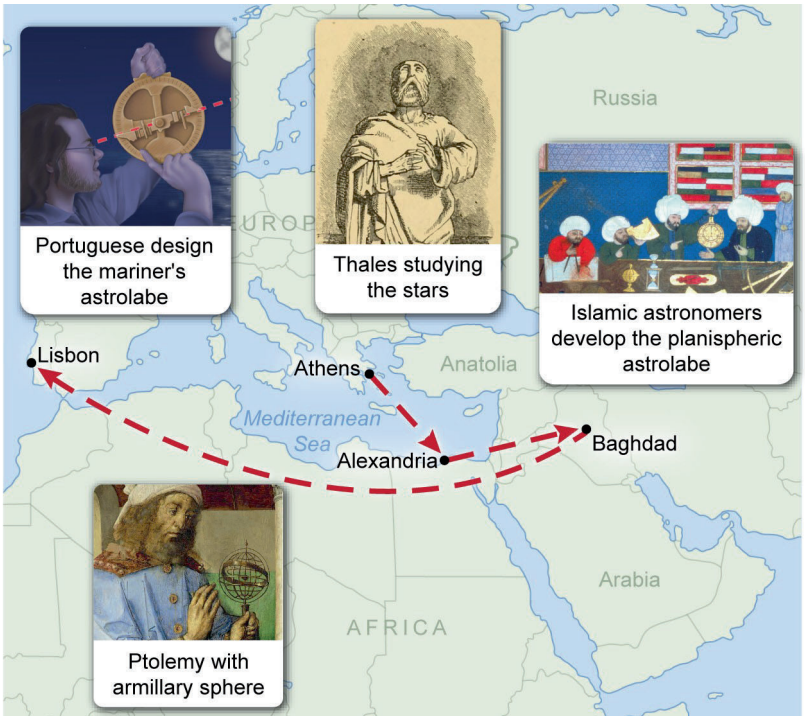
In the 1500s, European states experienced demographic pressures, partly stemming from populations rebounding after the Black Death. Additionally, some European leaders expanded their countries' horizons for God, gold, and glory. These factors both contributed to the Age of Exploration.

The explorations were boosted by ancient Greek, Asian, and Islamic developments—including ship designs and navigational tools—passed down to later generations of sailors. Creative Europeans improved upon many of those developments, aiding the early transoceanic journeys undertaken by Portuguese, Spanish, and Dutch mariners.

European mariners aided by earlier knowledge and technologies

Contributions from the Classical World

Around 600 B.C.E., the Greek philosopher Thales taught Greek mariners to navigate using constellations when sailing the Mediterranean and adjacent seas. Later, Hipparchus and Ptolemy made further progress with calculating celestial coordinates.



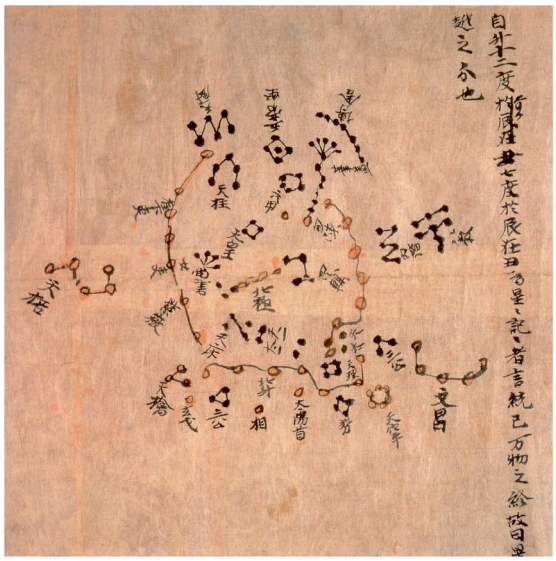
Knowledge of ancient Greek calculations and instruments, such as the armillary sphere, spread to future sailors in other regions. Similarly, Greek geographic knowledge was held in Byzantine and Islamic libraries, and was later spread via the Crusades and interregional trade.

