

Dendroclimatic investigations and cross-dating in the 1700s: the tree-ring investigations of Johan Leche (1704–1764) in southwestern Finland¹

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Abstract: Cross-dating is considered one of the most important principles of dendrochronology. The first known cross-dating attempts, conducted between the years 1737 and 1783 by independent researchers in France, Germany, and Sweden, were related to the identification of growth rings believed to have formed during the harsh winter of 1708–1709. In this paper, we present a novel perspective on the birth of dendrochronology and cross-dating in the 1700s. We focus on the ideas and experimental studies of one of the lesser known pioneers, Johan Leche (1704–1764), the Professor of Medicine at the Royal Academy (Turku, Finland). Instead of winter harshness, Leche was fascinated by the drought that killed and damaged several trees and tree species in the summer of 1757. Leche conducted several dendrochronological and field experiments described only in his unpublished manuscript filed in the National Archives in Sweden. Reviewing Leche's measurements of ring-width series of multiple radii and his comparisons between the radii, it seems only fair to include him in the long list of natural historians who made important contributions to the field of dendrochronology. His manuscript was never published, which is why Leche's dendrochronological experiments and recommendations never reached a wider audience.

Key words: tree-ring research, dendrochronology, dendroclimatology, cross-dating, history of science.

Résumé : La datation croisée est considérée comme un des plus importants principes de la dendrochronologie. Les premières tentatives connues de datation croisée, effectuées entre les années 1737 et 1783 par des chercheurs indépendants en France, en Allemagne et en Suède, étaient reliées à l'identification de cernes de croissance qu'on croyait avoir été formés durant le rude hiver de 1708–1709. Dans cet article, nous présentons une nouvelle perspective sur la naissance de la dendrochronologie et la datation croisée au cours des années 1700. Nous mettons l'accent sur les idées et les études expérimentales menées par un des pionniers moins connus, Johan Leche (1704–1764), le professeur de médecine à l'Académie royale (Turku, Finlande). Au lieu de la sévérité de l'hiver, Leche était fasciné par la sécheresse qui avait tué et endommagé plusieurs arbres et espèces d'arbres à l'été de 1757. Leche réalisa plusieurs études dendrochronologiques et expériences sur le terrain décrites seulement dans son manuscrit non publié déposé dans les Archives nationales en Suède. Lorsqu'on examine les mesures de Leche qui portent sur les séries dendrochronologiques de multiples rayons, il semble seulement juste de l'inclure dans la longue liste d'historiens de la nature qui ont apporté d'importantes contributions au domaine de la dendrochronologie. Son manuscrit n'a jamais été publié, ce qui explique pourquoi les travaux de Leche en dendrochronologie et ses recommandations n'ont jamais rejoint une plus large audience. [Traduit par la Rédaction]

Mots-clés : recherche sur les cernes des arbres, dendrochronologie, dendroclimatology, datation croisée, histoire des sciences.

Introduction

Climatic change has over recent decades led to a growing need to better understand historical climate variability. For this purpose, local and national archives are continuously and systematically scrutinized in the search for new and previously undocumented climate data (Brázdil et al. 2005). The quest for data has also resulted in a growing body of new information regarding the early stages of climate research, especially in the 18th century, when the need for a formalized and systematic method of measuring atmospheric parameters slowly materialized (Fleming 1998). In the 1700s, as new methods and instruments for measuring climatic parameters slowly spread across Europe, there was also a handful of scholars who became interested in the question of what governs and determines tree-ring growth.

The development of dendrochronology has a long and fragmented history. The roots of the discipline are found in the work of several early and well-known scientists, ranging from, for example, Theophrastus of Eresus (372–287 BC) to Leonardo da Vinci (1459–1519) (Glock 1941; Heizer 1956; Sarton 1954; Studhalter 1955, 1956). According to Studhalter (1956), significant dendrochronological breakthroughs began in the mid-1700s with the emergence of cross-dating, the use of two or several trees to date and assign specific years to growth rings. Comparing growth patterns in trees from nearby sites and (or) regions characterized by similar climatic or environmental factors ensures that each ring finds its correct place in a certain temporal sequence (Fig. 1). Contemporary cross-dating enables the construction of reliable long-term tree-ring chro-

