Study of the Impact of Past Scientific Research on Current Research

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Abstract

November 4, 2019 marked the 150th anniversary of *Nature*'s first issue. An Editorial published in advance of the anniversary (September 26, 2019; 573: 464) noted that there were only a handful of years between the newest and oldest citations on the reference list of many papers. The Editorial begs a fascinating question: what is the relevance of historical (older) papers for current science? To examine this question, I read and studied all the primary research papers published in *Nature* in its 151st year looking for citations at least approximately fifty years old that were relevant and generative for current research. I found that 117 out of 929 research papers (12.6%)—a not insignificant number—published in the year included such citations of older works, but that for only 22 papers (2.4% of 2019-2020 papers) was the older cited work essential or crucial for the current work. (I was also able to estimate the rate of failure by referees or editors to catch uncited important older reference to be only ~0.1-0.3%.) Citations go back to Aristotle's *Metrologica*, but there is a precipitous drop off with time with 44% of the older cited papers having been published between 1961 and 1970, 21% published 1951-1960 and 20% published 1921-1950. Most interestingly, 53% of the 2019-2020 papers citing older works were papers in the physical sciences, including 16.5/22 (75%) of papers for which the older cited work was essential or crucial for the current research significantly in excess ($p<0.01$) of the 39% of the total papers from the physical sciences in the year. This difference seems to be due to modern technologies allowing new testing and novel deployment of previously laid down fundamental principles in the physical sciences. These findings may have practical implications for the utilization of the scientific past in future research.

November 4, 2019 marked the 150th anniversary of *Nature*'s first issue. To commemorate its 150th year, *Nature* published[1] Essays, Comments, Features, Perspectives, Review Articles, a Podcast and a Video. These are historically interesting, informative and inspirational. In advance of the anniversary, an Editorial[2] published September 26, 2019 announced and described these plans. This Editorial also noted that there was only a handful of years between the newest and oldest citations on the reference list of many papers. The Editorial begs a fascinating question: what is the relevance of historical (older) papers for current science? To examine this question, I have read and studied all the primary research papers published in *Nature* in its 151st year looking for citations at least approximately fifty years old that are relevant and generative for current research. I found that 117 out of 929 research papers (12.6%) published in the year included such citations of older works, but that for only 22 papers (2.4% of 2019-2020 papers) was the older cited work essential or crucial for the current work. There is a precipitous drop off in citations with time with 44% of the older cited papers having been published between 1961 and 1970, 21% published 1951-1960 and 20% published 1921-1950. 53% of the 2019-2020 papers citing older works were papers in the physical sciences, including, interestingly, 16.5/22 (75%) of papers for which the older cited work was essential or crucial for the current research significantly in excess ($p<0.01$) of the 39% of the total physical science papers in the year. I was also able to estimate the rate of failure by referees or editors to catch uncited important older reference to be only ~0.1-0.3%. I discuss the implications of these findings for the future utility of the scientific past.

To study the question of the utility of older work for contemporary science, I have read through, looked at the reference list, and studied closely, when necessary, every primary research paper in *Nature* for the year from September 26, 2019 (Vol. 573 Issue 7775) through September 17, 2020—Articles and Letters for the September 26, October 3, 10, 17 issues and Articles in the rest of the issues—looking for relevant older citations. How old an old citation should be cannot be defined exactly, but I looked for articles at least approximately 50 years old (1970 or earlier). In particular, I was looking for articles not just from another generation, ~20-30 years old, but from another era such that the paper is not necessarily in the consciousness—or at least memory—of current scientists. A citation did not qualify as being scientifically important by the criteria implied by the Editorial simply by being old. Thus, for example, I did not include in the list (Supplementary Tables 1-5) citations of original fossil finds (e.g., ref.[3] cited in ref.[4]), chemical or material reference values (ref.[5] cited in ref.[6]) or well appreciated mathematical, statistical or experimental methods.

For a number of reasons, I believe that the 246 older works cited in 117 (out of 929) research papers published in *Nature*'s 151st year represent the true extent of the contribution and utility of historical scientific work to current research. There are not a significant number "absent" or "missing" citations due to ignorance, indifference or irreverence by current researchers to the science or scientists of the past, deliberate or unconscious omissions of references to past work, or errors by reviewers, editors (or authors): First, the consistent citation to reference works across the whole gamut of scientific disciplines, as mentioned above, as well as the papers listed in Supplementary Table 1 in which older work is cited essentially only for background or historical interest, show that current scientists are aware, willing and happy to cite the work of their scientific predecessors.

So too, arguing against ignorance or lack of interest in prior work are, for example, the citations in back to back papers[7,8] (see Supplementary Table 2) on symmetry breaking in supersolids that in their citations (refs.[9-11] cited in ref.[7] and refs.[11-17] cited in ref.[8]) show a deep, extensive and sophisticated knowledge of older work. As well, clearly showing the interest and knowledge of older scientific work by current scientists are the citations in one paper this year (ref.[18]) not only of an old foundational work (ref.[19]), but also "pre-discovery" work on the topic (ref.[20]).

Next, the citations in the 2019 paper by Asaad et al.[21] (see Supplementary Table 3) argue against a reluctance by present day scientists to cite past work. Asaad et al. showed that using RF electric fields for spin control—the Stark effect utilized in a magnetic resonance system—is a route to scaling up nuclear-spin-based quantum devices. After finishing their studies, the authors found out[22] that Nicholas Bloembergen (1920-2017) had proposed this idea near sixty years previously. Asaad et al. cited not only Bloembergen's short theoretical note[23], but also experimental work[24] Bloembergen had done with a student, going down the same line as Assad would six decades later.

Finally, the error rate of authors, reviewers and editors can be estimated: One paper from the year (ref.[25]) described a skin-integrated haptic interface useful for augmented and virtual reality. In the abstract, the authors state, "Traditional technologies for virtual reality (VR) and augmented reality (AR) create human experiences through visual and auditory stimuli that replicate sensations associated with the physical world. … In comparison to the eyes and the ears, the skin is a relatively underexplored sensory interface for VR and AR technology …" But not cited was a paper in *Nature* a half century ago by physician Paul Bach-Y-Rita and colleagues.[26] "Vision substitution by tactile image projection" which describes, "here a vision substitution system which is being developed as a practical aid for the blind and as a means of studying the processing of afferent information in the central nervous system." One error in not citing an important and relevant older paper from the 929 research published in *Nature*'s 151[st] year is clearly a lower bound, but would suggest that the error rate can be estimated at ~0.1-0.3%, which is quite small, and further confirms that the data in Supplementary Tables 1-5 indicate an accurate representation of the true extent of the utility of historical papers for current scientific work.

Results

Cited papers from 1970 and earlier are listed in Supplementary Tables 1-5 in increasing order of relevance and importance of the older work to the new paper. Dividing the papers into groups is somewhat of a subjective process, but the basic criteria used are as follows: Papers listed in Supplementary Table 1 are not utilized by the current scientific work but are interesting background material and often inspiring. Supplementary Table 3 lists papers for which the older cited work is utilized in the recent paper. Supplementary Table 5 lists papers for which the older paper is essential, important and proscriptive for new current science. (The best example of a contemporary experimental paper that was directly and dramatically inspired and guided by a centuries old work was the demonstration of femtosecond time-delay holography[27] which originated during a trip by first author Henry Chapman, his wife and fellow Lawrence Livermore National Laboratory scientist Saša Bajtand their daughter to a science museum where they saw a demonstration of Isaac Newton's "dusty mirror" experiment. See Box 1.) Papers listed in Supplementary Tables 2 and 4 fall in terms of importance and relevance to the current years' work in between the criteria for Supplementary Tables 1 and 3, and 3 and 5, respectively. Comments in the final column of the Tables sometimes suggest why a paper in Supplementary Table 2 is not in Supplementary Table 3, or one in Supplementary Table 4 is not in Supplementary Table 5. For example, if the older work has been continuously studied, the older cited paper then is not the direct impetus for the new research.

Table 1 lists the age of the older papers. There is a precipitous drop off in citations with time: 44% of the older cited papers having been published between 1961 and 1970, 21% published 1951-1960 and 20% published 1921-1950, 13% published 1851-1920 and only five citations to works from 1800-1850, three citations from the 1700s, two from pre-modern times and one from the ancient world (ref.[28] cited in ref.[29]).

Table 2 compares the older papers in terms of life and physical sciences. (Biochemistry, molecular biology, soil science and sociology of science are counted as life sciences; protein science, natural product synthesis and climate science as physical sciences.) 53% of 2019-2020 papers citing older works were papers from the physical sciences significantly higher than the percentage of papers from the life sciences published in *Nature* ~7/18 (39%). Furthermore, 16.5/22 (76%) of 2019-2020 papers for which older citations were essential or crucial—those listed in Supplementary Tables 4 or 5—were physical science papers, very significantly in excess ($p<0.01$) of the expected number based on percentage of life vs. physical science papers published in the year.

Table 3 tallies the non-English papers. Old books were referenced twenty times and monographs ten times.

It was noted in *Nature*'s own 150th years anniversary video[30] that physics papers published in *Nature* over the years have gone from having one or two authors to dozens or even hundreds of authors or more. There has also been an increase[31] in the past two decades in the number of authors of papers in the medical and health sciences and other fields. I found that this trend is a general one across all scientific disciplines. Indeed, in almost every single case (Supplementary Tables 1-5) in 2019-2020 (with only three partial exceptions) the older paper had fewer—typically far fewer—authors than the current paper that cited it. (Nett, Lau, & Sattely (ref.[32], see Supplementary Table 4) cite three older papers with four or five authors; however, the earliest relevant papers they reference have only one or two authors. Kumar & Bechhoefer (ref.[33]) in one of the few two author papers in the year cite two older papers with two authors, but the crucial oldest work they cite (ref.[28]) is by one author, Aristotle. The older work of Revelle and Suess[34] is an important reference for the new study by Bronselaer and Zanna[35].)

Three works published before 1970 (refs.[36,37,38]) were cited by two different papers in *Nature*'s 151st year:

Über merkwürdige diskrete Eigenwerte. [About strange discrete eigenvalues.] (ref.[36], Supplementary Table 4) by mathematician and mathematical physicist John von Neumann (1903-1957) and physicist Eugene Wigner (1902-1995) published in 1929 in *Zeitschrift für Physik* describes what are now known as bound states in the continuum (BIC). Wigner and von Neumann constructed a potential energy function such that there could in theory exist quantum mechanical states that have eigenvalues of sufficiently high energy to be in the continuum of states—the range in which all states radiate to infinity—but nonetheless do not. BIC have been found in electromagnetic, acoustic, and water waves and are currently being studied[39] in photonic crystals, optical waveguides, piezoelectric materials, quantum dots, graphene, and topological insulators.

In the current year, Jin et al.[40] proposed and demonstrated a new class of guided resonances in photonic crystal slabs that arise when multiple BICs merge in momentum space and enhance the quality factors of nearby resonances in the same band due to suppression of out-of-plane scattering losses. Yin et al.[41] propose and demonstrate a class of resonances in photonic crystal slabs that radiate only toward one side of the slab, with no mirror placed on the other side, that arise from the interaction of two half-integer topologically charged BICs.

A connection between Wigner and von Neumann brings their 1929 paper back yet another era, even into the 19th century: The two attended Fasori Evangélikus Gimnázium in Budapest for high school and had the same math teacher, László Rátz (1863-1930). Parents of both children sought Rátz for outside tutoring. He only provided this for von Neumann. Wigner was not bitter about this. Indeed, in his banquet luncheon address[42] before receiving the 1963 Nobel Prize in Physics for applications of group theory to quantum mechanics Wigner thanked Rátz. "My own history begins in the high-school in Hungary where my mathematics teacher, Rátz, gave me books to read and evoked in me a sense for the beauty of his subject."

Wigner and von Neumann's potential has yet to be experimentally demonstrated, and quantum mechanical examples of BICs are scarce[43], so future discoveries from Wigner and von Neumann's "strange" eigenvalues may still await.

Work tracing back to von Neumann is important for two other papers in this year's *Nature*: (1) In 1968[44] mathematician Dietrich Baess noticed that, curiously, traffic flow could get worse in some situations when a road was added to the network. This could happen if drivers are all making the self-optimized decision to take the quickest route. Then a shortcut would become over-subscribed, and traffic would now be slowed, not improved, by the addition of the extra road. Since then analogues of Braess's paradox have been observed in electrical, biologic and other networks.

Braess's paradox continues to inspire: Recently Motter and colleagues[45] (Supplementary Table 4) designed and implemented microfluidic networks exhibiting a nonlinear relation between the applied pressure and the flow rate, which can be used to switch the direction of internal flows solely by manipulating the input and/or output pressures. As per Braess's paradox, closing an intermediate channel results in a higher, rather than lower, total flow rate.