Ptolemy's world map, recreated in the 1400s

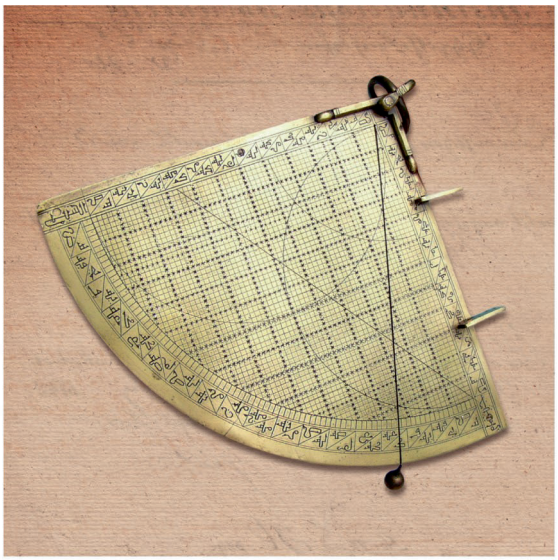
Contributions from the Islamic and Asian Worlds

By the 1300s, trade, diplomacy, and exploration diffused (spread) Islamic and Asian technologies to Europe, including:

- astronomical charts, which were based on Chinese and Muslim star catalogs, astronomical tables, and planetary models.
- the quadrant, which was used for measuring celestial bodies' altitudes to determine a ship's latitude.



8th-century Chinese star map of North Pole projection



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10th-century Arabic Rub'ul mujayyab, or sine quadrant

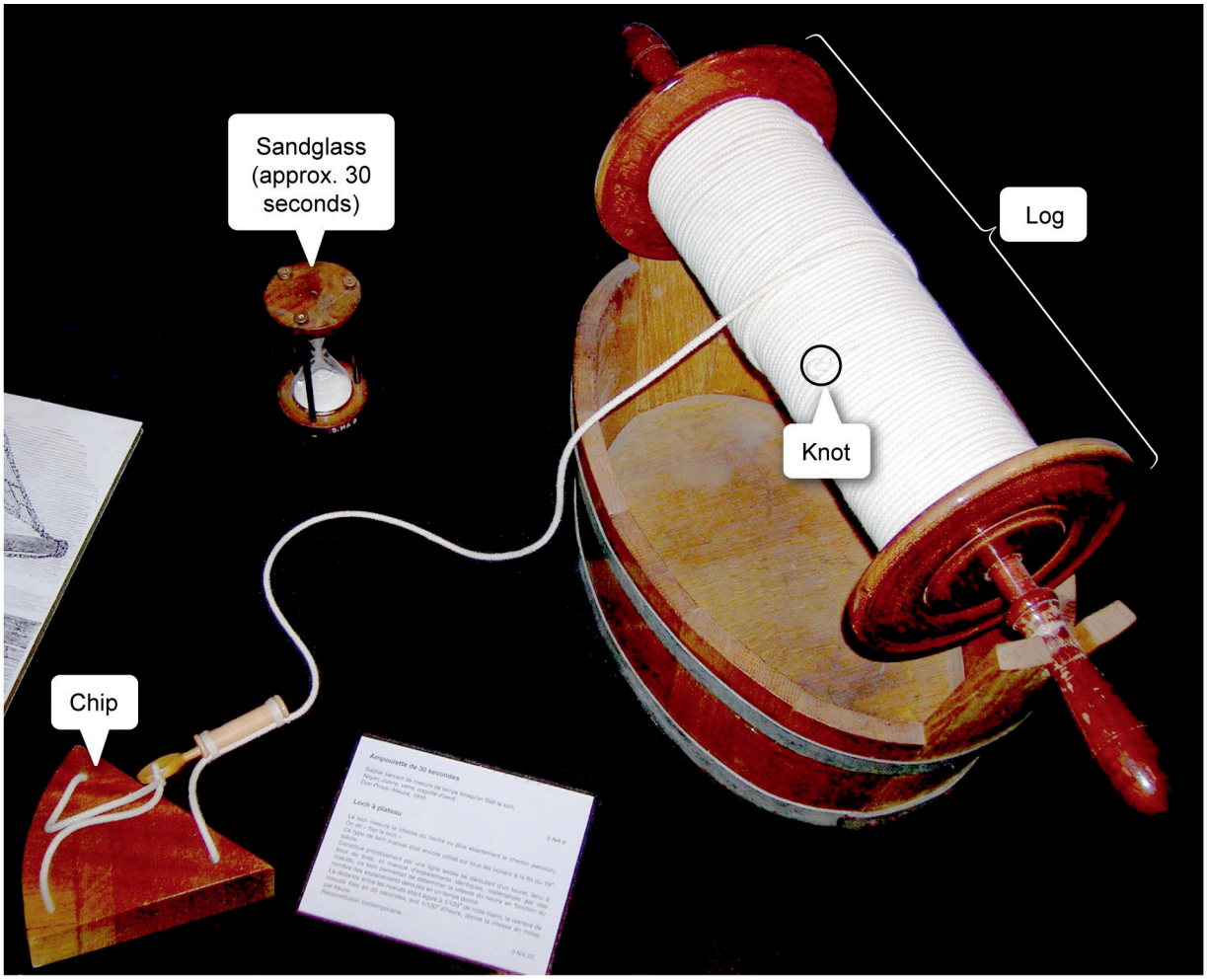
By the 1400s, Europeans had adopted other navigational advancements from the Middle and Far East, including:

- qâribs, which became the basis for the Portuguese caravel.
- lateen sails, which Arab traders adapted from Malaysian sails.
- the compass, invented in ancient China and passed to Arab merchants.
- the terrestrial astrolabe, developed by Islamic scholars.

Innovations in navigational tools facilitated transoceanic voyages

Chip Logs

Around the early 1500s, European mariners developed the "chip log" system to calculate a ship's speed in knots. The log was a spool of rope, with knots at uniform intervals, tied to a triangular chip of wood. After the chip was thrown into the water, watchmen counted the number of knots that unreeled in approximately 30-second increments, as timed by a sandglass.



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"Chip log" tools

Traverse Boards

A ship's direction was recorded every 30 minutes on a traverse board, which had a 32-point compass rose, with each point having eight holes. This pattern created eight concentric circles, each representing a 30-minute interval to be marked with a peg (based on compass readings) over a four-hour watch.

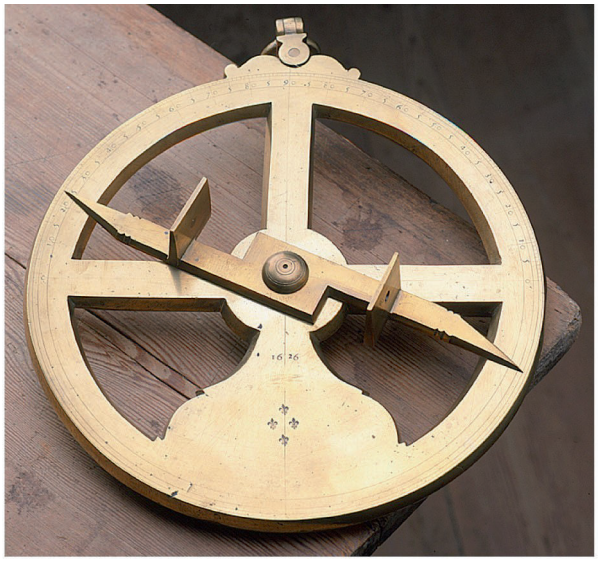
Source: Anneli Salo, CC BY-SA 3.0 (tinyurl.com/4puz4836)

Traverse board used for dead reckoning

Horizontal rows at the bottom of the board recorded the ship's speed at half-hour intervals using the same peg-and-hole method. After a watch, the collected information was recorded in the ship's log. The logbook was then passed to navigators who estimated the ship's location via dead reckoning, the primary method for determining longitude at sea.

Mariner's Astrolabe

In the late 1400s, King John II of Portugal sponsored engineers tasked with modifying the terrestrial astrolabe for seafaring.



17th-century mariner's astrolabe

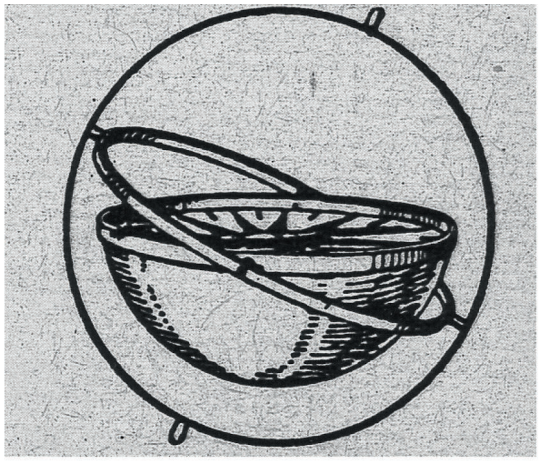
The engineers' efforts led to the mariner's astrolabe, with modifications that included:

- a simpler sighting device.
- a simpler graduated scale to determine angles.
- increased weight, making it less sensitive to a ship's movements.
- large openings, reducing its wind resistance.

