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CHRONICLES OF THE SEA: FROM ANCIENT GREEK GALLEYS TO MODERN MARVELS, JOURNEY TROUGH NAVAL HISTORY

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Abstract: This publication attempts to present the history of the sailing ships development, from ancient times to the present day. It is almost impossible to present the development history of such an important technological achievement in a few pages, so we only focus on the most significant turning points in the publication. We present the ancient ships, the long ships of the Vikings, the shipbuilding techniques of the age of great geographical discoveries. We analyse the characteristics of line of ships, which greatly influenced the battles of the great powers of the world. Finally, we give a small overview of currently used sailing ship technologies.

Keywords: *naval history, ancient ship, sailing ship, line of ship*

1. INTRODUCTION

The history of sailing ships is a captivating journey spanning millennium, intricately woven into the fabric of human civilization. Over time, shipbuilding has been one of the driving forces behind the development of technology, which has been replaced by aviation in recent times. Humanity has always wanted to know and discover the unknown. From the beginning of mankind, we felt the urge to conquer the waters and the air. This article provides a concise exploration of the pivotal milestones in the evolution of sailing ships, tracing their development from prehistoric times to the present day. We present the typical ship types of the ancient times (Egypt, Rome). We mention the long ships created by the Vikings and their ship building technology. Famous ships of the age of great geographical discoveries (Nina, Pinta, Santa-Maria). Horatio Nelson's flagship, the HMS Victory, and then we will come to today's sailing ships developed with modern technology, to which the technical knowledge acquired in the science of aviation has already imparted to humanity and can predict the future vision of shipping.

2. ANATOMY OF A SAILING SHIP

A sailing ship is a complex ensemble of carefully designed components that collectively ensure its functionality and navigation. From the commanding bow to the stern, the rear counterpart of ship, and the sides known as port and starboard, each

part plays a crucial role. The right and left sides of the ships have been given separate names so that it is always clear regardless of the current position of the crew. The deck serves as the main horizontal surface, while the hull, submerged beneath the waterline, provides buoyancy, and houses essential compartments. Above the deck lies the superstructure, housing cabins and the command centre – the bridge. The mast rises vertically, supporting sails or navigation equipment, while the rudder at the stern controls the moving direction of the ship by manipulating the flow of water. In *Figure 1* can be seen the parts of a regular sailing ship (Compton, 2014).

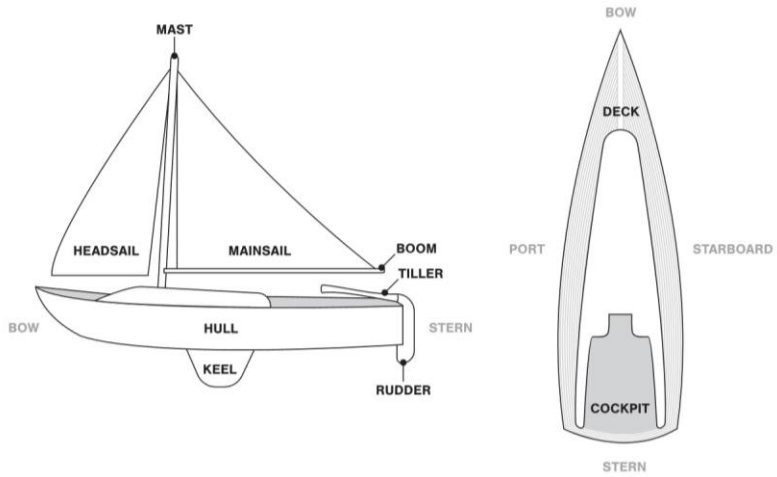


Figure 1. *The anatomy of sailing ship seen from the port (the left side of the vehicle) and from above*
https://www.sailrite.com/anatomy-of-a-sailboat

3. IMPORTANT STAGES IN SAILING SHIP HISTORY

The evolution of sailing ship has been profoundly influenced by technological advancements, economic demands, and strategic considerations. Several key stages mark this dynamic journey:

- ***Trade and Exploration:*** The expansion of maritime trade routes prompted the need for more efficient and capacious sailing ships. Innovations in hull design and rigging emerged to meet the growing demands of commerce.
- ***Navigation Technology:*** The development of navigation tools, from the compass to the sextant and the spring propelled mechanical clocks [John Harrison's (1693–1776) marine chronometer, the H4 from 1759], empowered sailors to navigate accurately across vast distances. These technological leaps influenced ship design to conquer diverse sea conditions.
- ***Military Needs:*** Naval powers drove innovations in shipbuilding to gain advantages in warfare. This led to the creation of various warships, emphasizing speed and manoeuvrability, shaping the evolution of sailboats.