More formally, Braess discovered that the Nash equilibrium[46] is not necessarily the best overall flow through a network. Mathematician John Nash (1928-2015) worked in the context of game theory, not network flows. von Neumann and economist Oskar Morgenstern introduced the concept of a mixed-strategy—when players choose probabilistically from a set of pure strategies—equilibrium in their 1944 classic *The Theory of Games and Economic Behavior*[47] and showed that an equilibrium will exist for any zero-sum game with a finite set of actions. Nash defined a mixed-strategy equilibrium for any game with a finite set of actions and proved that at least one (mixed-strategy) Nash equilibrium must exist in such a game.

(2) The Deep Mind group noted (ref.[48], see Supplementary Table 4) that the self-play algorithms they had used for producing high level play in chess and Go were not as useful in developing an AI program to play StarCraft II, as self-play could chase cycles such as A defeats B, and B defeats C, but A loses to C) indefinitely without progressive learning. Instead, they used fictitious self-play, originally rooted in a 1951 paper[49], to avoid cycles by computing a best response against a uniform mixture of all previous policies. The mixture converges to a Nash equilibrium in two-player zero-sum games.

Alar Toomre's Q parameter[37] to assess the approximate stability of rotating gaseous accretion discs was useful for two studies in the current year (Supplementary Table 3). MacArthur and Wilson's classic[38] on island biogeography was cited in one paper on island flora[50] and another paper on island bird fauna[51] (see Supplementary Table 3).

There was one paper in the year ref.[52] (Supplementary Table 3) that ingeniously, industriously and effectively built upon work from *two* prior eras: shortly after the discovery of the pion, Fermi and Teller[53] proposed the interesting idea that the negatively charged particle could replace an electron to make an exotic atom. A generation later, based on observations from helium bubble chamber experiments, George Condo[54] suggested that pions could be absorbed into an atom by helium nuclei, and these hypothetical atoms were studied theoretically some years later[55,56]. In a *Nature* paper this year Masaki Hori[52] and colleagues used modern laser technology to study these previously experimentally inaccessible atoms. Based on the prior theoretical work, Hori and colleagues initially searched for Rydberg states of the negative pion with a principal quantum number n of 16. But the paper by Hori and colleagues is not merely one of sophisticated modern technology verifying older previously set down theory. In the highest and also most basic and oldest experimental tradition, when various transitions from the (16, 15) state with principal and orbital quantum numbers (n, l)) could not be found, some absent transitions in a system with multiple complex effects still not understood even with their own post-hoc theoretical analysis, Hori and colleagues studied the $(n, l) = (17, 16) \rightarrow (17, 15)$ transition of pionic helium and found a strong signal.

(Rivilla et al.[57] (Supplementary Table 3) cite papers from three different eras but only one is directly useful for the experiments conducted.)

I want to mention one paper listed in Supplementary Table 5 (Xiang et al.[58]) which was published in print one weak earlier (September 19, 2019) than the time frame I studied, but also clearly illustrates the specific and directive utility of older science.

Phil Baran and colleagues studied the problem of synthesizing hindered ethers. They note that a 168-year old[59] method S_N2 substitution is not particularly effective in producing hindered ethers. They then go back to an even older reaction, indeed from the oldest synthetic organic electrochemical reaction, the Kolbe dimerization which was discovered[60] in 1847. Baran and colleague use the so-called interrupted Kolbe variant, also known as the Hofer–Moest reaction[61], and a later variant[62] as the start place for their method to synthesize hindered ethers. The utility of historical work continues as Xiang et al. note their use of more recent[63-66] but still older work helping in the specific development of their methods.

Discussion and the Future of the Scientific Past

117 out of 929 research papers (12.6%) published in *Nature*'s 151st year cited relevant papers published 1970 or earlier, a not insignificant number of current papers citing older works. However, for only 22 papers (2.4%) was the older work essential for the current year's work. There was a with a steep fall off of papers cited with increasing age. The omission rate of non-citation of important older papers is likely only a few tenths of a percent. So in answering in general terms the question posed in *Nature*'s pre-150th year anniversary Editorial[2], overall researchers are well aware and respectful of the scientific past, and quite efficient with respect to incorporating and building on work from the past.

Study of citations to older works illustrates a remarkable stability in the boundaries of scientific disciplines over time. There are only a few papers for which the older cited work and the current papers are in different fields: The paper by Nitzan et al.[67] (Supplementary Table 2) is a genetics paper, while the paper cited by Monge (1781)[68] is applied math. The protein structure paper by Senior et al.[69] (Supplementary Table 3) cites a 1935 physical chemistry paper (ref.[70]). The paper by Pagano et al.[71] describing the synthesis and characterization of complex inorganic compounds satisfying Hückel's rule for antiaromaticity (Supplementary Table 4) cites two older organic chemistry papers (refs.[72,73]) as models and inspiration. The molecular biology paper by Pillai et al.[74] (Supplementary Table 3) cites older papers from multiple disciplines. The paper of Ioannidis et al.[75] (Supplementary Table 4) uses modern genetic methods to assess older anthropologic theories. Conclusions of the neuronal cell biology paper by Reilly et al.[76] (Supplementary Table 3) were inspired by an evolutionary biology paper by Dobzhansky[77]. The soil science paper of Nottingham et al.[78] (Supplementary Table 2) makes use of an old geology monograph describing the locale used for their study.

Perhaps, most fittingly coming at the end of my 151st year review, the paper by Katanaev and colleagues[79] (Supplementary Table 5) describing the understanding and production of nanocoatings based on design principles of the Drosophila cornea is both a life science and physical science paper, the key reference and inspiring and guiding spirit for which is Alan Turing's 1952 classic paper[80] explaining morphogenesis using dynamical systems.

As shown in Table 2, for the papers in Supplementary Tables 1-3 the modern papers are split fairly equally between the physical and life sciences in terms of citing an older work, though the percentage of physical science papers significantly exceeds the expected number based on the percentage of physical science papers overall in *Nature* (~39%). However, in Supplementary Tables 4 and 5 there is an even greater percentage of papers from the physical sciences and again very significantly higher than expected based on the relative proportion of life science papers to physical science papers published in *Nature*. Why might this be? There may be more fundamental principles in the physical sciences that, once laid down, continue to be useful, and more modern technologies enable them to be tested and utilized more. Whereas, in the biologic sciences, principles may be less general and new technologies have initiated entireties of new fields supplanting use or relevance of older papers.

Table 3 shows that English has been the language of science since about 1930, replacing the French and German of the 19th and early 20th centuries. All the cited papers in Russian are physics papers, consistent with the parallel development of physics in the West and the former Soviet Union in the 1950s-1970s.

What is the use in the future for the scientific past? The biologic sciences are particularly efficient with respect to past work. Only very rarely are older works essential. Indeed, Darwin and Wallace were each cited just once in the year (ref.[81] cited in ref.[74], ref.[82] cited in ref.[83]) and Darwin only to say the given example of molecular evolution of a protein structure is *not* an example of classic gradualistic evolutionary change. (The paper citing Wallace (ref.[83], see Supplementary Table 2) took with Wallace's work on the geographic distribution of animals and plants as important background perspective at the implications for global biotic homogenization of human introduction of species to new locales.) For current physics research, it might be most useful when looking to past work, not to journals but collected works, such as of those who had more than one paper cited in *Nature*'s 151st year, e.g., I.M. Lifshitz (1917-1982) (ref.[9] cited in ref.[7] (Supplementary Table 2) and ref.[84] cited in ref.[85] (Supplementary Table 3)) and Wigner and von Neumann whose joint paper (ref.[36]) was cited twice (see above and Supplementary Table 4), as well two other papers by Wigner (refs.[86.87]) were cited in the year (by ref.[88] Supplementary Table 3, ref.[89] Supplementary Table 2), and for two papers discussed above (refs.[45,48]) von Neumann's work was a key precursor. (Two biochemistry papers by Jacques Monod (1910-1976) are cited by papers in Supplementary Table 3.) Organic chemistry seems to be iterative with respect to prior work, and thus it may be particularly useful in this field when looking for new reactions, enzymes, substrates or conditions to read old papers to look for examples, hints, analogies or related reactions.

Future studies can assess the current utility by field of more recent older papers—those from the 1970's, '80's and '90's.

We never know when we will visit a historic site, museum, go into a bookstore or library or go online and find inspiration and direction from an old work to solve an important new problem.

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Table 1 Number of papers cited by time period.

Time period	# papers cited in Tables 1-3	# papers cited in Tables 4 or 5	Total # of papers cited/decade
Ancient world	0	1	-
Pre-modern	0	2	-
1700s	3	0	0.3
1800-1850	3	2	1
1851-1900	8	5	2.6
1901-1910	9	3	12
1911-1920	6	1	7
1921-1930	7	5	12
1931-1940	15	1	16
1941-1950	13	6	19
1951-1960	35	18	53
1961-1970	82	29	111

Table 2 Recent papers in the physical vs. life sciences that cite papers from 1970 or earlier.

Table	Physical sciences	Life sciences
1	1	9
2	15	16
3	29	25
4	15	4
5	2.5	1.5

Table 3 Non-English older cited works (bold indicates key cited work from Table 4 or 5).

Language	Year of publication of cited work
Ancient Greek	**Aristotle (384-322 BCE)**
Latin	1710
French	1781, 1829, 1872, 1900, **1930**, 1954, 1962
German	1838, **1847**, **1851**, **1887**, 1892, 1899, 1901, 1901, **1902**, 1902, 1903, 1910, 1910, **1913**, 1915, 1919, **1929**, 1935, 1952, **1968**
Russian	**1950**, **1951**, 1960, 1966, 1967, 1967, 1969

Box 1 Newton's dusty mirror experiment still inspiring and specifically guiding new experiments three centuries later.

In 2005 husband and wife physicists from Lawrence Livermore National Laboratory Henry Chapman and Saša Bajt took their daughter to the Chabot Space and Science Center in Oakland, California. There, they saw a replica of an experiment in which Isaac Newton had sent a beam of light through a hole in a screen[1]. The beam reflected off a mirror and back onto the screen—which, to Newton's surprise, produced concentric rings of light.

Newton found[2] that the squares of the diameters of the bright rings followed an integer progression with their diameters depended on the thickness of the glass. The explanation for Newton's ring phenomenon was given[3] a century after Newton's experiment by scientist and physician Thomas Young (1773-1829). The effect is caused by interference at the screen between two paths of light scattering from dust particles on the mirror's front surface: (1) light scatters from a particle on its way in towards the mirror, after which it reflects from the silvered surface, and (2) light is first reflected from the silvered surface before scattering. (Interestingly, two generations before Newton, master experimentalist Robert Hooke (1635-1703) in his monumental classic *Micrographia*[4] described and illustrated Hooke's rings, an interference phenomenon not unrelated to that produced by Newton's dusty mirror.)

Chapman noted[5] that upon seeing the demonstration of Newton's experiment in the science museum, "It suddenly struck me that you could do the same thing with short pulses and X-ray mirrors, and it would be really interesting if the X- ray pulse was shorter than the time it takes for it to travel from the dust particle to the back of the mirror and back."

Chapman, Bajt and their colleagues then designed and demonstrated[6] a dynamic femtosecond—as opposed to Newton's static—X-ray wavelength version of Newton's visible light experiment to image an exploding sphere with unprecedented temporal and spatial resolution: They placed 140-nm-diameter spherical polystyrene particles—the analogue of Newton's dust—on a 20-nm-thick silicon nitride membrane that was mounted with a thin spacer in front of a multilayer mirror. Instead of reading results from a screen as Newton did, Chapman and colleagues used a second plane mirror angled at 45 degrees to reflect the interference pattern onto a back-illuminated CCD detector. Chapman and colleagues were then able to follow the explosion of the polystyrene spheres using a focused 25 fs pulse of 32.5 nm light. While the conditions in Newton's experiment were static, in the experiment of Chapman and colleagues they were dynamic with their "dusty particles" (the polystyrene spheres) changing size in the brief interval that the pulse takes to reflect back to the particle (and ultimately being vaporized by the X-ray pulse). The team described[6] their interference pattern as an X-ray hologram, caused by the interference of a reference beam scattered from the sphere on the first pass, and then scattered again from the "unknown object" (the exploding sphere) on the second pass.