Marine Compass

A simple compass requires only a rotating magnetized needle and a stationary compass card indicating cardinal and intercardinal directions. To compensate for a ship rolling in turbulent waters, the simple compass was improved by:

- attaching the magnetized needle to a rotating compass card that was balanced on a point.
- mounting the compass on gimbals, helping it remain horizontal as the ship rocked.



Dry mariner's compass with a gimbal mount, 1570

New ship designs facilitated transoceanic voyages

Carracks

Carracks were two- to four-masted ships vital to Portuguese fleets during the Age of Exploration.

Early 16th-century Portuguese three-masted carrack (*nao*) surrounded by other ships

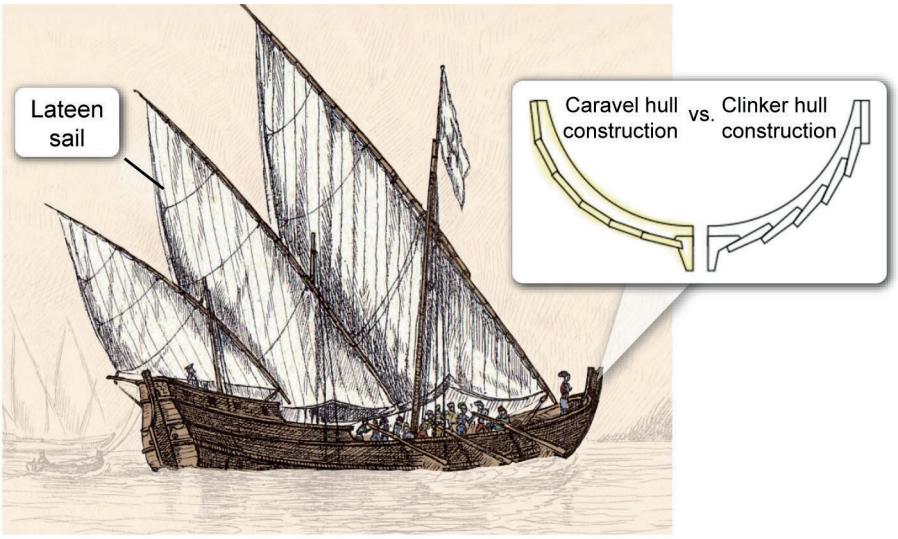
In the mid-1400s, Portuguese engineers designed the formidable carracks to have specific advantages over other European ships, including:

- increased carrying capacity for heavier cargo and more supplies for extended journeys.
- possessing a greater number of cabins, which could accommodate larger crews.
- supporting additional cannons on each side of a ship.

Caravels

In the late 15th century, Portuguese engineers also improved the Arab qârib by increasing its size to make transoceanic voyages possible. Over the following decades, the Portuguese further improved the qârib, designing caravels that included:

- a smoother hull, improving the ship's speed and maneuverability.
- supplementary masts fitted with lateen sails, permitting crews to sail toward the wind.



Example of caravel with typical elements of smoother hull and lateen sails

Additionally, caravels could be operated by small crews, reducing the food supplies needed for long voyages. Given the caravel's advantages, it became prized for transoceanic travel, beginning with Columbus' journeys to the New World.