- ***Scientific Inquiry:*** During the Age of Enlightenment, sailing ships became indispensable for scientific voyages. Expeditions led by figures like Captain James Cook (1728–1779) contributed to advancements in cartography, biology, and astronomy.
- ***Materials and Construction Techniques:*** The transition from wood to iron and eventually steel, along with improved construction methods, enhanced the durability and seaworthiness of sailboats, enabling larger and more complex designs.
- ***Cultural Exchange:*** Interaction between maritime cultures facilitated the exchange of shipbuilding knowledge. Techniques and designs from one region enriched the practices of another, fostering a global progression in sailing ship development.
- ***Competition and Innovation:*** Rivalry among maritime powers fuelled a competitive environment that propelled innovation. Each sought superiority in ship speed, cargo capacity, and naval dominance, resulting in continuous improvements in sailboat design.

In essence, the evolution of sailboats unfolds as a dynamic interplay of technological progress, economic imperatives, strategic considerations, and cultural exchange. This ongoing process has given rise to a diverse array of sailboat types, each optimized for specific purposes and conditions, contributing to the rich tapestry of maritime history (Anderson & Anderson, 2012).

4. SAILING THROUGH TIME: THE DYNAMIC EVOLUTION FROM PREHISTORY TO TODAY

4.1. Prehistory

Sailing, a practice rooted in ancient history, finds its origins in the humble beginnings of simple rafts and dugout canoes equipped with rudimentary sails crafted from animal hides or woven reeds *(Figure 2)*.

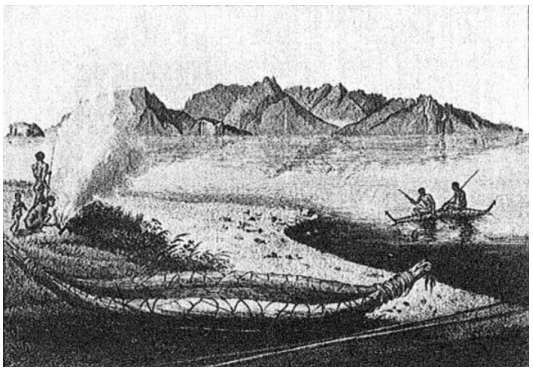


Figure 2. *The first boats: simple rafts or bark-bundle crafts* (Johnstone, 1980)

Early sailing vessels, initially used for fishing, transportation, and exploration, became crucial assets for civilizations like the Egyptians and Phoenicians. The maritime evolution of sailing witnessed notable contributions from the Egyptians and Phoenicians, particularly in the Atlantic tradition. Despite navigating both the Mediterranean Sea and the Atlantic Ocean, their influence diverged from other maritime cultures (Lavery, 2010). The earliest depiction of an Egyptian boat under sail dates back to 3500 BC, revealing reed rafts with masts on the Nile – a river pivotal to ancient Egyptian civilization. The discovery of the Cheops ship, a well-preserved artifact from 2600 BC, provides insight into ancient shipbuilding techniques. Although primarily a funeral ship, the Cheops (2589 BC-2566 BC) ship showcased the Egyptians' advanced maritime knowledge *(Figure 3)* (Leary, 2014).

By 2500 BC, wooden ships resembling river rafts emerged, facilitating trade along the Nile and the eastern Mediterranean coast. These flat-bottomed, square-ended vessels lacked a keel, limiting their size and suitability for coastal travel rather than open ocean navigation. While seagoing Egyptian boats resembled reinforced versions of river and coastal vessels, the Phoenicians, hailing from modern Lebanon, emerged as maritime experts in European antiquity. Despite limited evidence, Phoenician trading vessels with sturdy hulls and wooden plank decks revealed their prowess. By 1000 BC, Phoenician mariners ventured to Cornwall (Southwest part of the British Isle) for tin, and by 460 BC, they sailed as far as the Cape Verde Islands, marking a remarkable 2000-mile journey into the Atlantic Ocean. The work of the Phoenicians not confined only to trade, but they developed war galleys in response to Greek maritime competition, showcasing their versatility as seafarers. The Phoenician legacy in sailing underscores their crucial role in shaping ancient maritime history, setting the stage for further exploration and competition with emerging Mediterranean powers, particularly the Greeks (Lavery, 2010).



Figure 3. *Cheops ship (preserved in the Giza Solar boat museum, but was move to the Gran Egyptian Museum in August 2021)* (Stein, 2017)

4.2. Ancient Civilizations

In the vast expanse of ancient maritime endeavours, the Greeks and Romans emerge as masterful architects, refining sailing technology and leaving an enduring legacy on naval warfare and trade in the Mediterranean.

Sailing Dynamics: A Balancing Act

Ancient boat speed, whether determined by oars or canvas, set the stage for the Greeks and Romans. While both civilizations engaged in maritime commerce using sailing vessels, their approach to naval warfare took a different course. The Greeks and Romans navigated the seas with oar-powered galleys, setting them apart from the slower, yet sturdy, trading ships of the time. The iconic slender galleys, revered as maritime icons in European antiquity, outshone their bulkier trading counterparts. This preference was a testament to the limitations of sailing know-how during this era, with rigging consisting of one or two masts carrying a single square sail.