References

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3. Young, T. The Bakerian Lecture: On the theory of light and colours. *Phil. Trans. R. Soc.* **92**, 12–48 (1802) page 41.
4. Robert Hooke, *Micrographia, or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries thereupon.* (Jo. Martyn and Ja. Allestry, London, 1665).
5. https://www.llnl.gov/news/researchers-rely-newtons-interference-new-experiment
6. Chapman, H., Hau-Riege, S., Bogan, M. *et al.* Femtosecond time-delay X-ray holography. *Nature* **448,** 676–679 (2007).

Supplementary Table 1 References to older papers that provide background or historical examples.

Field of Study	2019-2020 paper	Old references	Comment
Physics	Lassaline, N., Brechbühler, R., Vonk, S.J.W. *et al.* Optical Fourier surfaces. *Nature* **582,** 506–510 (2020).	Hopkinson, F. & Rittenhouse, D. An optical problem, proposed by Mr. Hopkinson, and solved by Mr. Rittenhouse. *Trans. Am. Phil. Soc*. **2**, 201–206 (1786). Gabor, D. A new microscopic principle. *Nature* **161**, 777–778 (1948).	Purely historical examples.
Oceanography (life science)	Behrenfeld, M.J., Gaube, P., Della Penna, A. *et al.* Global satellite-observed daily vertical migrations of ocean animals. *Nature* **576,** 257–261 (2019).	Cuvier, G. *Le Règne Animal distribué d'après son Organisation pour à l'Histoire Naturelle des Animaux et d'Introduction à l'Anatomie Compare* (Deterville, 1829).	Reference of historical interest only, but how inspiring and clever to use ship net hauls to study this topic!
Neuropathology	Schweighauser, M., Shi, Y., Tarutani, A. *et al.* Structures of α-synuclein filaments from multiple system atrophy. *Nature* **585,** 464–469 (2020).	Dejerine, J. & Thomas, A. L'atrophie olivo-ponto-cérébelleuse. *Nouv. Iconogr. Salpêtrière* **13**, 330–370 (1900). Graham, J. G. & Oppenheimer, D. R. Orthostatic hypotension and nicotine sensitivity in a case of multiple system atrophy. *J. Neurol. Neurosurg. Psychiatry* **32**, 28–34 (1969).	Foundational clinical references.

Neuroscience	Sauerbrei, B.A., Guo, J., Cohen, J.D. *et al.* Cortical pattern generation during dexterous movement is input-driven. *Nature* **577,** 386–391 (2020).	Grünbaum, A. S. F. & Sherrington, C. S. Observations on the physiology of the cerebral cortex of some of the higher apes. *Proc. R. Soc. Lond*. **69**, 206–209 (1902). Penfield, W. & Boldrey, E. Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain* **60**, 389–443 (1937). Lawrence, D. G. & Kuypers, H. G. The functional organization of the motor system in the monkey. I. The effects of bilateral pyramidal lesions. *Brain* **91**, 1–14 (1968).	Background references.
Physiology	Tan, H., Sisti, A.C., Jin, H. *et al.* The gut–brain axis mediates sugar preference. *Nature* **580,** 511–516 (2020).	Elliott, Perry. *Production of Sugar in the United States and Foreign Countries* (US Department of Agriculture, 1917).	The old monograph didn't directly inspire the new paper, but it dramatically notes a ten-fold (4.5 kg to 45 kg) increase in refined sugar products consumed by the average American in the 1800s compared with today.
Evolution	Blasius, B., Rudolf, L., Weithoff, G. *et al.* Long-term cyclic persistence in an experimental predator–prey	Volterra, V. Fluctuations in the abundance of a species considered mathematically. *Nature* **118**, 558–	Just historical citations/background, but older papers are cited and not ignored

	system. *Nature* **577,** 226–230 (2020).	560 (1926). [Theory paper] Gause, G. F., Smaragdova, N. P. & Witt, A. A. Further studies of interaction between predators and prey. *J. Anim. Ecol*. **5**, 1–18 (1936). [Experimental study] Elton, C. & Nicholson, M. The ten-year cycle in numbers of the lynx in Canada. *J. Anim. Ecol*. **11**, 215–244 (1942). [field work]	
Immunology	Bashford-Rogers, R.J.M., Bergamaschi, L., McKinney, E.F. *et al.* Analysis of the B cell receptor repertoire in six immune-mediated diseases. *Nature* **574,** 122–126 (2019).	Nossal, G. J. V. & Lederberg, J. Antibody production by single cells. *Nature* **181**, 1419–1420 (1958).	Foundational reference.
Human biology	Thompson, D.J., Genovese, G., Halvardson, J. *et al.* Genetic predisposition to mosaic Y chromosome loss in blood. *Nature* **575,** 652–657 (2019).	Jacobs, P. A., Court Brown, W. M. & Doll, R. Distribution of human chromosome counts in relation to age. *Nature* **191**, 1178–1180 (1961). Jacobs, P. A., Brunton, M., Court Brown, W. M., Doll, R. & Goldstein, H. Change of human chromosome count distribution with age: evidence for a sex difference.	Foundational references; the topic has been studied continuously since.

		Nature **197**, 1080–1081 (1963).	
Neuroscience	Keller, A.J., Roth, M.M. & Scanziani, M. Feedback generates a second receptive field in neurons of the visual cortex. *Nature* **582,** 545–549 (2020).	Hubel, D. H. & Wiesel, T. N. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *J. Physiol. (Lond.)* **160**, 106–154 (1962).	Foundational reference in the field.
Physiology	Campbell, C., McKenney, P.T., Konstantinovsky, D. *et al.* Bacterial metabolism of bile acids promotes generation of peripheral regulatory T cells. *Nature* **581,** 475–479 (2020).	Hofmann, A. F. & Small, D. M. Detergent properties of bile salts: correlation with physiological function. *Annu. Rev. Med.* **18**, 333–376 (1967).	Still informative review article.

Supplementary Table 2 References to older papers that have some specific inspiration or utility for the current science.

Field of study	2019-2020 paper	Old references	Comment
Genetics (Applied math older papers)	Nitzan, M., Karaiskos, N., Friedman, N. *et al.* Gene expression cartography. *Nature* **576,** 132–137 (2019).	Monge, G. Mémoire sur la théorie des déblais et des remblais. *Historie de l'Academie Royale des Sciences de Paris* **1781**, 666–704 (1781). Villani, C. *Topics in Optimal Transportation* (American Mathematical Society, 2003). Villani, C. *Optimal Transport: Old and New* **Vol. 338** (Springer, 2008).	The topic studied in the new paper is modeled as an optimal transport problem—an idea which dates to the 18th century—but papers from the last decade or two on optimal transport are utilized.
Physiology	Alarcon-Martinez, L., Villafranca-Baughman, D., Quintero, H. *et al.* Interpericyte tunnelling nanotubes regulate neurovascular coupling. *Nature* **585,** 91–95 (2020).	Henle, F. Ueber die Ausbreitung des Epithelium im menschlichen Körper. *Arch. Anat. Physiol. Wiss. Med*. **1838**, 103–128 (1838). Cerletti, U. Die gefassvermehrung in zentralnervensystem. *Histol. Histopathol. Arb. Grosshirnr*. **4**, 1–168 (1910). Cammermeyer, J. A comparative study of intervascular connective tissue strands in the central nervous system. *J. Comp. Neurol*. **114**, 189–208 (1960).	Reminiscence of interpericyte tunneling nanotubes to structures observed nearly two centuries ago is highly intriguing.
Ecology	Fricke, E.C., Svenning, J. Accelerating	Wallace, A. R. *The Geographical Distribution of Animals*	Wallace's work on geographic distribution of animals

	homogenization of the global plant–frugivore meta-network. *Nature* **585,** 74–78 (2020).	*and Plants* (Harper & Brothers, 1876).	and plants is inspirational to modern scientists studying the impact on biotic homogenization caused by species introductions by humans.
Evolution	Todesco, M., Owens, G.L., Bercovich, N. *et al.* Massive haplotypes underlie ecotypic differentiation in sunflowers. *Nature* **584,** 602–607 (2020).	Romanes, G. J. Physiological selection; an additional suggestion on the origin of species. *Zool. J. Linn. Soc*. **19**, 337–411 (1886). Clausen, J. *Stages in the Evolution of Plant Species* (Cornell Univ. Press, 1951). Heiser, C. B., Jr. Hybridization in the annual sunflowers: *Helianthus annuus* × *H. debilis* var. *cucumerifolius*. *Evolution* **5**, 42–51 (1951). Heiser, C. B. Three new annual sunflowers (*Helianthus*) from the southwestern United States. *Rhodora* **60**, 272–283 (1958). Heiser, C. B. & Smith, D. M. *The North American Sunflowers (Helianthus)* (Seeman Printery, 1969).	The question of adaptation of a species to multiple environments dates back to criticism of Darwin's theories by his contemporaries. Older works provide helpful reference data on sunflowers.
Microbiology	Rafiqi, A.M., Rajakumar, A. & Abouheif, E. Origin and elaboration of a major evolutionary transition in individuality.	Blochmann, F. Über das Vorkommen bakterienähnlicher Gebilde in den Geweben und Eiern verschiedener Insekten.	Old observations of endosymbiosis between ants and bacteria and still relevant in driving current mechanistic studies.

	Nature **585,** 239–244 (2020).	*Zbl. Bakteriol*. **11**, 234–240 (1892). Tanquary, M. C. *Biological and Embryological Studies on Formicidae*. PhD thesis, Univ. of Illinois (1912). Buchner, P. *Endosymbiosis of Animals with Plant Microorganisms* (Interscience, 1965).	
Neurophysiology	Kim, J.J., Gharpure, A., Teng, J. *et al.* Shared structural mechanisms of general anaesthetics and benzodiazepines. *Nature* **585,** 303–308 (2020).	Meyer, H. Welche Eigenschaft der Anasthetica bedingt ihre narkotische Wirkung? *Naunyn Schmiedebergs Arch. Exp. Pathol. Pharmakol*. **42**, 109–118 (1899). Meyer, H. Zur Theorie der Alkoholnarkose: der Einfluss wechselnder Temperatur auf Wirkungsstärke und Theilungscoefficient der Narcotica. *Naunyn Schmiedebergs Arch. Exp. Pathol. Pharmakol*. **46**, 338–346 (1901). Overton, E. *Studien über die Narkose Zugleich ein Beitrag zur allgemeinen Pharmakologie* (Gustav Fischer, 1901).	Old ideas about the mechanism of action of general anesthetics still intriguing and inspiring further current research.
Organic chemistry	Garçon, M., Bakewell, C., Sackman, G.A. *et al.* A hexagonal	Werner, A. On the constitution and configuration of higher-order	General reference on the topic, inspirational but not specifically

	planar transition-metal complex. *Nature* **574,** 390–393 (2019).	compounds. Nobel Lecture, 11 December 1913. *The Nobel Prize*	useful for the modern study.
Human evolution	Hublin, J., Sirakov, N., Aldeias, V. *et al.* Initial Upper Palaeolithic *Homo sapiens* from Bacho Kiro Cave, Bulgaria. *Nature* **581,** 299–302 (2020).	Keith, A. Problems relating to the teeth of the earlier forms of prehistoric man. *Proc. R. Soc. Med*. **6**, 103–124 (1913). Shaw, J. *The Teeth, the Bony Palate and the Mandible in Bantu Races of South Africa* (Bale and Danielsson, London, 1938). Kallay, J. in *Dental Anthropology* (ed. Brothwell, D.) 75–86 (Pergamon, 1963).	Old method of characterization of molar teeth is useful in assigning fossil finds to Homo sapiens subspecies.
Glaciology	Lai, C., Kingslake, J., Wearing, M.G. *et al.* Vulnerability of Antarctica's ice shelves to meltwater-driven fracture. *Nature* **584,** 574–578 (2020).	Griffith, A. A. The phenomena of rupture and flow in solids. *Phil. Trans. R. Soc. A* **221**, 163–198 (1921). Irwin, G. R. Analysis of stresses and strains near the end of a crack traversing a plate. *J. Appl. Mech*. **24**, 361–364 (1957).	Old studies used by the current authors in the development of their model of ice-shelf fracturing.
Material science	Pan, J., Ivanov, Y.P., Zhou, W.H. *et al.* Strain-hardening and suppression of shear-banding in rejuvenated bulk metallic glass. *Nature* **578,** 559–562 (2020).	Taylor, G. I. The mechanism of plastic deformation of crystals. Part I.−Theoretical. *Proc. R. Soc. Lond. A* **145**, 362–387 (1934).	Old reference one method of plastic deformation; new paper another.
Immunology (Philosophy of science old work)	Jiang, C., Lian, X., Gao, C. *et al.* Distinct viral reservoirs in individuals with	Popper, K. *Die Logik der Forschung. Zur Erkenntnistheorie der modernen*	Popper's enunciation of the principle of empiric falsification continues to drive thoughts about further

	spontaneous control of HIV-1. *Nature* **585,** 261–267 (2020).	*Naturwissenschaft* (Springer, 1935).	experiments in a modern study.
Physics	Cheng, B., Mazzola, G., Pickard, C.J. *et al.* Evidence for supercritical behaviour of high-pressure liquid hydrogen. *Nature* **585,** 217–220 (2020).	Wigner, E. & Huntington, H. B. On the possibility of a metallic modification of hydrogen. *J. Chem. Phys*. **3**, 764–770 (1935). Ashcroft, N. W. Metallic hydrogen: a high-temperature superconductor? *Phys. Rev. Lett*. **21**, 1748–1749 (1968).	Old theoretic work continues to inspire recent computational studies.
Neurobiology	Hrvatin, S., Sun, S., Wilcox, O.F. *et al.* Neurons that regulate mouse torpor. *Nature* **583,** 115–121 (2020).	Teague, R. S. & Ranson, S. W. The role of the anterior hypothalamus in temperature regulation. *Am. J. Physiol*. **117**, 562–570 (1936). Herrington, L. P. The heat regulation of small laboratory animals at various environmental temperatures. *Am. J. Physiol*. **129**, 123–139 (1940). Nakayama, T., Eisenman, J. S. & Hardy, J. D. Single unit activity of anterior hypothalamus during local heating. *Science* **134**, 560–561 (1961).	Pioneering neuroanatomical and neurobehavioral studies.
Organic chemistry	Kumar, R., Flodén, N.J., Whitehurst, W.G. *et al.* A general carbonyl alkylative amination for tertiary amine synthesis. *Nature*	Reiber, H. G. & Stewart, T. D. The tetra alkyl methylene immonium salts. *J. Am. Chem. Soc*. **62**, 3026–3030 (1940).	Old paper that catalogs apparent difficulty of a reaction is inspiring, but not useful for the new paper.