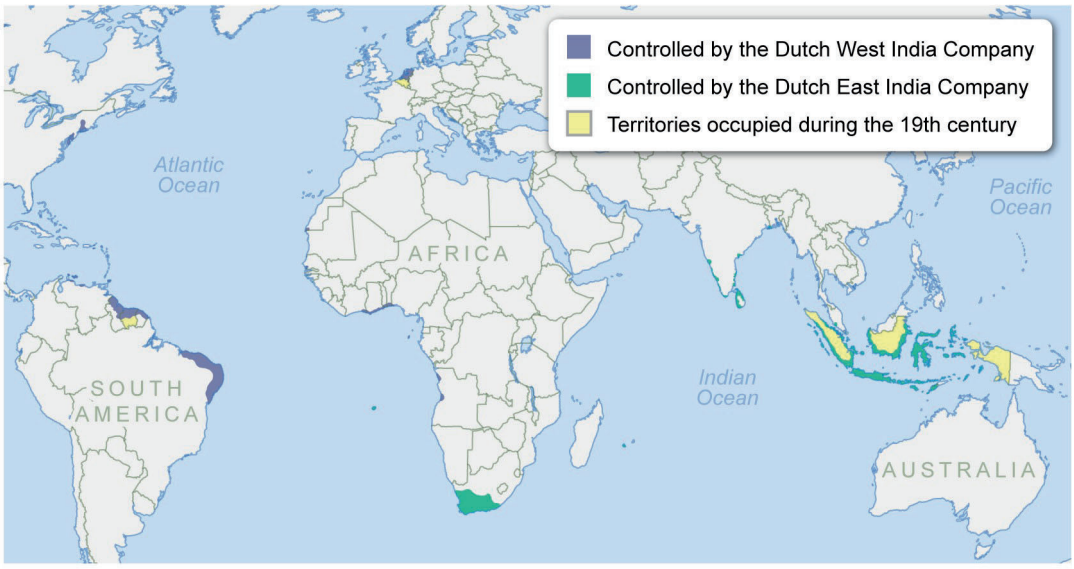
Fluyts

Like the caravel, the Dutch fluyt, designed in the 1590s, had advantages over traditional European ships. These advantages included:

- high maneuverability.
- low construction costs.
- being operable by smaller crews.
- bulbous (rounded) hulls that fit more cargo.
- three tall masts hoisting larger sails, increasing sailing speed.

Dutch fluyt

These features made the fluyt excellent vessels for long-distance trade for the Dutch West India Company and the Dutch East India Company, thereby helping the Netherlands expand its trading-post empire.



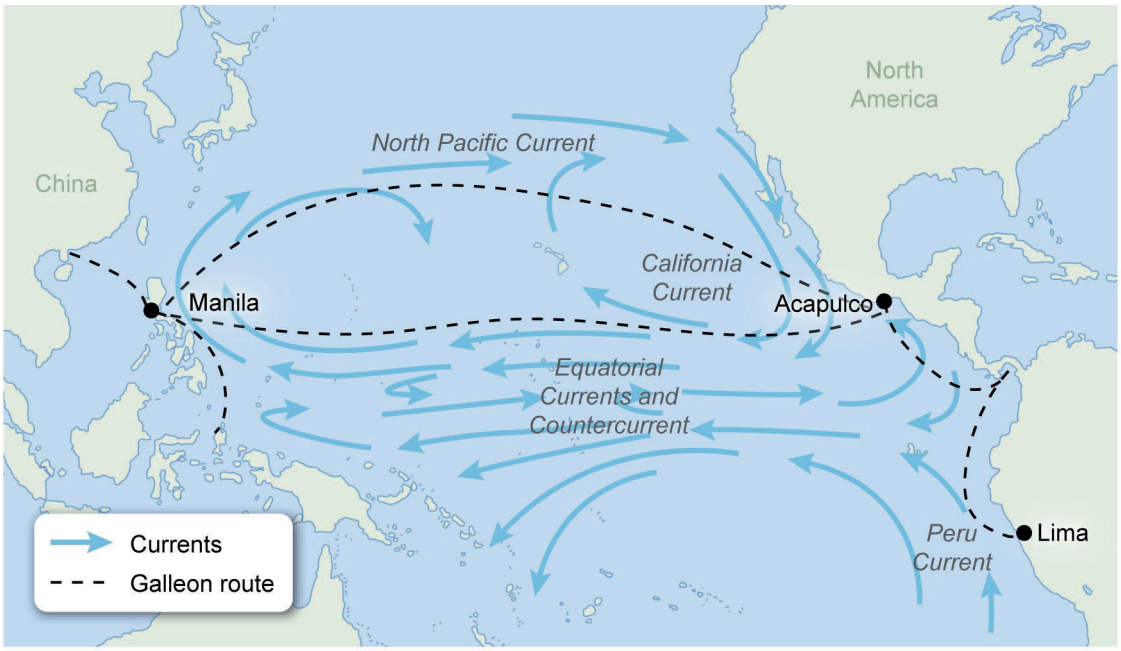
Source: Wikipedia: Chandrani87669; https://tinyurl.com/3c2u6v7y. Adapted to include key.