Galleys: Masters of Naval Warfare

Galleys emerged as dominant forces in ancient naval warfare. The intricate dance of sails, wind, and oars required ample deck space, posing a challenge for warships that needed a clear area for soldiers. Consequently, oars became the preferred choice for warships due to their efficient use of deck space, a practical solution to the constraints posed by sails during battle (Figure 4). Before the advent of gunpowder and cannons, naval warfare was essentially a land battle at sea. Greek and Roman galleys engaged in ramming tactics, and if this failed, soldiers poured over the gunwales for hand-to-hand combat. The need for speed dictated the design, leading to longer galleys and the introduction of biremes and triremes, with some boasting up to 170 oarsmen, dominating Mediterranean waters from the 6th to the 4th century BC (Lavery, 2010).

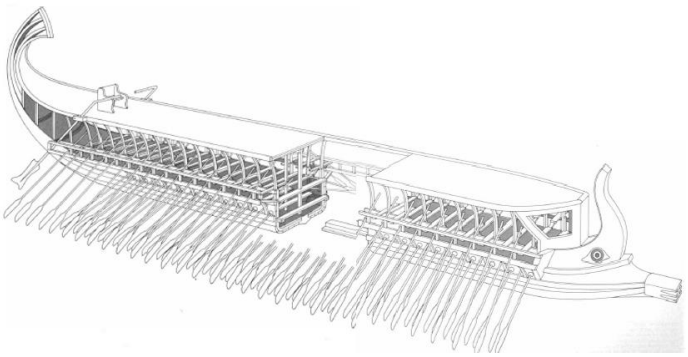


Figure 4. *An 18th-century engraving of a Roman warship*
© Stapleton Collection/CORBIS (Foley & Soedel, 1981)

Roman Naval Supremacy: Quadriremes and Quinqueremes

As Rome succeeded Greece as the Mediterranean powerhouse, Roman galleys evolved into larger quadriremes and quinqueremes. The nomenclature here refers not to banks of oars but to the number of oarsmen per oar. Roman engineering prowess, coupled with influences from the Greeks and Carthaginians, propelled these galleys to dominance, lasting until the 5th century AD. These robust vessels served as troop transporters and formidable weapons platforms, capable of carrying 120 soldiers along with oarsmen. Disembarkation occurred via hinged gangplanks, resembling manoeuvres executed by World War II landing craft.

Merchant Ships: The Backbone of Trade

In contrast to the formidable war galleys, merchant ships played a crucial role in facilitating trade. The Mediterranean's relative safety from piracy allowed Roman merchants to flourish. Roman merchant vessels *(Figure 5)* adopted the proven design of Greek hulls, featuring symmetrical twin steering oars for effective manoeuvring. Despite challenges such as ship-worm damage and the absence of dry-dock facilities, Roman merchant ships thrived. Rigging improvements, including square-rigged sails and lateen rigs, contributed to their success. By the 5th century AD, Roman merchant ships dominated trade routes, notably importing vast quantities of grain from Egypt (Lavery, 2010).

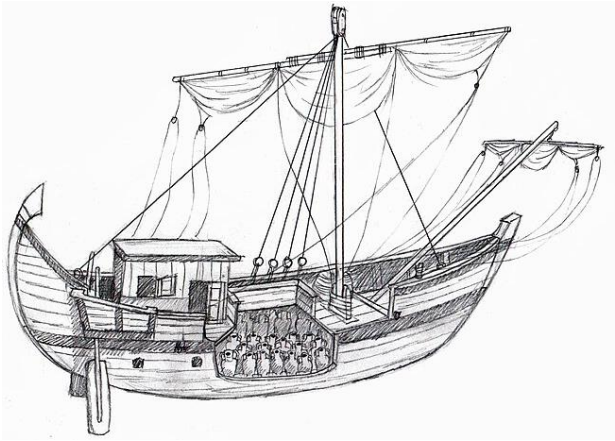


Figure 5. *Roman merchant ship*
(drawing made by Matthew Jose Fischer)

Legacy Unveiled: A Sailing Saga

In summary, the Greeks and Romans etched their indelible mark on ancient maritime history, refining sailing vessels for both war and trade. The legacy of their galleys and merchant ships paved the way for future advancements in naval architecture and navigation, leaving behind a sailing saga that resonates through the annals of time.

4.3. Medieval and Renaissance Era

The Middle Ages saw the emergence of lateen sails, which greatly improved manoeuvrability and allowed sailors to sail closer to the wind. The Age of Exploration in the 15th and 16th centuries saw the development of caravels and other sailing ships that enabled long-distance ocean exploration by European powers like Portugal and Spain. Delve deeper into Columbus and la Nina (which is the sailing vessel).