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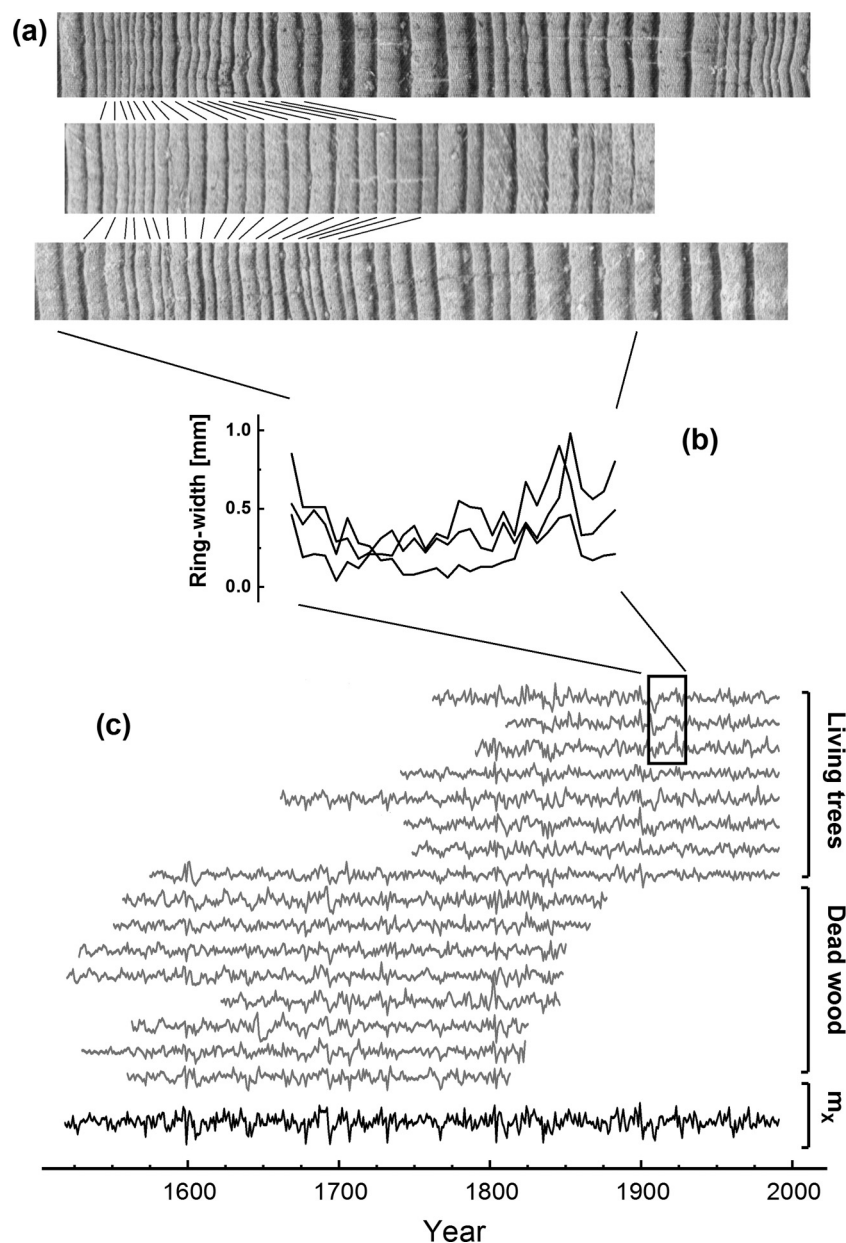
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Fig. 1. A simplified illustration of tree-ring cross-dating. (a) Visual inspection of ring features among multiple radii and synchronization of their patterns of wide and narrow rings, (b) analysis between the time series of tree-ring widths plotted for comparison, and (c) a composite tree-ring chronology containing ring-width series from living trees with a known sampling year and from dead wood materials dated against the master chronology representing the mean (m_x) of the sample series.



nologies and climate series and is considered one of the most important principles of dendrochronology (Fritts 1976).