Dutch trading-post empire

Understanding meteorological patterns facilitated transoceanic voyages

Regional Oceanic Currents

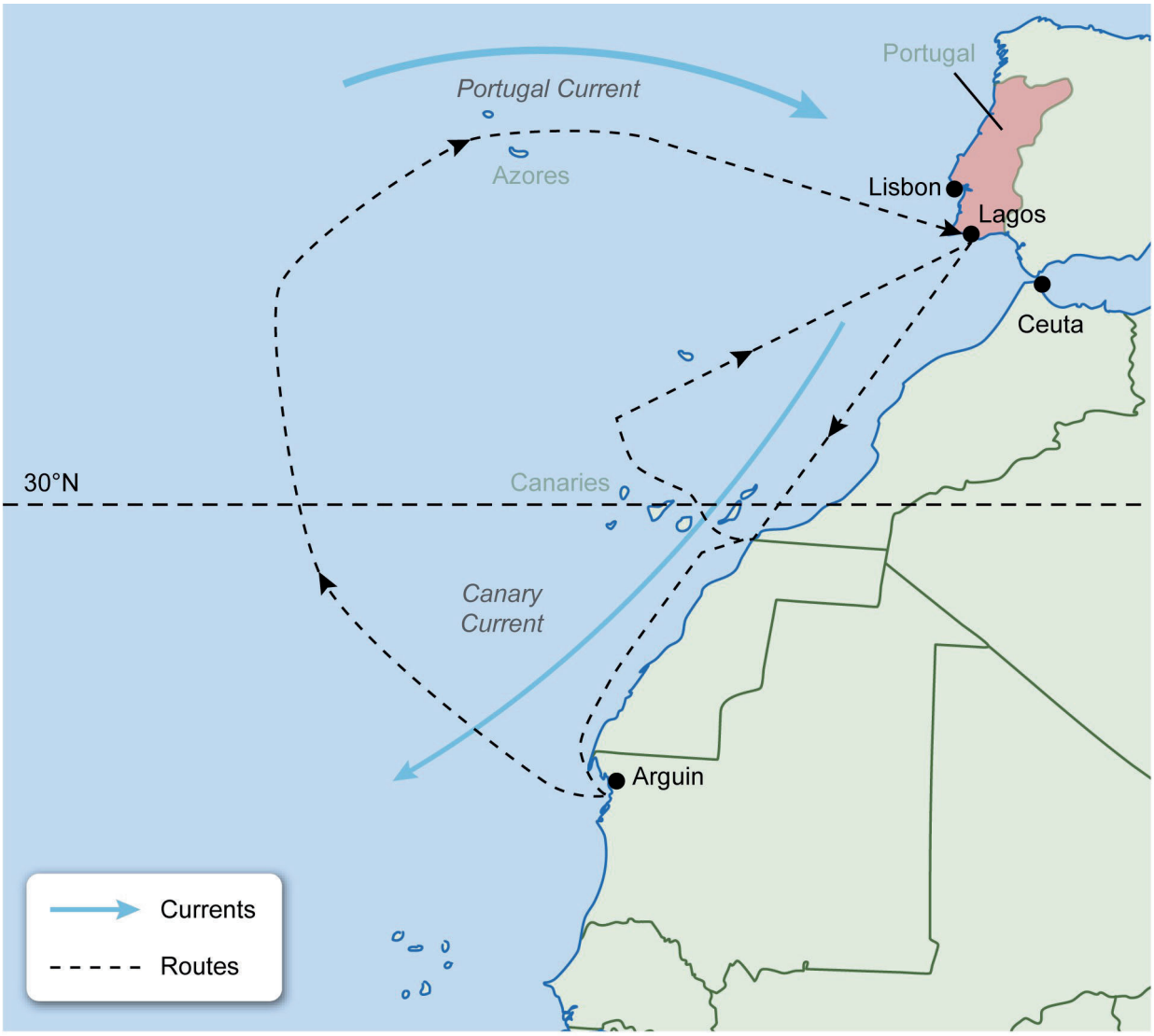
Spanish mariners learned to use the Pacific Ocean's currents to speed along ships involved in the Manila galleon trade. Near the equator, Spanish sailors used the cyclical currents and countercurrents; in northern latitudes, Spaniards took advantage of the North Pacific current when returning to the Americas.