Crafting the Seas: Clinker vs. Carvel Boat Building

Carvel construction *(Figure 7)*, rooted in the eastern Mediterranean and influenced by ancient Egyptian barge building, ushered in a technique laying long planks for a sleek exterior. The strength of carvel boats emanates from the frame, enabling the creation of larger vessels despite the demand for meticulous labour. Carvel built wooden boats and tall ships are made by fixing planks to a frame with all the planks butting up against one another. This creates a smooth hull that's stronger than a clinker-built hull. However, more caulking is needed between the joints in carvel construction than in the clinker method. The framing gives carvel construction a stronger hull, allowing it to carry a full sail plan and have a longer, broader hull.

In the untamed landscapes of northern Europe, clinker construction *(Figure 6)* emerged, fuelled by the absence of precise saws. Using adzes, shipbuilders shaped the keel, stem, and stern posts, fashioning a robust outer shell with overlapping planks (Romey, 2017). Clinker built (or lapstrake) vessels are lighter as they have less internal framing – with the planks overlapping along their edges. As they're lighter, they displace less water allowing them to move faster. Clinker vessels are less rigid than carvel constructions, limiting the type of sailing rigs the vessel can take. In summary, this exploration of clinker and carvel construction transcends mere techniques, weaving a rich tapestry of maritime innovation, regional influences, and pragmatic adaptations. As the annals of boat-building history unfold, the legacy of clinker and carvel methods endures, leaving an indelible mark on naval architecture (Lavery, 2010).

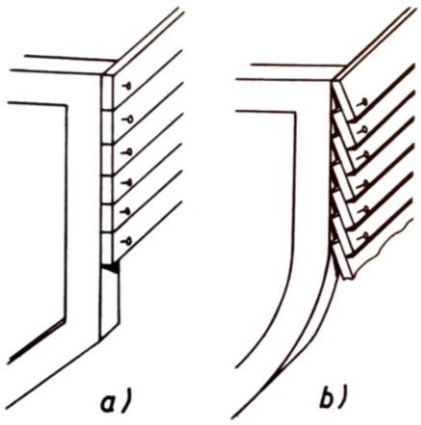


Figure 6. *Carvel (a) and Clinker (b) construction* (Somoskői, 1984)

Viking Longships: Marvels of Clinker-Built Mastery

The Viking longship represents the absolute maximum size for a clinker-built ships and vessels *(Figure 7)*. These double-ended boats, boasting a T-shaped keel and low freeboard, were propelled by oars, particularly in their early days. Similar to Greek and Roman counterparts, Vikings utilized oars for warships and sails for merchant knarrs, such as the high-sided knarr. By 800 AD, the longship evolved, featuring a sizable square sail on a removable mast for sea voyages. Despite their open design and lack of a deck, these vessels undertook daring journeys, reaching as far as Iceland, Greenland, and Newfoundland by 1000 AD. The shallow draft of longships, influenced by their northern origins, made river exploration feasible, extending deep into Russia and the Black Sea. Unlike Mediterranean traditions, northern boatbuilders had not embraced symmetrically placed steering oars. Steering a longship was less intuitive than Roman galleys, with a single oar conventionally placed on the right side, leading to the term "starboard". Quay approaches required strategic manoeuvring, keeping the steering oar away to avoid damage. Regarded by many as the most beautiful boats of the first millennium AD, Viking longboats like the Oseberg and Gokstad ships have left an indelible mark. Archaeological treasures, such as the Oseberg ship from a ninth-century burial mound and the Gokstad ship from a tenth-century site in Norway, showcase their excellence. Replicas of these vessels, demonstrating their seaworthiness, have even crossed the Atlantic, echoing the enduring legacy of Viking clinker-built mastery (Lavery, 2010).

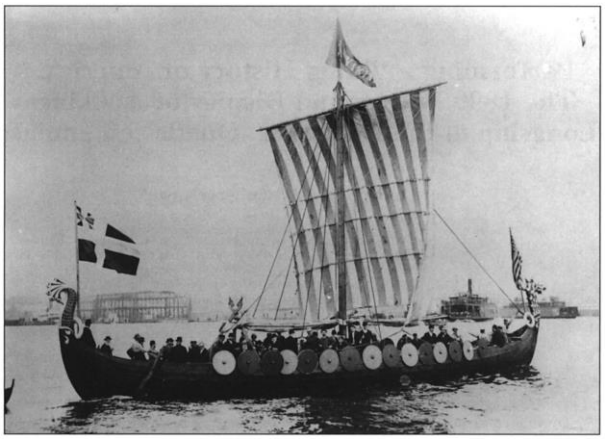


Figure 7. *A clinker-built Viking longship replica from 1893*
(Andersson & Magelssen, 2017)

The medieval contribution

The square sail (*Figure 8* left) was the first and most common sail invented to aid rowers in propelling early ships and were dependent on wind direction. The Lateen sail (*Figure 8* right) replaced the square rig beginning around the third century BC because it was more flexible and could adjust somewhat to the wind direction. In

Europe, around 1200 BC, the square sail was in use on the large ships then being built and remained in use through the Age of Sail (from the mid-16th to the mid-19th centuries), adding a triangular lateen sail in the late 1400s for additional manoeuvrability (Campbell, 1995).