In the 18th century, there was a common belief that wood formed throughout the year. The first known cross-dating attempts were related to the identification of narrower growth and frost injury believed to have formed during the harsh winter of 1708–1709 (Studhalter 1956). Independent researchers in France, Germany, and Sweden (Table 1) all believed that they could identify cold winters by the narrowness or frost injury of a tree's rings. Counting down the rings of various species, Henri-Louis Duhamel (1700–1782) and Georges-Louis Leclerc aka Comte de Buffon (1707–1788) in France and Friedrich von Burgsdorff (1747–1802) in Germany noted severe frost injuries that, according to them, corresponded with the winter of 1708–1709. In 1741, while studying an oak, the famous Swedish botanist, natural historian, and zoologist Carl

Linnaeus (1707–1778) noted an exceptionally narrow ring that he ascribed to the winter of 1708–1709.

Duhamel and Buffon published their findings in 1737, and Burgsdorff's more elaborate comparison was published in 1783. Based on the publication dates of these works, Studhalter (1955, 1956) established the birth of cross-dating to be either 1737 or 1783. Although, of the two, Burgsdorff may be able to claim the title of being the first, because as according to Studhalter (1956), Burgsdorff examined several tree species. Hence, cross-dating was born from the basic assumption that severe winters caused impaired growth, the reference point being the winter of 1708–1709, which was one of the coldest winters in Europe in the past 500 years (Luterbacher et al. 2004). It is worth mentioning that none of the previously mentioned scholars were old enough to observe the assumed effects themselves. Moreover, they had no tempera-

Table 1. The earliest developers of tree-ring cross-dating according to Studhalter (1956).

Year	Author(s)	Country	Description
1737	Duhamel and Buffon	France	Counted back to frost-injured ring of 1708–1709; assumed that a single growth ring is laid down in 1 year
1745	Linnaeus	Sweden	Counted back to narrow ring formed because of severe winter of 1708–1709; called tree rings the “chronicles of winters”
1783	Burgsdorff	Germany	Counted back to frost-injured ring of 1708–1709 in beech and most other trees; compared several trees and species

ture data to rely on, which is why their deductions were based on the collective climate memory. Meanwhile, in Turku, Finland, Johan Leche (1704–1764), the Professor of Medicine at the Royal Academy, approached the growth of tree rings from almost the opposite perspective and actually questioned the impact of winter severity on tree growth.

In this paper, we present a novel perspective on the birth of dendrochronology and cross-dating in the 1700s. We focus on the ideas and experimental studies of Johan Leche, a medical doctor by trade — a zoologist and botanist by interest — but a climatologist at heart. In this context, Leche approached tree rings differently than his contemporary colleagues.

Leche conducted several dendrochronological experiments and ventilated his first ideas in an unpublished manuscript titled “The dry and hot summer 1757” (Leche 1757). The manuscript, written in Swedish, is six pages long, including drawings, and appears to be unfinished. It was found alongside early meteorological data from Finland in the 18th century in the National Archives in Sweden (Finland was a part of Sweden in the 18th century). The manuscript was never published, which is why Leche’s dendrochronological experiments and recommendations never reached a wider audience. However, he incorporated some of his ideas from the 1757 experiment in two papers that he published 6 years later.

Leche is quite unknown and there is no known picture of him, which is why we will begin this paper with a short biography. Our aim is to provide a better understanding of Leche’s background and his climatic interest, which we also believe explains his dendroclimatological perspective and reasoning. Previous research has focused on Leche’s achievements in botany, agriculture, and horticulture (Väre 2008); his general studies in climatology (Johansson 1913; Holopainen 2004; Holmberg 2012); and his contributions to phenology (Väre 2008) and cryophenology (Norrgård and Helama 2019). Here, however, we will discuss Leche’s dendrochronological insights, which, to our knowledge, have never been cited. We have divided the paper according to the four different themes that we have identified. This way we hope to better demonstrate the diversity of Leche’s dendrochronological studies.

Johan Leche

Born in Barkåkra, Sweden, Leche was raised in a home with strong clerical traditions. It was therefore only natural that Leche would go to Lund University to study theology. His first position after university, however, was as a private tutor in botany and natural history in Simonstorp in southwestern Sweden. New to the subjects, Leche became a self-taught natural historian. He compiled a collection of birds and insects, including over 500 types of plant species, both wild and cultivated, which later resulted in *Florula Simonstorpiana* (Roland 1765; Hjelt 1868).