	581, 415–420 (2020).		
Neurobiology	Qian, H., Kang, X., Hu, J. *et al.* Reversing a model of Parkinson's disease with in situ converted nigral neurons. *Nature* **582,** 550–556 (2020).	Abercrombie, M. Estimation of nuclear population from microtome sections. *Anat. Rec*. **94**, 239–247 (1946).	Old method still useful.
Material science	Cheema, S.S., Kwon, D., Shanker, N. *et al.* Enhanced ferroelectricity in ultrathin films grown directly on silicon. *Nature* **580,** 478–482 (2020).	Merz, W. J. The effect of hydrostatic pressure on the Curie point of barium titanate single crystals. *Phys. Rev*. **78**, 52 (1950).	The symmetry property of perovskite discussed in the old paper is practically a reference value.
Material science	Zhao, X., Song, P., Wang, C. *et al.* Engineering covalently bonded 2D layered materials by self-intercalation. *Nature* **581,** 171–177 (2020).	Zener, C. Interaction between the *d* shells in the transition metals. *Phys. Rev*. **81**, 440–444 (1951).	Zener's seventy-year old theory of ferromagnetism being induced by a double exchange mechanism is well-known and appreciated. The method shows its continued durability and utility as Zhao et al. use it to explain how the magnetization of self-intercalation Ta_7S_{12} produced by charge transfer from intercalation of tantalum to TaS_2.
Physics	Lakhotia, H., Kim, H.Y., Zhan, M. *et al.* Laser picoscopy of valence electrons in solids. *Nature* **583,** 55–59 (2020).	Smith, S. J. & Purcell, E. M. Visible light from localized surface charges moving across a grating. *Phys. Rev*. **92**, 1069 (1953). Hüller, S. & Meyer-Ter-Vehn, J. High-order harmonic radiation from solid	Older, commonly cited works, still providing analogies relevant and insightful in appreciating the theory used to explain current experiments.

		layers irradiated by subpicosecond laser pulses. *Phys. Rev. A* **48**, 3906–3909 (1993). Henneberger, W. C. Perturbation method for atoms in intense light beams. *Phys. Rev. Lett*. **21**, 838–841 (1968). Gavrila, M. & Kamiński, J. Z. Free-free transitions in intense high-frequency laser fields. *Phys. Rev. Lett*. **52**, 613–616 (1984).	
Physics	Rui, J., Wei, D., Rubio-Abadal, A. *et al.* A subradiant optical mirror formed by a single structured atomic layer. *Nature* **583,** 369–374 (2020).	Dicke, R. H. Coherence in spontaneous radiation processes. *Phys. Rev*. **93**, 99–110 (1954).	New instance of effect described decades ago.
Microbiology	Pasquina-Lemonche, L., Burns, J., Turner, R.D. *et al.* The architecture of the Gram-positive bacterial cell wall. *Nature* **582,** 294–297 (2020).	Mitchell, P. & Moyle, J. Autolytic release and osmotic properties of protoplasts from *Staphylococcus aureus*. *J. Gen. Microbiol*. **16**, 184–194 (1957).	Tensile properties of bacterial cell walls measured decades ago still useful data.
Dinosaurs	Norell, M.A., Wiemann, J., Fabbri, M. *et al.* The first dinosaur egg was soft. *Nature* **583,** 406–410 (2020).	Romer, A. S. Origin of the amniote egg. *Sci. Monthly* **85**, 57–63 (1957). Hadek, R. The structure of the mammalian egg. *Int. Rev. Cytol*. **18**, 29–71 (1965).	Useful background information.
Physics	Guo, M., Böttcher, F., Hertkorn, J. *et*	Gross, E. P. Unified theory of interacting	Older crucial theoretical papers, but

	al. The low-energy Goldstone mode in a trapped dipolar supersolid. *Nature* **574,** 386–389 (2019).	bosons. *Phys. Rev*. **106**, 161 (1957). Yarnell, J., Arnold, G., Bendt, P. & Kerr, E. Energy vs momentum relation for the excitations in liquid helium. *Phys. Rev. Lett*. **1**, 9 (1958). Anderson, P. W. Random-phase approximation in the theory of superconductivity. *Phys. Rev*. **112**, 1900 (1958). Goldstone, J. Field theories with superconductor solutions. *Il Nuovo Cimento (1955–1965)* **19**, 154–164 (1961). Nambu, Y. & Jona-Lasinio, G. Dynamical model of elementary particles based on an analogy with superconductivity. *Phys. Rev*. **124**, 246 (1961). Higgs, P. W. Broken symmetries and the masses of gauge bosons. *Phys. Rev. Lett*. **13**, 508 (1964). Leggett, A. J. Can a solid be "superfluid"? *Phys. Rev. Lett*. **25**, 1543–1546 (1970).	the topic continuously studied. See text for further discussion on this and the next paper.
Physics	Tanzi, L., Roccuzzo, S.M., Lucioni, E. *et al.* Supersolid symmetry breaking from compressional oscillations in a	Andreev, A. F. & Lifshitz, I. M. Quantum theory of defects in crystals (in Russian). *Sov. Phys. JETP* **29**, 1107–1113 (1969).	Older crucial theoretical papers, but the topic continuously studied. See text for further discussion on this and the preceeding paper.

	dipolar quantum gas. *Nature* **574,** 382–385 (2019).	Chester, G. V. Speculations on Bose–Einstein condensation and quantum crystals. *Phys. Rev. A* **2**, 256–258 (1970). Leggett, A. J. Can a solid be "superfluid"? *Phys. Rev. Lett*. **25**, 1543–1546 (1970).	
Soil science (Older reference geology)	Nottingham, A.T., Meir, P., Velasquez, E. *et al.* Soil carbon loss by experimental warming in a tropical forest. *Nature* **584,** 234–237 (2020).	Woodring, W. P. Geology of Barro Colorado Island. *Smithson. Misc. Collect*. **135**, 1–39 (1958).	Old monograph still a relevant reference on the locale used for the current study.
Vertebrate evolution	Cappellini, E., Welker, F., Pandolfi, L. *et al.* Early Pleistocene enamel proteome from Dmanisi resolves *Stephanorhinus* phylogeny. *Nature* **574,** 103–107 (2019).	Eastoe, J. E. Organic matrix of tooth enamel. *Nature* **187**, 411–412 (1960).	Old reference notes a property of enamel that would make it potentially useful for proteomic analysis.
Human biology	Asgari, S., Luo, Y., Akbari, A. *et al.* A positively selected *FBN1* missense variant reduces height in Peruvian individuals. *Nature* **582,** 234–239 (2020).	Lasker, G. W. Differences in anthropometric measurements within and between three communities in Peru. *Hum. Biol*. **34**, 63–70 (1962).	Old reference with still useful data.
Material science	Wu, M., Zhang, Z., Xu, X. *et al.* Seeded growth of large single-crystal copper foils with high-index facets. *Nature* **581,** 406–410 (2020).	Dunn, C. G. & Walter, J. L. Surface energies and other surface effects relating to secondary recrystallization textures in high-purity iron, zone-refined iron,	Topic continuously studied since the 1960s.

		and 0.6 Pct Si-Fe. *Trans. Metall. Soc. AIME* **224**, 518–533 (1962). Rhead, G. E. & McLean, M. Variation of surface energy with crystallographic orientation in silver. *Acta Metall*. **12**, 401–407 (1964). McLean, M. & Mykura, H. The temperature dependence of the surface energy anisotropy of platinum. *Surf. Sci*. **5**, 466–481 (1966).	
Organic chemistry	U. Dighe, S., Juliá, F., Luridiana, A. *et al.* A photochemical dehydrogenative strategy for aniline synthesis. *Nature* **584,** 75–81 (2020).	Olah, G. A. *Friedel-Crafts And Related Reactions* (Wiley, 1963).	Old method a classic, but not as versatile as newer one.
Neurobiology	Pashkovski, S.L., Iurilli, G., Brann, D. *et al.* Structure and flexibility in cortical representations of odour space. *Nature* **583,** 253–258 (2020).	Amoore, J. E. Stereochemical theory of olfaction. *Nature* **198**, 271–272 (1963).	Fundamental paper in the field.
Astronomy	Plavchan, P., Barclay, T., Gagné, J. *et al.* A planet within the debris disk around the pre-main-sequence star AU Microscopii. *Nature* **582,** 497–500 (2020).	Eggen, O. J. Narrow- and broad-band photometry of red stars. II. Dwarfs. *Astrophys. J. Suppl. Ser*. **16**, 49 (1968).	Star properties.
Infectious disease	Arnold, F.M., Weber, M.S., Gonda, I. *et al.* The	Snow, G. A. & White, A. J. Chemical and biological properties of	*M. tuberculosis* produces two classes of siderophore, lipid-

	ABC exporter IrtAB imports and reduces mycobacterial siderophores. *Nature* **580,** 413–417 (2020).	mycobactins isolated from various mycobacteria. *Biochem. J.* **115**, 1031–1045 (1969).	bound mycobactin and water-soluble carboxymycobactin.

Supplementary Table 3 References to older papers that provide specific utility or inspiration to the modern paper.

Field of study	2019-2020 paper	Old references	Comment
Inorganic chemistry	Simonov, A., De Baerdemaeker, T., Boström, H.L. *et al.* Hidden diversity of vacancy networks in Prussian blue analogues. *Nature* **578,** 256–260 (2020).	Frisch, J. L. Notitia cœrulei Berolinensis nuper inventi. *Misc. Berolin*. **1**, 377–378 (1710). Keggin, J. F. & Miles, F. D. Structures and formulæ of the Prussian blues and related compounds. *Nature* **137**, 577–578 (1936).	Possibly one could have mused on the old work about Prussian blue compounds and component atomic valences to conceive the new study, but I doubt this was the authors' approach.
Astronomy	Alves, J., Zucker, C., Goodman, A.A. *et al.* A Galactic-scale gas wave in the solar neighbourhood. *Nature* **578,** 237–239 (2020).	Herschel, J. F. W. *Results of Astronomical Observations Made During the Years 1834, 5, 6, 7, 8, at the Cape of Good Hope; Being the Completion of a Telescopic Survey of the Whole Surface of the Visible Heavens, Commenced in 1825* (Smith, Elder and Company, 1847). Gould, B. A. On the number and distribution of the bright fixed stars. *Am. J. Sci*. **38**, 325–333 (1874). Bobylev, V. V. The Gould belt. *Astrophysics* **57**, 583–604 (2014).	An older very influential model of the local interstellar medium is perhaps not correct.
Molecular biology	Pillai, A.S., Chandler, S.A., Liu, Y. *et al.* Origin of complexity in haemoglobin evolution. *Nature* **581,** 480–485 (2020).	Darwin, C. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* 204–208 (John Murray, 1859). Pauling, L. et al. Sickle cell anemia, a molecular disease. *Science* **110**, 543–548 (1949).	Classics from a number of different fields—molecular biology, protein structure, medical genetics and evolution—still informative and inspiring for this paper.