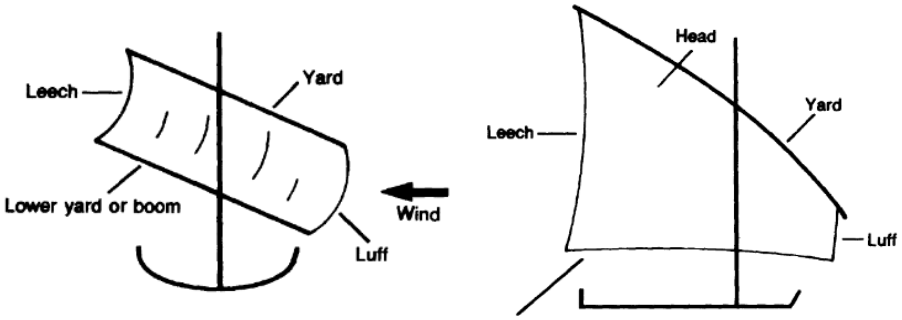


Figure 8. *The square sail (left), the Lateen sail (right)* (Campbell, 1995)

Sailing into the medieval era, the dissolution of the Roman Empire spurred a wave of innovation in shipbuilding. With fluid borders and evolving trade routes, the once-predictable voyages of merchantmen demanded vessels capable of navigating diverse wind and sea conditions, fostering the transition from oar-powered galleys to square-rigged sailing ships. Around the year 1000 AD, sailing technology witnessed a significant leap with the introduction of the lateen sail.

This triangular sail, suspended from a long, oblique yard, was influenced by Arab dhows, and found its place in Byzantine dromos. Dromos were that kind of warships that combined oar propulsion with substantial canvas sails. These vessels, showcasing both speed and manoeuvrability, marked a shift from traditional naval tactics, emphasizing long-range combat over ramming and boarding. In the eastern Mediterranean, the reign of dromos extended from the sixth to the twelfth century AD, sidelining the old square sail. Meanwhile, the clinker zone in northern and western Europe clung to the square sail due to rougher seas. The lateen sail excelled in the sheltered Mediterranean but struggled in the stormy North Sea and Atlantic. Notably, it allowed tacking into the wind, a capability absent in square sails limited to downwind or crosswind manoeuvres. A subsequent breakthrough emerged in the 12th century AD, as stern rudders made their debut in the cold waters of Scandinavia. It originates from China centuries earlier, this efficient steering mechanism spread through northern Europe, challenging the dominance of steering oars. While Mediterranean shipbuilders lagged in adopting stern rudders, the potential of this innovation extended beyond improved steering – it removed size constraints on ships, particularly in open ocean conditions. The explosive growth in sailing ship size arose from the marriage of clinker and carvel strands of the Atlantic tradition. As these two approaches converged, previously separate realms discovered the advantages held by the other, propelling a rapid evolution in sailing technology (Lavery, 2010).

The age of exploration Carrack and Caravel

Navigating the early fifteenth century, the Atlantic shipbuilding tradition experienced a surge, marking an era of remarkable sailing ship development. The blending of northern clinker and Mediterranean carvel designs, initiated during the Crusades, blossomed into a melting pot of ship-building ideas, culminating in the creation of the iconic carrack. The carrack, a carvel-built ship featuring a stern rudder, emerged as a groundbreaking vessel. Originating around Genoa in the fourteenth century, its evolution led to substantial size growth from 600 to 1,600 tons by the sixteenth century. Characterized by high sides, and castles on the stern, the carrack became a staple in Atlantic trade and exploration. Equipped with two to four masts and a fusion of square and lateen rigging, the carrack exemplified the convergence of northern and Mediterranean sailing technologies. Playing a pivotal role in the Age of Exploration, carracks like the Santa Maria accompanied Christopher Columbus to the New World in 1492, showcasing their seaworthiness *(Figure 9)*. As the need for expanding trade and providing effective gun platforms converged, the carrack stood as a testament to the amalgamation of ship-building wisdom.