After 4 years as a tutor, Leche abandoned his theological calling in 1733 and returned to Lund University to study medicine, during which time he also supervised the university’s natural collections. Leche received the title of Doctor of Medicine in 1740. Thereafter, he worked as a provincial physician, a position he disliked and quickly relinquished. Nonetheless, inspired by Carl Linnaeus, Leche continued his studies of fauna until 1742, when he applied for the position of Professor of Medicine at Lund University. He

did not receive the position, but this period was an important catalyst for Leche’s interest in measuring climatic parameters. To improve his chances of attaining the position as professor, Leche travelled to Stockholm, where he came in personal contact with Linnaeus. He also maintained correspondence with the astronomer Anders Celsius (1701–1744) in Uppsala, who together with the mathematician Pehr Elvius (1710–1749) at the Royal Swedish Academy of Sciences inspired Leche to conduct meteorological observations (Lindroth 1967; Hjelt 1868).

In 1745, Leche served as the physician for the Swedish East India Company in Gothenburg. During this period, he continuously conducted meteorological observations and studied local flora and fauna. He sent his findings to Linnaeus, who was so impressed by Leche’s contribution that he later named both a genus of herbs (*Lechea* L.) and species of insect (*Phalaena lecheana* Linnaeus, 1758; also known as Leche’s twist moth) after him (Fig. 2). In 1746, Leche was elected a member of the Royal Swedish Academy of Sciences (Roland 1765; Hjelt 1868).

In February 1748, Leche was appointed as the Professor of Medicine at the Royal Academy in Turku, Finland. He arrived in Turku in September, and by October, he was conducting meteorological observations (e.g., Holopainen 2004). He would continue his observations until his death in 1764. According to his friend Pehr Kalm (1716–1779), the last tasks Leche performed were writing down the daily weather observations that he made in his garden (Roland 1765; Hjelt 1868).

Leche’s scientific publications (17 in total) reveal a scrupulous and methodological interdisciplinary scientist with a strict sense of reasoning and modern approach to science. Leche refrained from outlandish speculations and meticulously collected observational data before presenting his results.

In Leche’s network of famous and esteemed colleagues, he is one of the lesser known pioneers. Leche has probably remained in the shadows of his contemporaries because he was less productive than his colleagues. For example, Leche supervised only a handful of theses (including one medical licentiate thesis), whereas his colleague and best friend, Linnaeus’ apostle Pehr Kalm — famous for his travels in North America and descriptions of Niagara Falls — supervised 146 master theses.

During his time in Turku, Leche seems to have been more or less obsessed with his daily meteorological observations, which he made almost every day, several times a day, for almost 15 years (Holopainen 2004). He introduced the mercury thermometer with two fixed points to Turku and diligently manufactured and calibrated all meteorological instruments himself. Leche might be unknown today, but he was well regarded by several of his colleagues and contemporaries. For instance, Pehr Wargentin (1717–1783), responsible for the meteorological observations in Stockholm, stated that hardly anyone has made observations as meticulously as Leche (Wargentin 1762). Kalm also spoke highly of Leche, calling his work “Herculean” (Roland 1765). Hence, when conducting his dendrochronological studies, Leche was already an experienced zoologist and botanist, but more importantly, he also had two decades of experience studying weather and climate.

Fig. 2. A photograph of *Phalaena lecheana* Linnaeus, 1758, subsequently synonymized with *Ptycholoma lecheana* (Linnaeus, 1758), the species of Lepidoptera named in honour of Johan Leche. Photograph by J. Tyllinen and reproduced with his permission. [Colour online.]



Subject I: Periodicity

In the summer of 1757, Johan Leche observed that the prevailing drought had killed and damaged several trees and tree species (e.g., spruces, pines, junipers, and oaks). Subsequently, Leche hypothesized that previous and equally adverse droughts should also have affected tree growth in the past and that the tree rings should contain evidence of this. He therefore intended to determine how much time had passed since the last drought of similar magnitude.