		Perutz, M. F. et al. Structure of haemoglobin: a three-dimensional Fourier synthesis at 5.5-A. resolution, obtained by X-ray analysis. *Nature* **185**, 416–422 (1960). Kendrew, J. C. et al. Structure of myoglobin: a three-dimensional Fourier synthesis at 2 A. resolution. *Nature* **185**, 422–427 (1960). Monod, J., Wyman, J. & Changeux, J. P. On the nature of allosteric transitions: a plausible model. *J. Mol. Biol*. **12**, 88–118 (1965). Zuckerkandl, E. The evolution of hemoglobin. *Sci. Am*. **212**, 110–118 (1965). Tyuma, I., Benesch, R. E. & Benesch, R. The preparation and properties of the isolated α and β subunits of hemoglobin A. *Biochemistry* **5**, 2957–2962 (1966).	
Oceanography (life sciences)	Katija, K., Troni, G., Daniels, J. *et al.* Revealing enigmatic mucus structures in the deep sea using DeepPIV. *Nature* **583,** 78–82 (2020).	Fol, H. Etudes sur les Appendiculaires du détroit de Messine. *Mem. Soc. Phys. Hist. Nat. Geneve* **21**, 445–499 (1872). Körner, W. F. Untersuchungen über die gehäusebildung bei appendicularien (*Oikopleura dioica* Fol). *Z. Morphol. Oekol. Tiere* **41**, 1–53 (1952).	Old studies of appendages still relevant.
Vertebrate evolution	Cloutier, R., Clement, A.M., Lee, M.S.Y. *et al. Elpistostege* and the	Cope, E. D. On the phylogeny of the Vertebrata. *Proc. Am. Phil. Soc*. **30**, 278–281 (1892).	Discovery of the tetrapod humerus–ulna–radius pattern, first

	origin of the vertebrate hand. *Nature* **579,** 549–554 (2020).		identified in *Eusthenopteron* over a century ago, is confirmed to have an even deeper evolutionary origin.
Astronomy	Armstrong, D.J., Lopez, T.A., Adibekyan, V. *et al.* A remnant planetary core in the hot-Neptune desert. *Nature* **583,** 39–42 (2020).	Strehl, K. Über die Bildschärfe der Fernrohre. *Astron. Nachr*. **158**, 89–90 (1902).	Long ago described parameter of a quality of optical image formation still useful.
Physics	Nahas, Y., Prokhorenko, S., Fischer, J. *et al.* Inverse transition of labyrinthine domain patterns in ferroelectric thin films. *Nature* **577,** 47–51 (2020).	Tammann, G. *Kristallisieren und Schmelzen* (Johann Ambrosius Barth, 1903).	The recent paper shows that the inverse transition of a labyrinthine domain is a general phenomenon.
Physical chemistry	Sun, J., Sobolev, Y.I., Zhang, W. *et al.* Enhancing crystal growth using polyelectrolyte solutions and shear flow. *Nature* **579,** 73–79 (2020).	Noyes, A. A. The physical properties of aqueous salt solutions in relation to the ionic theory. *Science* **20**, 577–587 (1904). Lewis, G. N. & Randall, M. *Thermodynamics And The Free Energy Of Chemical Substances* (McGraw-Hill, 1923). Cohn, E. J. The physical chemistry of the proteins. *Physiol. Rev*. **5**, 349–437 (1925). De Gennes, P. G. Coil-stretch transition of dilute flexible polymers under ultrahigh velocity gradients. *J. Chem. Phys*. **60**, 5030–5042 (1974).	The current paper utilizes a phenomenon somewhat analogous to salting out, and the old papers seem to have been somewhat inspirational in this regard. Also a more recent but still old paper is relevant to shear thinning, which is also crucial to the method described in the new paper.

Invertebrate evolution	Chen, H., Parry, L.A., Vinther, J. *et al.* A Cambrian crown annelid reconciles phylogenomics and the fossil record. *Nature* **583,** 249–252 (2020).	Allen, E. J. The anatomy of *Poecilochaetus*, Claparede. *Q. J. Microsc. Sci*. **48**, 79–151 (1904). Barnes, R. D. Tube-building and feeding in the chaetopterid polychaete, *Spiochaetopterus oculatus*. *Biol. Bull*. **127**, 397–412 (1964). Jones, M. L. On the morphology, feeding, and behavior of *Magelona* sp. *Biol. Bull*. **134**, 272–297 (1968).	According to Google Scholar this paper was only cited once previously, in a book in 1917. Old studies of extant species are still useful in understanding a newly discovered fossil.
Applied math	Kanazawa, K., Sano, T.G., Cairoli, A. *et al.* Loopy Lévy flights enhance tracer diffusion in active suspensions. *Nature* **579,** 364–367 (2020).	Campbell, N. The study of discontinuous phenomena. *Proc. Camb. Philos. Soc*. **15**, 117–136 (1909). Holtsmark, J. Über die Verbreiterung von Spektrallinien. *Ann. Phys*. **363**, 577–630 (1919).	New paper uses models for stochastic and other processes from older papers.
Dinosaurs	Ibrahim, N., Maganuco, S., Dal Sasso, C. *et al.* Tail-propelled aquatic locomotion in a theropod dinosaur. *Nature* **581,** 67–70 (2020).	Stromer, E. Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wüsten Ägyptens. II. Wirbeltier-Reste der Baharîje -Stufe (unterstes Cenoman). 3. Das Original des Theropoden *Spinosaurus aegyptiacus* nov. gen., nov. spec. *Abh. Kgl. Bayer. Akad. Wiss. Math. Phys. Kl. München* **28**, 1–28 (1915).	A more than century old paper describing the type specimen of a large spinosaurid which was destroyed in WWII inspired the search for and study of a new fossil, which establishes the anatomic adaptations to an aquatic lifestyle.
Human evolution	Grün, R., Pike, A., McDermott, F. *et al.* Dating the skull from Broken Hill, Zambia, and its position in human	Woodward, A. S. A new cave man from Rhodesia, South Africa. *Nature* **108**, 371–372 (1921).	Old paper still inspiring study using current technology.

	evolution. *Nature* **580,** 372–375 (2020).		
Human biology	Venkadesan, M., Yawar, A., Eng, C.M. *et al.* Stiffness of the human foot and evolution of the transverse arch. *Nature* **579,** 97–100 (2020).	Morton, D. J. Evolution of the longitudinal arch of the human foot. *J. Bone Joint Surg*. **6**, 56–90 (1924). Morton, D. J. Evolution of the human foot II. *Am. J. Phys. Anthropol*. **7**, 1–52 (1924).	Old papers discussed the importance of the longitudinal arch in human foot mechanics; the new paper discusses the importance of the transverse arch.
Physics	Ramos, R., Spierings, D., Racicot, I. *et al.* Measurement of the time spent by a tunnelling atom within the barrier region. *Nature* **583,** 529–532 (2020).	MacColl, L. A. Note on the transmission and reflection of wave packets by potential barriers. *Phys. Rev*. **40**, 621–626 (1932). Wigner, E. P. Lower limit for the energy derivative of the scattering phase shift. *Phys. Rev*. **98**, 145–147 (1955). Baz', A. I. Lifetime of intermediate states (in Russian). *Sov. J. Nucl. Phys*. **4**, 182–188 (1966). Rybachenko, V. F. Time of penetration of a particle through a potential barrier (in Russian). *Sov. J. Nucl. Phys*. **5**, 635–639 (1967).	Older theoretical work still inspirational and useful for current experiments.
Protein structure (Physical chemistry older paper)	Senior, A.W., Evans, R., Jumper, J. *et al.* Improved protein structure prediction using potentials from deep learning. *Nature* **577,** 706–710 (2020).	Kirkwood, J. Statistical mechanics of fluid mixtures. *J. Chem. Phys*. 3, 300–313 (1935).	Old concept useful for new algorithm.
Physics	Rivilla, I., Aparicio, B., Bueno, J.M. *et al.* Fluorescent bicolour sensor for low-background	Majorana, E. Theory of the symmetry of electrons and positrons. *Nuovo Cim*. **14**, 171–184 (1937).	Foundational paper.

	neutrinoless double β decay experiments. *Nature* **583,** 48–54 (2020).	Benesi, H. A. & Hildebrand, J. H. A spectrophotometric investigation of the interaction of iodine with aromatic hydrocarbons. *J. Am. Chem. Soc*. **71**, 2703–2707 (1949). Sakharov, A. D. Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe (in Russian). *Pis'ma Z. Eksp. Teor. Fiz*. **5**, 32–35 (1967).	Still useful method. Classic paper on possible implications of the unambiguous detection of double β decay.
Physics	Aveline, D.C., Williams, J.R., Elliott, E.R. *et al.* Observation of Bose–Einstein condensates in an Earth-orbiting research lab. *Nature* **582,** 193–197 (2020).	Jenkins, F. A. & Segrè, E. The quadratic Zeeman effect. *Phys. Rev*. **55**, 52–58 (1939).	Long ago described affect used to confine BEC in space experiment.
Immunology (old paper Applied toxicology)	Chan, L.N., Murakami, M.A., Robinson, M.E. *et al.* Signalling input from divergent pathways subverts B cell transformation. *Nature* **583,** 845–851 (2020).	Bliss, C. I. The toxicity of poisons applied jointly. *Ann. Appl. Biol*. **26**, 585–615 (1939).	Old statistical model still useful for analyzing current experiment.
Chemistry	Shieh, P., Zhang, W., Husted, K.E.L. *et al.* Cleavable comonomers enable degradable, recyclable thermoset plastics. *Nature* **583,** 542–547 (2020).	Flory, P. J. Molecular size distribution in three dimensional polymers. I. Gelation. *J. Am. Chem. Soc*. **63**, 3083–3090 (1941). Flory, P. J. Random reorganization of molecular weight distribution in linear condensation polymers. *J.*	Old theories still useful to help guide development of modern polymers.

		Am. Chem. Soc. **64**, 2205–2212 (1942). Stockmayer, W. H. Theory of molecular size distribution and gel formation in branched polymers: II. General cross linking. *J. Chem. Phys*. **12**, 125–131 (1944).	
Anthropology (Older papers geology, botany)	Ardelean, C.F., Becerra-Valdivia, L., Pedersen, M.W. *et al*. Evidence of human occupation in Mexico around the Last Glacial Maximum. *Nature* **584,** 87–92 (2020).	Johnston, I. M. Plants of Coahuila, eastern Chihuahua, and adjoining Zacatecas and Durango, *V. J. Arnold Arbor*. **25**, 133–182 (1944). Folk, R. L. Practical petrographic classification of limestones. *Bull. Am. Assoc. Petrol. Geol*. **43**, 1–38 (1959). Dunham, R. J. Classification of carbonate rocks according to depositional texture. In *Classification of Carbonate Rocks—A Symposium* (ed. Ham, W. E.) 108–121 (The American Association of Petroleum Geologists, 1962).	Old botany and geology studies provide useful information for a current anthropology paper.
Physics	Vepsäläinen, A.P., Karamlou, A.H., Orrell, J.L. *et al*. Impact of ionizing radiation on superconducting qubit coherence. *Nature* **584,** 551–556 (2020).	Dicke, R. The measurement of thermal radiation at microwave frequencies. *Rev. Sci. Instrum*. **17**, 268–275 (1946).	To detect very small signals, the authors of the 2020 study used an approach inspired by Dicke's switch radiometer measurement.
Physics	Hori, M., Aghai-Khozani, H., Sótér, A. *et al*. Laser spectroscopy of pionic helium atoms.	Fermi, E. & Teller, E. The capture of negative mesotrons in matter. *Phys. Rev*. **72**, 399–408 (1947). Condo, G. T. On the absorption of negative	See text for discussion of this paper which utilizes papers from two older eras.