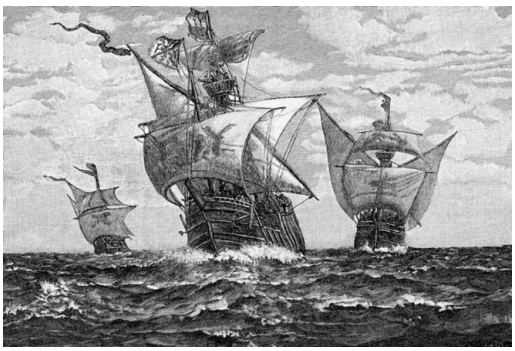


Figure 9. *Two caravels: Niña and Pinta and one carrack: Santa Maria* (Romey, 2017)

Alongside the carrack, the caravel emerged as a smaller but agile counterpart, originating in Portugal and associated with Iberian explorers. Typically measuring 20-25 m, the caravel boasted superior sailing characteristics, proving more manoeuvrable and faster than its larger counterpart. With variations in rigging, such as lateen or square sails, caravels excelled in windward sailing and remained the vessel of choice for open ocean exploration and trade until the late sixteenth century. In this dynamic period, the carrack and caravel symbolize the evolving maritime landscape, embodying the fusion of diverse ideas that shaped the course of naval history (Lavery, 2010). Sailing into the annals of maritime history, the Nina, a caravel of the fifteenth century, became an instrumental vessel in the Age of Exploration. Commissioned by Christopher Columbus for his legendary transatlantic voyages, the Nina exemplifies the pinnacle of caravel design. Measuring approximately 20 to 25 meters, the Nina was a nimble and seaworthy craft. Caravels like the Nina were

carvel-built, featuring a shallower draft, a raised stern, and no forecastle. The hull design provided buoyancy and resistance to leeway, enhancing the ship's manoeuvrability and speed. The Nina was equipped with a distinctive aft castle built on the square stern, and with a practical deck. The rigging of the Nina, crucial to its exceptional sailing capabilities, typically included three or four masts, predominantly lateen-rigged. This sail arrangement allowed the caravel to harness the wind efficiently, making it adept at sailing into the wind, an invaluable trait for exploration voyages where varied wind conditions were encountered. Commissioned by Columbus for his historic journey to the New World in 1492, the Nina played a pivotal role in the first transatlantic crossing. Alongside its counterparts, the Pinta and the Santa Maria, the Nina ventured into uncharted waters, contributing significantly to the European exploration of the Americas. The agility of caravel and manoeuvrability made it suitable for navigating tight bays and close to rocky shorelines, essential qualities for exploration endeavours. As part of Columbus's fleet, the Nina carried the explorers across the Atlantic, showcasing the resilience and adaptability of caravels in the face of the unknown. The historic voyage, while fraught with challenges, marked a transformative moment in world history, with the Nina standing as a testament to the technological prowess and navigational expertise of its time. In the wake of Columbus's journey, the Nina remains an enduring symbol of exploration, embodying the spirit of adventure that defined the Age of Discovery (Lavery, 2010).

4.4. 17th to 19th Century

The 17th century brought innovations like the frigate and brigantine *(Figure 10)*, which were used by navies for both exploration and warfare. The frigates became renowned for their balanced combination of speed, firepower, and endurance. These ships were adaptable, serving various roles such as convoy protection, reconnaissance, and engaging enemy vessels. Brigantines, with their two-masted design, offered agility and versatility, making them valuable assets for both naval and private enterprises (Lavery, 2010).

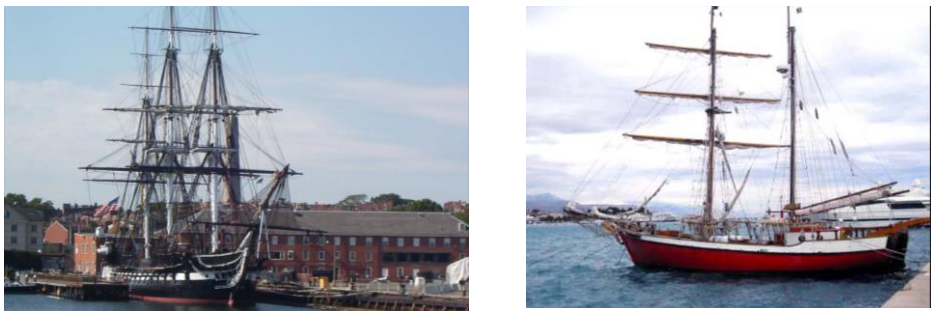


Figure 10. *Frigate sailing ship (left), Brigantine sailing ship (right)*
(Britannica Encyclopedia, 1974)

The 18th century marked the Golden Age of Piracy, with pirates like Blackbeard (Edward Teach) operated sleek schooners, frigates and sloops, prized for their ability to navigate shallow waters. These ships were well-suited for surprise attacks, allowing pirates to exploit their targets with speed and precision.

The 19th century saw the transition from wooden sailing ships to iron and eventually steel, leading to the development of powerful warships and merchant vessels, revolutionized naval architecture. Ironclads, featuring iron armour, emerged as formidable warships, transforming naval warfare *(Figure 11)*. This technological evolution extended to merchant vessels, enhancing their durability and cargo capacity. The transition from sail to steam power further propelled maritime innovation, enabling ships to traverse longer distances with increased efficiency (Lavery, 2010).