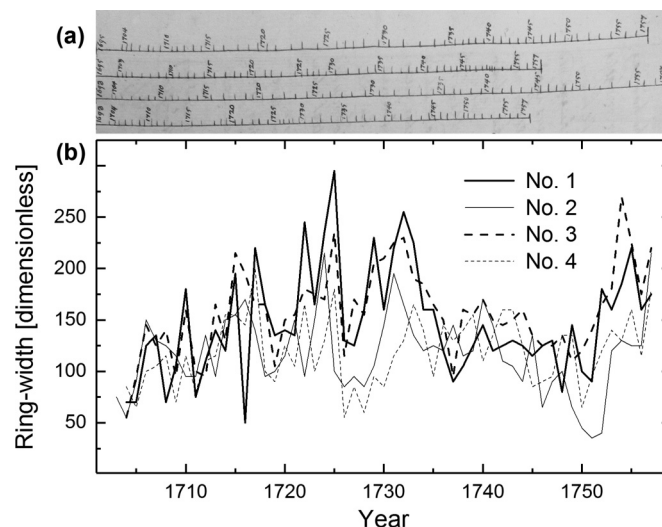
Leche hoped to prove the existence of climate periodicity (today, often termed “return period” or “recurrence interval”), as this would benefit agricultural productivity. His aims were understandable, considering the impact of the drought. Leche’s measurements from 1757 (Leche 1763a; Holopainen 2004) show that April and May were slightly wetter than normal, and rainfall was just below normal in June. There was no rainfall in July and August, which made them the driest on record. The summer of 1757 turned out to be the driest summer during Leche’s 13 years (1750–1762) of measurements.

To determine the return period of droughts, Leche harvested a spruce that grew on a rock and was surrounded by other trees that also appeared to have suffered from the drought. Because it grew on a rock, the spruce had shallow roots, and because of the site, the tree epitomized the assumed effects of the drought (Leche 1757).

Leche estimated that the tree had grown for at least 60 years. The exact age was undeterminable because the innermost rings, those likely between 1697 and 1720, were too fine to distinguish. He noted that the wider ring of 1725 concurred with the wetness that same year but that the ring in 1726, despite the wetness, was not as wide as the ring in 1725. Seemingly disappointed by the fact that the years 1735–1736 were not as wet as 1745–1746 and 1755–1756, Leche dismissed the existence of a recurring (10-year) wetness cycle. Moreover, he found no indications of past droughts similar to that of 1757, and based on the additional assumption that similar events would have killed the trees, he dismissed the occurrence of adverse drought events. It is worth noting that there are no known rainfall records from Turku before Leche’s, which is why the degree of wetness before the 1750s was speculative and based on the collective memory.

Unable to find evidence of climatic periodicity in his first sample, Leche then harvested a second tree. This time, he chose a site and tree that were almost the opposite of the first. If a tree growing at a dry site did not register droughts, then the reversed conditions would. Leche therefore harvested a healthy spruce, the largest he could find, its diameter twice that of the previously investigated tree. It grew, undisturbed, in a moister part of the

Fig. 3. (a) A hand-drawn line diagram showing the ring widths of the four radii measured by Leche, as discovered from his manuscript (photograph by Stefan Norrgård), compared with (b) the digitized data of the ring-width series representing the four radii.



forest. He counted the rings twice, in two different places (radii). He then cut the tree 20 cm higher up and again counted the rings (Fig. 3a). Nonetheless, the second tree was, despite its size, as old as the first tree. As with the first tree, Leche could not establish a connection between narrow rings and dry years and, moreover, between wide rings and wet years. Regarding the rings and any existing patterns, Leche wrote that it is “as if they appear by chance” (Leche 1757).

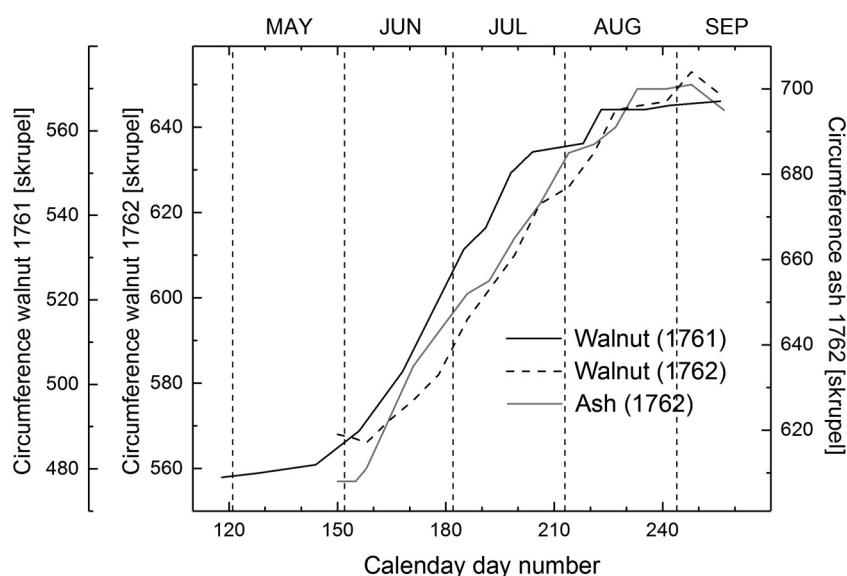
Subject II: Winter severity and temperature