Pacific currents as used in Spain's Manila galleon route

Along the Americas' western coasts, Spanish navigators utilized the southward flowing California current to reach Spain's Central and South American domains. Farther south, they used the Peruvian current to launch ships bound for Manila.

Similarly, Portugal's expeditions along Africa's western coast helped Portuguese sailors understand and use the North Atlantic Gyre in conjunction with the trade winds near the Tropic of Cancer.

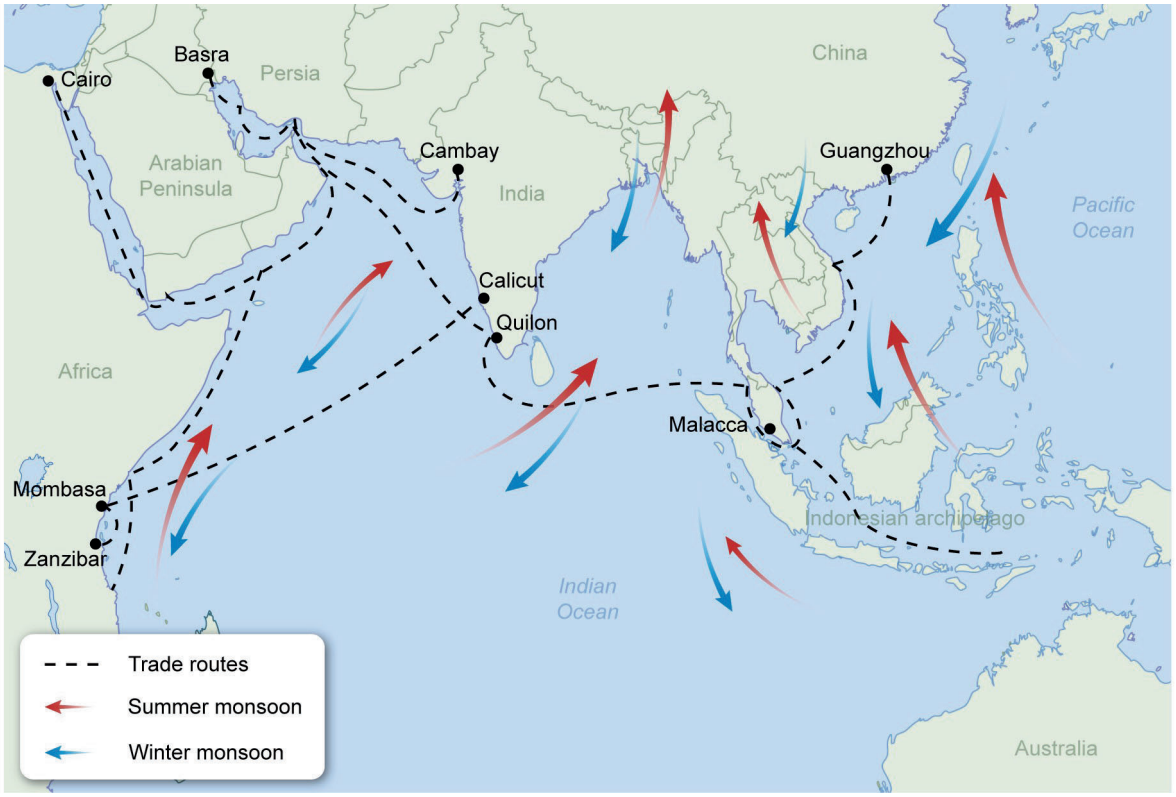


North Atlantic gyre as used by early Portuguese navigators

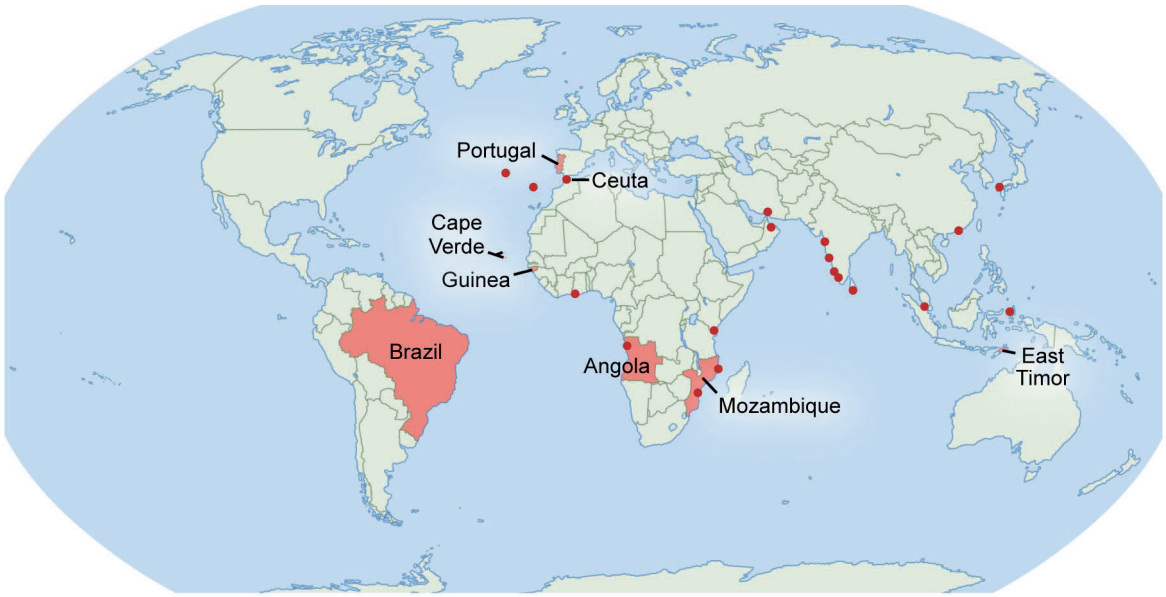
Near the Tropic of Cancer, the gyre's clockwise current sped Portuguese mariners southward toward the country's ports in the Canary Islands and along West Africa. Going northward, the gyre pushed Portuguese sailors toward the Azores Islands before returning to Portugal.

Regional Wind Patterns

Early Portuguese voyages also yielded information regarding weather patterns, such as the timing of monsoons. For example, in 1500, Pedro Álvares Cabral's fleet was en route to India, but six vessels sank during a storm off the southern tip of Africa. Although tragic, the incident contributed to mariners' growing body of knowledge about the South Atlantic's seasonal wind patterns.



From Cabral's voyage, mariners also discovered the best seasons for utilizing monsoon winds that propelled ships in the Indian Ocean trade, which was vital to the Portuguese global trading-post empire.



Portuguese global trading-post empire

Things to remember

Between roughly 1450 and 1750, Europeans utilized knowledge and equipment passed down from the Classical, Islamic, and Asian worlds, such as:

- methods of navigating using constellations.
- instruments, such as the armillary sphere, simple compass, and terrestrial astrolabe.
- the qârib and its lateen sails.

European technological innovations included:

- navigational tools, such as:
  - the mariner's astrolabe.
  - the marine compass.
  - the chip log system.
  - the traverse board.
- new ship designs, such as:
  - the Portuguese carrack and caravel.
  - the Dutch fluyt.

Expansion of European knowledge included greater understandings of environmental phenomena, as demonstrated by:

- Spanish sailors using Pacific oceanic currents.
- Portuguese mariners utilizing the North Atlantic Gyre and learning when to take advantage of the Indian Ocean's monsoon seasons.

4.1 Check for Understanding

1. **Ancient Greek achievements in astronomy initially spread to the Middle East via**

   A. fluyts and carracks.

   B. the North Atlantic gyre.

   C. the Crusades and trade.

2. **The compass was invented in _____ and spread to _____.**

   A. ancient China; Arab merchants

   B. the Malay Archipelago; Abbasid scholars

   C. ancient Greece; Portuguese missionaries

3. **In the chip log system, a chip was**

   A. a spool of rope with knots at uniform intervals.

   B. a piece of wood that was thrown into the water.

   C. a board that displayed a 32-point compass rose.

4. **Portuguese engineers modified the terrestrial astrolabe for seafaring by**

   A. creating small openings to increase its wind resistance.

   B. attaching a magnetized needle to a rotating compass card.

   C. increasing its weight, making it less sensitive to movement.

5. **For trading-post empires, which of the following was an advantage of using carracks?**

   A. They were highly maneuverable and had low construction costs.

   B. They carried heavier cargo and more supplies for extended journeys.

   C. They required small crews, reducing the food stocks needed for long voyages.

6. **Which of the following trading-post empires is credited with being the first to understand how to use the North Atlantic gyre to reach West Africa's coast?**

   A. Spain

   B. Portugal

   C. The Netherlands