	Nature **581,** 37–41 (2020).	pions by liquid helium. *Phys. Lett*. **9**, 65–66 (1964). Russell, J. E. Metastable states of $\alpha\pi^-e^-$, αK^-e^-, and $\alpha\bar{p}e^-$ atoms. *Phys. Rev. Lett*. **23**, 63–64 (1969). Russell, J. E. Structure of neutral mesonic atoms formed in liquid helium. *Phys. Rev. A* **1**, 721–734 (1970).	
Ecology	Cámara-Leret, R., Frodin, D.G., Adema, F. *et al.* New Guinea has the world's richest island flora. *Nature* **584,** 579–583 (2020).	Good, R. On the geographical relationships of the angiosperm flora of New Guinea. *Bull. Br. Mus. Nat. Hist*. **2**, 205–226 (1960). Souter, G. *New Guinea: The Last Unknown* (Angus and Robertson, 1963). van Steenis, C. G. G. J. (ed.) *Flora Malesiana series I* Vol. I (Noordhoff-Kolff, 1950). Backer, C. A. & Bakhuizen van den Brink, R. C. Jr. *Flora of Java* Vol. 1–3 (Wolters Noordhoff, 1968). MacArthur, R. H. & Wilson, E. O. *The Theory of Island Biogeography* (Princeton Univ. Press, 1967).	The preponderance of plant species endemic to New Guinea was noted in an early study. Previous studies of New Guinea and flora on other islands provide helpful comparisons to the current survey.
Physics	Rhim, J., Kim, K. & Yang, B. Quantum distance and anomalous Landau levels of flat bands. *Nature* **584,** 59–63 (2020).	Onsager, L. Interpretation of the de Haas–van Alphen effect. *Philos. Mag*. **43**, 1006–1008 (1952). Roth, L. M. Semiclassical theory of magnetic energy levels and magnetic susceptibility of Bloch electrons. *Phys. Rev*. **145**, 434–448 (1966).	Old theory still a useful starting place for new theoretical work.

Physics	Henry, L., Mezouar, M., Garbarino, G. *et al.* Liquid–liquid transition and critical point in sulfur. *Nature* **584,** 382–386 (2020).	Braune, H. & Moller, O. The specific heat of liquid sulfur. *Z. Naturforsch. B* **9a**, 210–217 (1954). Tobolsky, A. V. & Eisenberg, A. Equilibrium polymerization of sulfur. *J. Am. Chem. Soc*. **81**, 780–782 (1959). Sauer, G. E. & Borst, L. B. Lambda transition in liquid sulfur. *Science* **158**, 1567–1569 (1967).	Old experimental and theoretical work on the lambda transition and associated phases in sulfur provide a most relevant comparison to the newly discovered phase transition.
Microbiology	Liang, G., Zhao, C., Zhang, H. *et al.* The stepwise assembly of the neonatal virome is modulated by breastfeeding. *Nature* **581,** 470–474 (2020).	Jacob, F. & Wollman, E. Spontaneous induction of the development of bacteriophage lambda during genetic recombination in *Escherichia coli K12* (in French). *C.R. Acad. Sci*. **239**, 317–319 (1954). Jacob, F., Sussman, R. & Monod, J. On the nature of the repressor ensuring the immunity of lysogenic bacteria (in French). *C. R. Acad. Sci*. **254**, 4214–4216 (1962).	Older papers still useful.
Physiology	Redhai, S., Pilgrim, C., Gaspar, P. *et al.* An intestinal zinc sensor regulates food intake and developmental growth. *Nature* **580,** 263–268 (2020).	Waterhouse, D. F. & Stay, B. Functional differentiation in the midgut epithelium of blowfly larvae as revealed by histochemical tests. *Aust. J. Biol. Sci*. **8**, 253–277 (1955). Poulson, D. F. & Waterhouse, D. F. Experimental studies on pole cells and midgut differentiation in Diptera. *Aust. J. Biol. Sci*. **13**, 541–567 (1960).	Unappreciated role of interstitial cells—a population of enterocytes—found sixty-five years after discovery of the cells. In the recent paper a receptor was found by molecular means, then localized to the interstitial cells. So the new research does not directly descend

			from the older research.
Physics	Li, J., Wilson, C.B., Cheng, R. *et al.* Spin current from sub-terahertz-generated antiferromagnetic magnons. *Nature* **578,** 70–74 (2020).	Dayhoff, E. S. Antiferromagnetic resonance in Cr_2O_3. *Phys. Rev*. **107**, 84 (1957). Foner, S. High-field antiferromagnetic resonance in Cr_2O_3. *Phys. Rev*. **130**, 183–197 (1963).	Old papers guide choice of material for new study.
Climate science	Bronselaer, B., Zanna, L. Heat and carbon coupling reveals ocean warming due to circulation changes. *Nature* **584,** 227–233 (2020).	Revelle, R. & Suess, H. S. Carbon dioxide exchange between atmosphere and ocean and the questions of an increase of atmospheric CO_2 during the past decades. *Tellus* **9**, 18–27 (1957).	Revelle’s buffer factor still useful for current modeling of ocean warming.
Botany	Zhao, Y., Antoniou-Kourounioti, R.L., Calder, G. *et al.* Temperature-dependent growth contributes to long-term cold sensing. *Nature* **583,** 825–829 (2020).	Erickson, R. O. & Michelini, F. J. The plastochron index. *Am. J. Bot*. **44**, 297–305 (1957).	Old model still useful in modeling current experiments.
Physics	Shi, Y., Xu, S., Yang, Y. *et al.* Electronic phase separation in multilayer rhombohedral graphite. *Nature* **584,** 210–214 (2020).	Haering, R. R. Band structure of rhombohedral graphite. *Can. J. Phys*. **36**, 352–362 (1958). Mcclure, J. W. Electron energy band structure and electronic properties of rhombohedral graphite. *Carbon* **7**, 425–432 (1969).	Old calculations still relevant and useful.
Chemistry	Sperling, J.M., Warzecha, E.J., Celis-Barros, C. *et al.* Compression of curium pyrrolidine-dithiocarbamate enhances covalency.	Carnall, W. T. & Fields, P. A study of the complexes of curium (iii) by absorption spectrometry. *J. Am. Chem. Soc*. **81**, 4445–4449 (1959). Dachille, F. & Roy, R. High-pressure phase	Older data and methods still useful.

	Nature **583,** 396–399 (2020).	transformations in laboratory mechanical mixers and mortars. *Nature* **186**, 34–35 (1960). Carnall, W. T. & Wybourne, B. G. Electronic energy levels of the lighter actinides: U^{3+}, Np^{3+}, Pu^{3+}, Am^{3+}, and Cm^{3+}. *J. Chem. Phys*. **40**, 3428–3433 (1964). Wybourne, B. G. *Spectroscopic Properties of Rare Earths* (Wiley, 1965).	
Anthropology	Inomata, T., Triadan, D., Vázquez López, V.A. *et al.* Monumental architecture at Aguada Fénix and the rise of Maya civilization. *Nature* **582,** 530–533 (2020).	Drucker, P., Heizer, R. F. & Squier, R. H. *Excavations at La Venta, Tabasco, 1955* (Smithsonian Institution, 1959). Millon, R. The beginnings of Teotihuacan. *Am. Antiq*. **26**, 1–10 (1960) Erasmus, C. J. Monument building: some field experiments. *Southwest. J. Anthropol*. **21**, 277–301 (1965).	Old reports about the current and other dig sites, and field experiments on work output, still useful.
Physics	Hu, G., Ou, Q., Si, G. *et al.* Topological polaritons and photonic magic angles in twisted α-MoO_3 bilayers. *Nature* **582,** 209–213 (2020).	Lifshitz, I. M. Anomalies of electron characteristics of a metal in the high-pressure region (in Russian). *Sov. Phys. JETP* **11**, 1130-1135 (1960).	Analagous phenomenon to previously described phase transition in electron systems found in a photonic system.
Physics	Asaad, S., Mourik, V., Joecker, B. *et al.* Coherent electrical control of a single high-spin nucleus in silicon. *Nature* **579,** 205–209 (2020).	Bloembergen, N. Linear Stark effect in magnetic resonance spectra. *Science* **133**, 1363–1364 (1961). Dixon, R. & Bloembergen, N. Electrically induced perturbations of halogen nuclear quadrupole interactions in polycrystalline compounds.	The authors of the recent paper independently (re)discovered the previously suggested effect and demonstrated it experimentally. See text for further discussion.

		ii. Microscopic theory. *J. Chem. Phys*. **41**, 1739–1747 (1964).	
Sociology of science	Yin, Y., Wang, Y., Evans, J.A. *et al.* Quantifying the dynamics of failure across science, startups and security. *Nature* **575,** 190–194 (2019).	Merton, R. K. Singletons and multiples in scientific discovery: a chapter in the sociology of science. *Proc. Am. Phil. Soc*. **105**, 470–486 (1961). Kuhn, T. S. *The Structure of Scientific Revolutions* (Chicago Univ. Press, 2012 [1962]).	Older work helpful in establishing model parameters used in current work. This paper cites the 2012 4^{th} edition of Kuhn's classic *The Structure of Scientific Revolutions*, but the ideas used in the recent paper were present in the original 1962 edition. (One possible source of unappreciated older citations is use of more recent editions or printings of books. However, I have not found any other examples of this.)
Physics	Gunawan, O., Pae, S.R., Bishop, D.M. *et al.* Carrier-resolved photo-Hall effect. *Nature* **575,** 151–155 (2019).	Fowler, A. Photo-Hall effect in CdSe sintered photoconductors. *J. Phys. Chem. Solids* **22**, 181–188 (1961). Dresner, J. The photo-Hall effect in vitreous selenium. *J. Phys. Chem. Solids* **25**, 505–511 (1964). Hall, E. H. On a new action of the magnet on electric currents. *Am. J. Math*. **2**, 287–292 (1879).	Modern experimental methods enable simultaneous measurement of the mobility and concentration of both majority and minority carriers in the photo-Hall effect.
Organic chemistry	Lv, J., Chen, X., Xue, X. *et al.* Metal-free directed sp^2-C–	Letsinger, R. L. & MacLean, D. B. Organoboron compounds.	Old studies showed that metal-free directed

	H borylation. *Nature* **575,** 336–340 (2019).	XVI. Cooperative functional group effects in reactions of boronoarylbenzimidazoles. *J. Am. Chem. Soc*. **85**, 2230–2236 (1963). Davis, F. A. & Dewar, M. J. S. New heteroaromatic compounds. XXX. A derivative of 10, 9-borathiarophenanthrene. *J. Am. Chem. Soc*. **90**, 3511–3515 (1968).	borylation with good regioselectivity is possible, but required harsh conditions and the use of aluminuium salts.
Evolution	Valente, L., Phillimore, A.B., Melo, M. *et al.* A simple dynamic model explains the diversity of island birds worldwide. *Nature* **579,** 92–96 (2020).	MacArthur, R. H. & Wilson, E. O. An equilibrium theory of insular zoogeography. *Evolution* **17**, 373–387 (1963). MacArthur, R. H. & Wilson, E. O. *The Theory of Island Biogeography* (Princeton Univ. Press, 1967).	The new paper uses modern phylogenetic methods to prove an older theory.
Physiology	Quinn, R.A., Melnik, A.V., Vrbanac, A. *et al.* Global chemical effects of the microbiome include new bile-acid conjugations. *Nature* **579,** 123–129 (2020).	Peric-Golia, L. & Jones, R. S. Ornithocholanic acids and cholelithiasis in man. *Science* **142**, 245–246 (1963). Gordon, B. A., Kuksis, A. & Beveridge, J. M. R. Separation of bile acid conjugates by ion exchange chromatography. *Can. J. Biochem. Physiol*. **41**, 77–89 (1963).	After nearly six decades new bile-acid conjugates found.
Neurobiology	Norimoto, H., Fenk, L.A., Li, H. *et al.* A claustrum in reptiles and its role in slow-wave sleep. *Nature* **578,** 413–418 (2020).	Gabor, A. J. & Peele, T. L. Alterations of behavior following stimulation of the claustrum of the cat. *Electroencephalogr. Clin. Neurophysiol*. **17**, 513–519 (1964).	The authors of the recent paper cite in the abstract as motivation for their study a 2005 paper discussing proposed multifaceted roles for the claustrum. It is not until the

			second to last paragraph that the authors cite this older paper and go on to say that its results are uncertain because selective stimulation of the mammalian claustrum is difficult. Nevertheless, it seems this old paper continues to have an impact.
Neuronal cell biology (Evolutionary biology older paper)	Reilly, M.B., Cros, C., Varol, E. *et al.* Unique homeobox codes delineate all the neuron classes of *C. elegans*. *Nature* **584,** 595–601 (2020).	Dobzhansky, T. Biology, molecular and organismic. *Am. Zool*. **4**, 443–452 (1964).	Dobzhansky's dictum that 'nothing in biology makes sense except in the light of evolution', inspired the authors of the current study to conclude by speculating that homeodomain proteins were recruited into the specification of neuronal identity very early in the evolution of the nervous system.
Human genetics (Anthropology older paper)	Cassidy, L.M., Maoldúin, R.Ó., Kador, T. *et al.* A dynastic elite in monumental Neolithic society. *Nature* **582,** 384–388 (2020).	Goggin, J. M. & Sturtevant, W. P. in *Explorations in Cultural Anthropology. Essays in Honour of George Peter Murdock* (ed. Goodenough, W. H.) 179–219 (McGraw-Hill, 1964).	Prior analysis still important and relevant.
Astrophysics	Neeleman, M., Prochaska, J.X., Kanekar, N. *et al.* A	Toomre, A. On the gravitational stability of a	An older theoretical parameter is used