Devoid of instrumental observations, Leche considered tree rings the only way to gain knowledge on past climate variability and disregarded the notion that trees continued growing during the winter months. By focusing on the drought and the summer months, Leche’s approach contrasted with the investigations carried out by Duhamel and Buffon, as well as those by Linnaeus and Burgsdorff, who all used the severity of the winter of 1708–1709 as their reference point. For example, Linnaeus ascribed the width of the rings to winter severity, and noting that the rings in several trees in 1587 and 1658 were as narrow as those in 1708–1709, he suggested that tree rings could provide a chronicle of past winters over the last 200–300 years (Linnaeus 1745).

Leche was evidently aware of the prevailing assumption that winter severity affected tree-ring growth. He most likely knew about Linnaeus’s observations even though he never referred to them. Nonetheless, Leche referred to Ulric Rudenschöld (1704–1765), who explained that the growth rings were formed in the winter when the sap was pressed together (Rudenschöld 1746) (i.e., a cold winter would, because of lower temperatures and greater pressure, generate even narrower rings). Leche emphatically questioned the idea that tree rings would register the severity of past winters. Especially because tree growth, as he noted, occurs between May and August, and it is the wetness during these months that decides the width of the tree rings (Leche 1757).

Leche shortly returned to the subject of winter effect in 1763. This time, he noted that cold winters with stable temperatures, regardless of severity, would not damage tree growth (Leche 1763b). However, he added that mild weather followed by extreme cold might affect the sap-filled buds and cause them to “explode”, which Leche claimed had happened to the walnut trees in January 1762. Denying the impact of winter temperatures meant that Leche needed to assess if summer conditions determined growth. For this

Fig. 4. Circumference of walnut and mountain-ash tree stems as a function of calendar day number through the growing season, as measured by Leche, in 1761 and 1762. Unit of measurement is skrupel (0.0297 mm).



purpose, he conducted a field experiment and measured the circumference of two trees, walnut and mountain-ash (brought to Finland by Kalm), two cubits (118.76 cm) above the ground, approximately once per week during the summers of 1761 and 1762 (Leche 1763b).

Leche hypothesized that if the prevailing warmth determined growth, then the peak in radial growth should occur in July, and the growth in June and August should be equal. His results, however, demonstrated that the selected trees started growing in June and that their growth rates were higher in June than in July. Moreover, the trees' growth rate was higher in July than in August (Fig. 4). Thus, the growth rate peaked in accordance with high soil moisture, which also concurred with the time of year, as Leche argued, when the leaves needed energy.

Subject III: Cross-dating

The trees harvested by Leche were circa 60 years old, and their age was probably one reason why he never published the results of his experiment in 1757. Locating older trees was difficult because of the harvesting demands of the shipyard industry. The regional timber had been effectively exploited, and shipbuilders were forced to venture farther inland to find the appropriate mast material. Moreover, while still living in Sweden in 1742, Leche had seen a tree (used as a ship's mast) with nearly 300 rings (Leche 1757). Furthermore, also in Sweden, in 1748, Leche encountered an ash with 210 rings (Leche 1763a). In other words, Leche's encounters with much older trees might have been a reason why he considered his own experiments with relatively younger trees fruitless and not worth sharing. However, his accumulated experience from dealing with much older trees probably led to his initial impetus to conduct cross-dating.

Leche's attempts at counting the tree rings highlighted a dilemma that Rudenschöld (1746) also addressed: it was difficult to distinguish the innermost and (or) outermost tree rings. Only the rings between the innermost and outermost rings were easily discernible. To overcome this dilemma, Leche suggested cross-dating young and old trees, thereby matching the correct growth ring and rate with the correct year. Furthermore, if the rings indicated the occurrence of "dire" years, Leche suggested verifying the results with information obtained from historical records (Leche 1763a). Thus, even if the ring widths were not accurate in regard to single events, a chronology could be used to assess if the

rings exhibited a periodicity in relation to those observed in precipitation estimates.