Figure 11. *Sail to steam propulsion. The Great White Fleet painting by John Charles Roach, 1984, depicting U.S. Atlantic Fleet battleships steaming at sea during their 1907–1909 World cruise. Courtesy of the U.S. Navy Art Collection, Washington, D.C. U.S. Naval History and Heritage Command photograph. Catalogue #: 95513-KN.*
https://www.history.navy.mil/browse-by-topic/communities/surface/steam.html

Overall, these centuries witnessed a dynamic evolution in ship design and technology, shaping the strategies of exploration, trade, and conflict on the high seas.

The HMS Victory *(Figure 12)*, a renowned ship of the line, epitomized naval power during the 18th and 19th centuries. The HMS Victory was launched at Chatham in 1765. She was a 100-gun ship of the line with a length of 186 feet (57 m), a load capacity of 2,162 tons, and a crew of more than 800 men (Britannica Encyclopedia, 1974). As a first-rate ship, it boasted an impressive three-gun decks, carrying a formidable array of cannons. Typically crewed by hundreds of sailors and marines, ships of the line like the HMS Victory were instrumental in major naval engagements, serving as the backbone of fleets. These vessels were characterized by their massive size, robust construction, and imposing firepower.



Figure 12. *HMS Victory*
(Britannica Encyclopedia, 1974)

The term “ship of the line” referred to their role in forming a line of battle, a strategic formation employed in naval warfare during this era. The imposing broadside of cannons, combined with sturdy hulls, made them formidable adversaries and key assets in securing maritime dominance. The HMS Victory, most famously associated with Admiral Horatio Nelson (1758–1805) and the Battle of Trafalgar in 1805, remains a symbol of naval supremacy and the peak of ship-of-the-line design and effectiveness during the Age of Sail (Lavery, 2010), (Britannica Encyclopedia, 1974).

4.5. 20th Century to Present

The early 20th century witnessed the decline of sail in favour of steam and internal combustion engines for propulsion. Sailing for recreation and sport became increasingly popular, leading to the development of various sailboat classes and regattas. Modern sailing vessels often incorporate advanced materials, like fiberglass and carbon fibre, as well as computer technology for navigation and sail control. Today, sailing boats serve a wide range of purposes, from leisure and sport to cargo transportation and even cutting-edge racing competitions like the America's Cup. The history of sailing boats reflects humanity’s enduring connection to the sea and the ongoing technological advancements that have shaped the world of sailing (Stalmokaitė et al., 2023).

Rotor sail: driving with the wind forenvironmentally friendly and economical sailing

Wind-Assisted Sail Propulsion (WASP) provides an ecological and economical solution for the growing maritime transport sector, responsible for 90% of global shipments. Currently, traditional ships emit significant amounts of air pollutants, contributing to an estimated annual carbon dioxide emission of 812 million tons. Rotor ships, based on the innovative Wind Propulsion Technology (WPT), offer a sustainable

approach. The rotor drive concept has roots dating back almost a century, thanks to the German engineer Anton Flettner. Although past economic crises slowed the development of this technology, recent interest has been revived, exemplified by the Alcyone, a research vessel built in 1985. Rotor transmission harnesses the Magnus effect, known in sports and now applied technologically. As the rotor rotates, it creates an air pressure difference, generating a lateral force propelling the ship forward. This propulsion method enables efficient navigation, with the lateral force countered by the ship's hull. The rotation of the rotor cylinder, driven by a low-power motor, allows easy manoeuvrability, enabling the ship to move even in crosswinds. Additionally, adjusting the rotor direction ensures optimal performance in various weather conditions without the need to reduce sail area in strong winds. This technology offers additional advantages, including ease of control from a sheltered pilot position. In summary, rotor propulsion emerges as a promising solution for more sustainable maritime navigation, effectively combining ecological and economic benefits. The increasing demand for rotor solutions is experiencing a resurgence in maritime navigation. Several companies are experimenting with rotor sails to harness the opportunities of wind propulsion, yielding increasingly promising results.



Figure 13. *A rotor sail wind powers Scandlines*
(Werner S., Nisbet J., Hörteborn A., & Nielsen R., 2021)

A pioneer in this field is the E-Ship 1, a modern cruiser measuring 130 meters, built in 2008 and operational since 2010. Equipped with 4-meter Flettner rotors mechanically linked to the propellers, this hybrid ship from the German company Enercon has demonstrated an average fuel saving of 25% compared to a ship with Mitsubishi diesel engines. In 2020, Scandlines successfully installed a rotor (Figure 13) on a four-year-old ferry, named Copenhagen *(Figure 13)*, achieving a 5% reduction in carbon dioxide emissions.

Larger rotors, measuring 40 × 40 meters, are now in use on the Maersk Pelican. Other innovative solutions include rotors that can be laterally moved on the deck, as seen in the case of the 2017-built TR Lady, optimizing port loading. The SV Connector, a 12,000-ton Norwegian Ro-Ro ship, represents a step forward as the first

tiltable rotor ship. Equipped with Norsepower sails, an advanced version of Flettner rotors, this vessel provides further insight into the ongoing evolution of wind propulsion technologies in modern maritime practices (Nuttall & Kaitu'u, 2016).