	cold, massive, rotating disk galaxy 1.5 billion years after the Big Bang. *Nature* **581,** 269–272 (2020).	disk of stars. *Astrophys. J.* **139**, 1217–1238 (1964). Goldreich, P. & Lynden-Bell, D. I. Gravitational stability of uniformly rotating disks. *Mon. Not. R. Astron. Soc*. **130**, 97 (1965).	to validate explanations of recent observations.
Astrophysics	Rizzo, F., Vegetti, S., Powell, D. *et al.* A dynamically cold disk galaxy in the early Universe. *Nature* **584,** 201–204 (2020).	Toomre, A. On the gravitational stability of a disk of stars. *Astrophys. J.* **139**, 1217–1238 (1964).	Toomre's parameter useful in assessing the level of axisymmetric disk instabilities in new measurements.
Cancer biology	Ubellacker, J.M., Tasdogan, A., Ramesh, V. *et al.* Lymph protects metastasizing melanoma cells from ferroptosis. *Nature* **585,** 113–118 (2020).	Wallace, A. C. & Hollenberg, N. K. The transplantability of tumours by intravenous and intralymphatic routes. *Br. J. Cancer* **19**, 338–342 (1965).	Old study showing lymph can protect metastases demonstrated an intriguing idea.
Astrophysics	Wang, J., Bose, S., Frenk, C.S. *et al.* Universal structure of dark matter haloes over a mass range of 20 orders of magnitude. *Nature* **585,** 39–42 (2020).	Einasto, J. On the construction of a composite model for the galaxy and on the determination of the system of galactic parameters. *Trudy Astrofizicheskogo Instituta Alma-Ata* **5**, 87–100 (1965).	Einasto's model useful in assessing the new simulation of formation of dark matter haloes.
Immunology	Jin, Z., Du, X., Xu, Y. *et al.* Structure of M^{pro} from SARS-CoV-2 and discovery of its inhibitors. *Nature* **582,** 289–293 (2020).	Rubin, B. & Waugh, M. H. Antiphlogistic effects of antiserotonin (SQ 10,643) and aminopyrine in rats versus endotoxin and other agents. *Proc. Soc. Exp. Biol. Med*. **119**, 438–443 (1965).	Old work helpful for recent study on repurposing drugs against a novel pandemic agent.
Physics	Dehollain, J.P., Mukhopadhyay, U., Michal, V.P. *et al.*	Nagaoka, Y. Ferromagnetism in a narrow, almost half-filled *s*	A model theoretical system described more

	Nagaoka ferromagnetism observed in a quantum dot plaquette. *Nature* **579,** 528–533 (2020).	band. *Phys. Rev*. **147**, 392–405 (1966). Lieb, E. & Mattis, D. Theory of ferromagnetism and the ordering of electronic energy levels. *Phys. Rev*. **125**, 164–172 (1962). Thouless, D. J. Exchange in solid ^{3}He and the Heisenberg Hamiltonian. *Planet. Space Sci*. **86**, 893–904 (1965).	than half a century ago, and studied since, is realized experimentally. Other relevant papers.
Neurophysiology	Yang, A.C., Stevens, M.Y., Chen, M.B. *et al.* Physiological blood–brain transport is impaired with age by a shift in transcytosis. *Nature* **583,** 425–430 (2020).	Reese, T. S. & Karnovsky, M. J. Fine structural localization of a blood–brain barrier to exogenous peroxidase. *J. Cell Biol*. **34**, 207–217 (1967).	An older lower resolution study does not show structural features seen in recent study.
Cell biology	Jimenez-Blasco, D., Busquets-Garcia, A., Hebert-Chatelain, E. *et al.* Glucose metabolism links astroglial mitochondria to cannabinoid effects. *Nature* **583,** 603–608 (2020).	King, T. E. in *Methods in Enzymology* Vol. 10 (eds Estabrook, R. W. & Pullman, M. E.) 216–225 (Academic, 1967). Wharton, D. C. & Tzagoloff, A. in *Methods in Enzymology* Vol. 10 (eds Estabrook, R. W. & Pullman, M. E.) 245–250 (Academic, 1967). Shepherd, D. & Garland, P. B. The kinetic properties of citrate synthase from rat liver mitochondria. *Biochem. J*. **114**, 597–610 (1969).	Older methods still useful for current research.
Plant science	Nagai, K., Mori, Y., Ishikawa, S. *et al.* Antagonistic regulation of the gibberellic acid	Kawahara, H., Chonan, N. & Wada, K. Studies on morphogenesis in rice plants. 3. Interrelation of the growth among leaves,	Molecular mechanisms responsible for previously described features

	response during stem growth in rice. *Nature* **584,** 109–114 (2020).	panicle and internodes, and a histological observation on the meristem of culm. *Proc. Crop Sci. Soc. Jpn* **37**, 372–383 (1968). Suetsugu, I. Studies on the first jointing stage in rice plants. *Proc. Crop Sci. Soc. Jpn* **37**, 489–498 (1968).	of morphogenesis are elucidated in the new study.
Astronomy	Becker, H.N., Alexander, J.W., Atreya, S.K. *et al.* Small lightning flashes from shallow electrical storms on Jupiter. *Nature* **584,** 55–58 (2020).	Lewis, J. S. The clouds of Jupiter and the NH_3–H_2O and NH_3–H_2S systems. *Icarus* **10**, 365–378 (1969).	Old theory helpful in trying to understand new observations of lightning flashes on Jupiter.
Physics	Campagne-Ibarcq, P., Eickbusch, A., Touzard, S. *et al.* Quantum error correction of a qubit encoded in grid states of an oscillator. *Nature* **584,** 368–372 (2020).	Aharonov, Y., Pendleton, H. & Petersen, A. Modular variables in quantum theory. *Int. J. Theor. Phys.* **2**, 213–230 (1969).	The concept of a modular quantum variable introduced in the old reference is utilized in the current experimental study.

Supplementary Table 4 References to older papers which are either essential for the current work or strongly inspirational for the current work.

Field of study	2019-2020 paper	Older references	Comment
Physics	Kumar, A., Bechhoefer, J. Exponentially faster cooling in a colloidal system. *Nature* **584,** 64–68 (2020).	Aristotle [384-322 BCE] *Meterologica* Book 1, Part 12 (transl. Webster, E. W.) (Clarendon Press, 1923). Mpemba, E. B. & Osborne, D. G. *Phys. Educ*. **4**, 172–175 (1969). Lu, Z. & Raz, O. Nonequilibrium thermodynamics of the Markovian Mpemba effect and its inverse. *Proc. Natl Acad. Sci. USA* **114**, 5083–5088 (2017). Lebowitz, J. L. & Bergmann, P. G. Irreversible Gibbsian ensembles. *Ann. Phys*. **1**, 1–23 (1957).	New experiments demonstrate and prove the specific conditions for an ancient observation to hold true! A useful older paper on non-equilibrium thermodynamics.
Material science	Kürnsteiner, P., Wilms, M.B., Weisheit, A. *et al.* High-strength Damascus steel by additive manufacturing. *Nature* **582,** 515–519 (2020).	~500-1700 CE, anonymous skilled blacksmiths. Peterson, D. T., Baker, H. H. & Verhoeven, J. D. Damascus steel, characterization of one Damascus steel sword. *Mater. Charact*. **24**, 355–374 (1990). Verhoeven, J. D. Genuine Damascus steel: a type of banded microstructure in hypereutectoid steels.	To make steel with a combination of optimal properties, hard and soft layers were introduced by folding and forging techniques of blacksmiths. Inspired by this process, the modern work employs alternating soft

		Steel Res. **73**, 356–365 (2002). Mintách, R., Nový, F., Bokůvka, O. & Chalupová, M. Impact strength and failure analysis of welded Damascus steel. *Mater. Eng*. **19**, 22–28 (2012).	and hard layers introduced by fabricating layered microstructures produced by exploiting rapid quenching, sequential in situ heating and local phase transformations.
Climate science	Blöschl, G., Kiss, A., Viglione, A. *et al.* Current European flood-rich period exceptional compared with past 500 years. *Nature* **583,** 560–566 (2020).	1500 – 2016 (CE)	Chronicles, annals, administrative and legal records, newspapers and private and official correspondence used to compile a comprehensive flood history of the past 500 years.
Human genetics/anthropology (older works Anthropology)	Ioannidis, A.G., Blanco-Portillo, J., Sandoval, K. *et al.* Native American gene flow into Polynesia predating Easter Island settlement. *Nature* **583,** 572–577 (2020).	Seemann, B. *Flora Vitiensis* (L. Reeve, 1865). Brown, J. M. *The Riddle of the Pacific* (T. F. Unwin, 1924). Hornell, J. Was there pre-Columbian Contact between the Peoples of Oceania and South America? *J. Polynesian Soc*. **54**, 167–191 (1945). Heyerdahl, T. *American Indians in the Pacific* (Allen & Unwin, 1952).	Old theories and data confirmed by modern genetics.
Microbiology	Yu, H., Leadbetter, J.R. Bacterial chemolithoautotrophy via manganese	Winogradsky, S. Über schwefelbakterien. *Bot. Ztg* **45**, 489ff (1887).	New experiments provide evidence to support important old

	oxidation. *Nature* **583,** 453–458 (2020).	Beijerinck, M. Oxydation des mangancarbonates durch Bakterien und Schimmelpilze. *Folia Microbiol. (Delft)* **2**, 123–134 (1913).	theories with fundamental and possible global ecologic importance.
Physics	Jin, J., Yin, X., Ni, L. *et al.* Topologically enabled ultrahigh-*Q* guided resonances robust to out-of-plane scattering. *Nature* **574,** 501–504 (2019). Yin, X., Jin, J., Soljačić, M. *et al.* Observation of topologically enabled unidirectional guided resonances. *Nature* **580,** 467–471 (2020).	von Neumann, J. & Wigner, E. Über merkwürdige diskrete Eigenwerte. *Phys. Z.* **30**, 465–467 (1929). McMaster, W. H. Polarization and the stokes parameters. *Am. J. Phys*. **22**, 351–362 (1954).	The paper by von Neumann and Wigner introducing the idea of a bound state in the continuum is the only paper before 1970 cited by two different papers in *Nature* this year. See text for discussion. Yin et al. cite this paper in the Methods section.
Astronomy	Howard, R.A., Vourlidas, A., Bothmer, V. *et al.* Near-Sun observations of an F-corona decrease and K-corona fine structure. *Nature* **576,** 232–236 (2019).	Russell, H. N. On the composition of the Sun's atmosphere. *Astrophys. J*. **70**, 11 (1929). Furth, H. P., Killeen, J. & Rosenbluth, M. N. Finite-resistivity instabilities of a sheet pinch. *Phys. Fluids* **6**, 459 (1963). Allen, C. W. *Astrophysical Quantities* (University of London, 1955).	Important theory predictions not yet having been verified by observation. And even still useful data.
Physics	Fruchart, M., Zhou, Y. & Vitelli, V. Dualities and non-Abelian mechanics.	Kramers, H. A. Théorie générale de la rotation paramagnétique dans les cristaux. *Proc. K. Akad.*	The authors find that a degeneracy they find in their mechanical system is an

	Nature **577,** 636–640 (2020).	*Wet. C* **33**, 959–972 (1930). Klein, M. J. On a degeneracy theorem of Kramers. *Am. J. Phys*. **20**, 65–71 (1952).	analogue of a degeneracy of electron states described by Kramers.
Inorganic chemistry (Organic chemistry older works)	Pagano, J.K., Xie, J., Erickson, K.A. *et al.* Actinide 2-metallabiphenylenes that satisfy Hückel's rule. *Nature* **578,** 563–567 (2020).	Lothrop, W. C. Biphenylene. *J. Am. Chem. Soc.* **63**, 1187–1191 (1941). Garratt, P. J. & Vollhardt, K. P. C. Benzo[3,4]cyclobuta[1,2-c]thiophen (2-thianorbiphenylene). *J. Chem. Soc. D., Chem. Commun.* 109 (1970).	One could stare at the structures of these two older known (organic) biphenylene analogues (compounds in which one of the benzene rings has been replaced by a different (4n + 2) π-electron system) and dream of new inorganic ones.
Physics	Mueller, N.S., Okamura, Y., Vieira, B.G.M. *et al.* Deep strong light–matter coupling in plasmonic nanoparticle crystals. *Nature* **583,** 780–784 (2020).	Purcell, E. M., Torrey, H. C. & Pound, R. V. Resonance absorption by nuclear magnetic moments in a solid. *Phys. Rev*. **69**, 37–38 (1946). De Liberato, S. Light-matter decoupling in the deep strong coupling regime: the breakdown of the Purcell effect. *Phys. Rev. Lett*. **112**, 016401 (2014). Hopfield, J. J. Theory of the contribution of excitons to the complex dielectric constant of crystals. *Phys. Rev*. **112**, 1555–1567 (1958).	Conditions are demonstrated experimentally where a classic old effect breaks down. An old formalism still useful in modeling and interpreting new experimental data.