When Leche cut down his second tree in 1757, he counted the rings twice, made a new cut, and then counted them twice again along different radii, which resulted in four individual series of ring widths. He drew a picture of the ring widths in the margins of his manuscript (Fig. 3a). A visual analysis and comparison of Leche's drawing shows no missing or falsely added rings. Digitizing the drawing and quantifying the signal (e.g., Briffa and Jones 1990) according to the guidelines of modern dendrochronology allows for an analysis of Leche's investigation (Fig. 3b). The results show that Leche's mean (Pearson) correlation value ($r = 0.45$) between the ring-width time series is markedly higher than the more recently observed value ($r = 0.25$) in the radii from multiple spruce trees in southern Finland (Mäkinen et al. 2001).

Based on these results, it seems appropriate to say that Leche's criticism of his own results seems unjustified, especially when considering that there were only a handful of publications at that time that even suggested that tree rings contained evidence of climatic events, while the general applicability of cross-dating was not yet understood (Glock 1941; Studhalter 1955, 1956). Despite lacking suitable theoretical frameworks and statistical methods to rely on, and limited by the scarcity of older trees, Leche was on the right track. His choice of method (i.e., increasing the number of radii, replicating his observations (instead of relying on individual series), and comparing these) was the correct approach and procedure. While each individual series appears far from identical to each other, they seem to indicate a common signal. A larger sample size might have strengthened Leche's beliefs in his own approach.

Subject IV: Methodological recommendations

Leche was highly systematic when observing climatic parameters. In his articles, he described the instruments and procedures he utilized when carrying out meteorological observations (e.g., Leche 1763b). Concerning tree rings, he chose to share his own recommendations and guidelines for how to proceed. Leche's guidelines are the only part of his investigations that merges the ideas in his unpublished manuscript from 1757 with his publications in 1763. It is worth noting that Leche conducted his first tree-ring observations in 1741 (Leche 1757) while he still lived in Sweden. His guidelines are therefore most likely the results of a

much longer process than the content of the articles discussed here. Leche's guidelines, which relate to both praxis and methodological approaches, also act as evidence of an extensive but undocumented work in progress.

First, Leche pointed to the importance of studying species with identifiable tree rings. In Finland, this included pine, spruce, ash, elm, and oak (Leche 1757, 1763a). Leche dismissed junipers because of their fine and barely distinguishable rings, an argument substantiated again much later by Hallikainen (1985). Leche's examples suggest that he had studied several tree species; otherwise, why would he have produced a list of recommended tree species and detailed observations on their habitats? For example, Leche (1763a) noted that trees growing in drier soils produced wider rings in wet years, whereas spruce trees, which grow in moister soils, produced less identifiable rings from the previous summer's drought or wetness. This indicates that he elaborated on his previous ideas.

Second, regarding the site, Leche preferred trees from upland sites because he considered these trees to produce rings that distinguished dry years from wet years (Leche 1757). Like Reinerus Reineri Broocman in 1736 (Tunón 2016) and Rudenschöld (1746) 10 years later, Leche suggested that rings should be counted from the southern side of the stem. These were, according to Leche, wider and easier to distinguish from each other than the rings on the northern sector. Moreover, he stressed the importance of being observant when counting rings, as errors would result in a misconception of the climatic conditions (Leche 1763a).

Third, regarding stand density, Leche stated that dense forests resulted in tree rings that were difficult to distinguish. In his understanding (Leche 1757), stand density affected branch density, which is why he suggested cutting branches to a height of four or five cubits to improve ring discernibility.

After his 1757 study, Leche seem to have refined his method and identified the practical pitfalls and challenges encountered when counting tree rings. He noted that knowing when a tree was cut down was essential. However, if the rings could not be properly dated (i.e., by matching the correct ring with the correct year), then one could at least identify patterns and the order in which wet and dry years occurred, as well as determine if there were any type of periodicity. Further, he suggested using a cross section on a plane to improve discernibility (not to inflate growth estimates), using a microscope if necessary, and when reading from the bark towards the heart, marking every tenth ring with a pen or pencil (Leche 1763a).