The Oceanbird: a fusion of tradition and technology

The Oceanbird *(Figure 14)* is a visionary concept in the maritime world, representing a cutting-edge approach to sustainable shipping. This innovative vessel is designed to harness wind energy, reducing reliance on traditional fuel sources and minimizing environmental impact. With its towering wing sails, the Oceanbird is a striking symbol of green shipping technology, aiming to revolutionize the industry by combining efficiency and eco-friendliness. As the maritime sector seeks solutions for a more sustainable future, the Oceanbird emerges as a promising and forward-thinking answer to the challenges of modern shipping (Stalmokaitė, Larsson Segerlind, & Yliskylä-Peuralahti, 2023). Is it a majestic vessel renowned for its sleek design and formidable performance, effortlessly navigates the open seas. With a harmonious blend of cutting-edge technology and timeless craftsmanship, this maritime masterpiece embodies the spirit of adventure and the thrill of the open water. From its meticulously crafted hull to the state-of-the-art rigging, every element of the Ocean Bird is a testament to the artistry and engineering prowess that define this extraordinary sailing vessel. From stem to stern, this sailboat exemplifies the marriage of tradition and innovation, inviting seafarers to embark on adventures with style and performance at the forefront. The Oceanbird provides wings for a shipping revolution. (Stalmokaitė, Larsson Segerlind, & Yliskylä-Peuralahti, 2023)



Figure 14. *The Oceanbird*
(Stalmokaitė, Larsson Segerlind, & Yliskylä-Peuralahti, 2023)

5. SUMMARY

Summarizing what we learned at the end of our trip, we can say that shipping and sailing ships have played a significant role in the history of mankind. They made new discoveries possible not only in the geographical sense, but contributed to the development of mathematics, physics, biology and medicine. We still deserve to admire these brilliant engineering creations and remember with respect those people who served on sailing ships of different eras.

REFERENCES

Anderson, R., & Anderson, R. (2012). *A short History of The Sailing Ship.* Dover Publications.

Andersson, A., & Magelssen, S. (2017). Performing a Viking History of America: The 1893 Voyage and Display of a Viking Longship at the Columbus Quadricentennial. *Theatre Journal*, 69 (2), 175–195. https://doi.org/10.1353/tj.2017.0023

Britannica Encyclopedia (15th ed., Vol. 29). (1974). Encyclopaedia Britannica (UK) Ltd.

Campbell, I. (1995). The Lateen Sail in World History. *Journal of World History*, 6 (1), 1–23. Retrieved from http://www.jstor.org/stable/20078617

Compton, N. (2014). *The Anatomy of Sail.* London: Bloomsbury Publishing Plc.

Foley, V., & Soedel, W. (1981). Ancient Oared Warships. *Scientific American*, 244 (4), 148–163. https://doi.org/10.1038/scientificamerican0481-148

Freire, J., Farinha, N., Fialho, A., & Correia, F. (2007). Contributo para o estudo da tecnologia naval romana, a partir da reconstrução gráfica de um navio tipo Corbita. *Conimbriga*, 46, 281–290. https://doi.org/10.14195/1647-8657_46_12

Johnstone, P. (1980). *The Sea-craft of Prehistory.* Routledge & Kegan Paul Ltd.

Lavery, B. (2010). *Ship: 5000 Years of Maritime Adventure.* Dorling Kindersley.

Leary, J. (2014). *Past Mobilities - Archaeological Approaches to Movement and Mobility.* Routledge. https://doi.org/10.4324/9781315599632

Nuttall, P., & Kaitu'u, J. (2016). The Magnus Effect and the Flettner Rotor: Potential Application for Future Oceanic Shipping. *The Journal of Pacific Studies*, 36 (2), 162–183. https://doi.org/10.33318/jpacs.2016.36(2)-9

Romey, K. (2017). *Why haven't found Columbus' ships?* Retrieved from National Geographic: https://www.nationalgeographic.com/history/article/co lumbus-nina-pinta-santa-maria-shipwreck-archaeology

Somoskői, E. (1984). *Élethű versenyhajó modellek építése.* Budapest: Műszaki Könyvkiadó.

Stalmokaitė, I., Larsson Segerlind, T., & Yliskylä-Peuralahti, J. (2023, 2). Revival of wind-powered shipping: Comparing the early-stage innovation process of an incumbent and a newcomer firm. *Business Strategy and the Environment*, 32 (2), 958–975. https://doi.org/10.1002/bse.3084

Stein, S. (2017). *The Sea in World History.* ABC-CLIO.

Werner S., Nisbet J., Hörteborn A., & Nielsen R. (2021). Speed trial verification for a wind assisted ship. *International Conference on Wind Propulsion*, 61–72. https://doi.org/10.3940/rina.win.2021.09