Leche's suggestion to mark every tenth ring is almost identical to the method suggested by A.E. Douglass (1921, 1940, 1941), who formalized and standardized the modern cross-dating techniques, the distinction being that Douglass used a needle. This praxis, used to facilitate the control of the sample and guard against mistakes (such as missing a ring or losing one's position), is still the recommended praxis for new generations of dendrochronologists (e.g., Stokes and Smiley 1968; Baillie 1995; Speer 2010).

Leche's findings in the 20th century context

Leche did his first observations in Sweden in the early 1740s; however, it took an extreme climatic event almost 20 years later before he conducted his first dendrochronological experiments. By then, however, he was a skilled observer of atmospheric parameters, a skill that made him an excellent dendrochronologist and one of the early pioneers and developers of tree-ring studies in general and tree-ring cross-dating and methodology in particular.

Leche's observations of drought-related tree decline and dieback, as well as the potential effects of drought on tree growth and ring width, have later been confirmed as a recent spruce dieback was connected to a prevailing drought in the 1990s (Mäkinen et al. 2001). Leche's musings of past events also mirror

the growth-based assessments of drought- and heat-induced tree mortality in the footsteps of climate change (Allen et al. 2010; Gao et al. 2018; Desoto et al. 2020). Leche's arguments regarding the annual growth of spruce in rocky substrate have also recently been confirmed. In southern Finland, ring-width chronologies of *Picea abies* (L.) Karst. demonstrate positive correlations to June precipitation (Henttonen 1990), especially when the samples were collected from rocky sites (Mäkinen et al. 2001).

Further, Leche was not wrong in questioning the assumed effect of winter severity on tree growth. Extremely low temperatures during the dormancy period do not affect growth directly; however, the climatic signals in tree rings of some tree species and sites are strong and stable enough to be used as proxies for winter climate variability (e.g., Cook et al. 1998, 2019). For example, analyses of climate and tree-ring data from *Quercus robur* L. in southern Sweden indicate that low winter temperatures may have caused exceptionally narrow rings in 1940, 1947, 1956, and 1965 (Drobyshev et al. 2008). However, tree-ring chronologies from Sweden and southwestern Finland (Drobyshev et al. 2008; Hilasvuori and Berninger 2010; Helama et al. 2014) indicate that summer precipitation (June–August) has the strongest correlation with growth in *Q. robur*, which is roughly also what Leche established.

Conclusions

Reviewing Johan Leche's dendrochronological experiments, it seems only fair to include him in the long list of natural historians who made important contributions to the field of dendrochronology. Or, at least he could have contributed, but as is the case with many pioneering ideas born in a world not ready for them, his ideas were lost in the archives.

It is particularly intriguing that Leche did not follow the contemporary scientific trends of his time. Whereas Linnaeus made assumptions between cause and effect (i.e., a narrow ring must have been caused by winter severity), Leche approached the question empirically. This is partially what distinguishes Leche from his contemporary colleagues. Several of his conclusions on tree rings and growth also overlap principles from modern dendrochronology (Fritts 1976; Fritts and Swetnam 1989) such as (i) tree and site selection, (ii) cross-dating, (iii) sample replication, (iv) experimenting with limiting factors such as drought and temperature, and (v) uniformitarianism (presupposing the historical climate–growth relationship).

Leche is one of several early scientific pioneers whose ideas were lost in the noise of many other 18th century scientific endeavours. There were several scholars who, throughout the 1800s and 1900s, applied some form of cross-dating in their investigations (e.g., Glock 1941; Heizer 1956; Sarton 1954; Studhalter 1955, 1956; Wimmer 2001), but no investigations seem to have impressed or caught the attention of the scientific society before Douglass's (1867–1962) seminal work and, for example, his revolutionary use of tree rings to date the prehistoric ruins in southwestern North America (Dean 1978; Robinson 1990; Nash 1997; Creasman et al. 2012).

Since then, the techniques have become fine-tuned, developed, and adopted and widely applied in several scientific fields such as forest research, biogeography, archeology, ecology, and paleoclimate research (Schulman 1956; Fritts 1976; Hollstein 1980; Schweingruber 1988; Cook and Kairiukstis 1990; Baillie 1995; Spiecker et al. 1996; Speer 2010). Hence, trees and their annually dated growth variations have again — more than 250 years after Leche's first experiments — become an integral part of paleoclimatic research and function as important indicators of historical climate variability.

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