Physics	Piccardo, M., Schwarz, B., Kazakov, D. *et al.* Frequency combs induced by phase turbulence. *Nature* **582,** 360–364 (2020).	Ginzburg, V. L. & Landau, L. D. On the theory of superconductivity (in Russian). *Zh. Eksp. Teor. Fiz.* **20**, 1064-1082 (1950). Aranson, I. S. & Kramer, L. The world of the complex Ginzburg–Landau equation. *Rev. Mod. Phys*. **74**, 99–143 (2002).	A new application of Ginzburg and Landau's theory of phase is found. (The 1950 Ginzburg & Landau paper is not cited in the 2020 *Nature* paper, but this is the starting place for the 2002 Rev. Mod. Phys. paper which is cited and plays a prominent and crucial role in the new work.)
Physics (fluid mechanics, mechanics)	Apffel, B., Novkoski, F., Eddi, A. *et al.* Floating under a levitating liquid. *Nature* **585,** 48–52 (2020).	Kapitza, P. L. Dynamic stability of a pendulum when its point of suspension vibrates (in Russian). *Sov. Phys. JETP* **21**, 588–597 (1951). Faraday, M. On a peculiar class of acoustical figures; and on certain forms assumed by groups of particles upon vibrating elastic surfaces. *Philos. Trans. R. Soc. Lond*. **121**, 299–340 (1831). Lord Rayleigh. Investigation of the character of the equilibrium of an incompressible heavy fluid of variable density.	Kapitza's method for dynamic stabilization of an inverted pendulum is the key to the main effect in the new paper whereby a boat can float upside down under a levitating liquid. Other old works are useful for generating the effect in the current paper.

		Proc. Lond. Math. Soc. **14**, 170–177 (1883). Bjerknes, V. F. K. *Fields of Force: Supplementary Lectures, Applications to Meteorology* (Columbia Univ. Press and Macmillan, 1906). Lewis, D. J. The instability of liquid surfaces when accelerated in a direction perpendicular to their planes. II. *Proc. R. Soc. Lond. A* **202**, 81–96 (1950). Baird, M. H. I. Resonant bubbles in a vertically vibrating liquid column. *Can. J. Chem. Eng*. **41**, 52–55 (1963). Jameson, G. J. The motion of a bubble in a vertically oscillating viscous liquid. *Chem. Eng. Sci*. **21**, 35–48 (1966). Wolf, G. H. The dynamic stabilization of the Rayleigh–Taylor instability and the corresponding dynamic equilibrium. *Z. Phys*. **227**, 291–300 (1969). Wolf, G. H. Dynamic stabilization of the interchange instability of a liquid–gas interface. *Phys. Rev. Lett*. **24**, 444–446 (1970). Chelomei, V. N. Mechanical paradoxes caused by vibrations. *Sov. Phys. Dokl*. **28**, 387–390 (1983).	

Applied math	Vinyals, O., Babuschkin, I., Czarnecki, W.M. *et al.* Grandmaster level in StarCraft II using multi-agent reinforcement learning. *Nature* **575,** 350–354 (2019).	Brown, G. W. Iterative solution of games by fictitious play. *Act. Anal. Prod. Alloc*. **13**, 374–376 (1951). Leslie, D. S. & Collins, E. J. Generalised weakened fictitious play. *Games Econ. Behav*. **56**, 285–298 (2006). Heinrich, J., Lanctot, M. & Silver, D. Fictitious self-play in extensive-form games. *Proc. Intl Conf. Machine Learning* **32**, 805–813 (2015).	Fictitious play is the key to the new paper—see text for further discussion. (More recent relevant papers weaken somewhat the direct influence and necessity of the old paper.)
Meteorology	Cai, W., Ng, B., Geng, T. *et al.* Butterfly effect and a self-modulating El Niño response to global warming. *Nature* **585,** 68–73 (2020).	Lorenz, E. N. *Empirical Orthogonal Functions and Statistical Weather Prediction* Statistical Forecast Project Report 1 (MIT Department of Meteorology, 1956). Lorenz, E. N. Deterministic nonperiodic flow. *J. Atmos. Sci*. **20**, 130–141 (1963). Lorenz, E. N. The predictability of a flow which possesses many scales of motion. *Tellus* **21**, 289–307 (1969).	A method of analysis used by Lorenz and Lorenz's butterfly effect are central for the current study.
Infectious disease	Huestis, D.L., Dao, A., Diallo, M. *et al.* Windborne long-distance migration of malaria mosquitoes in the Sahel. *Nature* **574,** 404–408 (2019).	Garrett-Jones, C. The possibility of active long-distance migrations by *Anopheles pharoensis* Theobald. *Bull. World Health Organ*. **27**, 299–302 (1962). Sellers, R. F. Weather, host and vector—their interplay in the spread of insect-borne animal virus	There was a case where separate outbreaks of malaria in Egypt and Israel were attributed to *A. pharoensis* travelling more than 280 km.

		diseases. *J. Hyg. (Lond.)* **85**, 65–102 (1980). Glick, P. A. *The Distribution of Insects, Spiders, and Mites in the Air*. Technical Bulletin No. 673 (US Department of Agriculture, 1939).	Despite this case, the authors of the recent work note that the prevailing view had been that the dispersal of malaria mosquitoes is not further than 5 km. Useful data.
Human biology	Zhang, B., Ma, S., Rachmin, I. *et al.* Hyperactivation of sympathetic nerves drives depletion of melanocyte stem cells. *Nature* **577,** 676–681 (2020).	Ephraim, A. J. On sudden or rapid whitening of the hair. *AMA Arch. Derm.* **79**, 228–236 (1959). Lerner, A. B. Gray hair and sympathectomy. Report of a case. *Arch. Dermatol.* **93**, 235–236 (1966).	The old papers suggest a role for the sympathetic nervous system in whitening hair.
Natural product synthesis	Nett, R.S., Lau, W. & Sattely, E.S. Discovery and engineering of colchicine alkaloid biosynthesis. *Nature* **584,** 148–153 (2020).	Leete, E. & Nemeth, P. E. The biogenesis of the alkaloids from *Colchicum*. I. The incorporation of phenylalanine into colchicine. *J. Am. Chem. Soc*. **82**, 6055–6057 (1960). Battersby, A. R. & Reynolds, J. J. Biosynthesis of colchicine. *Proc. Chem. Soc*. **50**, 346–347 (1960). Leete, E. The biosynthesis of the alkaloids of *Colchicum*. III. The incorporation of phenylalanine-2-C^{14} into colchicine and demecolcine. *J. Am.*	Older studies extremely useful for new research looking to identify enzymes responsible for colchicine biosynthesis.

		Chem. Soc. **85**, 3666–3669 (1963). Battersby, A. R., Binks, R., Reynolds, J. J. & Yeowell, D. A. Alkaloid biosynthesis. Part VI. The biosynthesis of colchicine. *J. Chem. Soc*. 4257–4268 (1964). Leete, E. Biosynthesis of the tropolone ring of colchicine. *Tetrahedr. Lett*. **6**, 333–336 (1965). Battersby, A. R., Herbert, R. B., McDonald, E., Ramage, R. & Clements, J. H. Biosynthesis of colchicine from a 1-phenethylisoquinoline. *Chem. Commun*. **17**, 603–605 (1966). Barker, A. C., Battersby, A. R., McDonald, E., Ramage, R. & Clements, J. H. Biosynthesis of colchicine: ring expansion and later stages. Structure of speciosine. *Chem. Commun*. **8**, 390–392 (1967). Battersby, A. R., Dobson, T. A., Foulkes, D. M. & Herbert, R. B. Alkaloid biosynthesis. Part XVI. Colchicine: origin of the tropolone ring and studies with the C_6–C_3–C_6–C_1 system. *J. Chem. Soc. Perkin Trans. I* **14**, 1730–1736 (1972). Battersby, A. R., Herbert, R. B., McDonald, E., Ramage, R. & Clements, J. H. Alkaloid biosynthesis. Part XVIII.	Key for the approach of the new study was utilization of the

		Biosynthesis of colchicine from the 1-phenethylisoquinoline system. *J. Chem. Soc. Perkin Trans. I* **14**, 1741–1746 (1972). Wildman, W. C. in *Alkaloids: Chemistry and Physiology* (ed. Manske, R. H. F.) Vol. 6, 247–288 (Academic, 1960). Hartung, E. F. History of the use of colchicum and related medicaments in gout. *Ann. Rheum. Dis*. **13**, 190–200 (1954). Tjio, J. H. & Levan, A. The chromosome number of man. *Hereditas* **42**, 1–6 (1956).	older observations on differential tissue distribution of colchicine in a plant. Old paper on the history of medical uses of colchicine provides interesting background for the current study. Also interesting, inspiring and thought provoking to read that the anti-mitotic action of colchicine via its interaction with tubulin was used to help identify the number of human chromosomes.
Applied math	Case, D.J., Liu, Y., Kiss, I.Z. *et al.* Braess's paradox and programmable behaviour in microfluidic networks. *Nature* **574,** 647–652 (2019).	Braess, D. Über ein Paradoxon aus der Verkehrsplanung. *Unternehmensforschung* **12**, 258–268 (1968).	New use for Braess's paradox. See text for further discussion.
Material science	Meiners, T., Frolov, T., Rudd, R.E. *et al.* Observations of grain-boundary phase transformations in an elemental metal.	Hart, E. W. Two-dimensional phase transformation in grain boundaries. *Scr. Metall*. **2**, 179–182 (1968).	An old theory verified.

	Nature **579,** 375–378 (2020).		

Supplementary Table 5 References to older papers that provided significant and specific operational direction and inspiration for current work.

Field of study	2019-2020 paper	Older references	Comment
Organic chemistry	Xiang, J., Shang, M., Kawamata, Y. *et al.* Hindered dialkyl ether synthesis with electrogenerated carbocations. *Nature* **573,** 398–402 (2019).	Beobachtungen über die oxydirende wirkung des sauerstoffs, wenn derselbe mit hülfe einer elektrischen säule entwickelt wird. *J. Prakt. Chem*. **41**, 137–139 (1847). Williamson, W. Ueber die theorie der aetherbildung. *Justus Liebigs Ann. Chem*. **77**, 37–49 (1851). Kolbe, H. Hofer, H. & Moest, M. Mittheilung aus dem elektrochemischen Laboratorium der Königl, Technischen Hochschule zu München. *Justus Liebigs Ann. Chem*. **323**, 284–323 (1902). Corey, E. J., Bauld, N. L., La Londe, R. T., Casanova, J., Jr & Kaiser, E. T. Generation of cationic carbon by anodic oxidation of carboxylic acids. *J. Am. Chem. Soc*. **82**, 2645–2646 (1960). Koehl, W. J. Anodic oxidation of aliphatic acids at carbon anodes. *J. Am. Chem. Soc*. **86**, 4686–4690 (1964). Bunyan, P. J. & Hey, D. H. The electrolysis of some aryl-substituted, aliphatic acids. *J. Chem. Soc*. 1360–1365 (1962). Ross, S. D. & Finkelstein, M. Anodic oxidations. V. The Kolbe oxidation of	Old paper specifically sets new paper on research course. See text for further discussion.

		phenylacetic acid and 1-methylcyclohexaneacetic acid at platinum and at carbon. *J. Org. Chem*. **34**, 2923–2927 (1969). Schäfer, H. J. Recent contributions of Kolbe electrolysis to organic synthesis. *Top. Curr. Chem*. **152**, 91–151 (1990).	
Biomimetic material science (older paper Dynamical systems)	Kryuchkov, M., Bilousov, O., Lehmann, J. *et al.* Reverse and forward engineering of *Drosophila* corneal nanocoatings. *Nature* **585,** 383–389 (2020).	Turing, A. M. The chemical basis of morphogenesis. *Philos. Trans. R. Soc. Lond. B* **237**, 37–72 (1952). Bernhard, C. G. & Miller, W. H. A corneal nipple pattern in insect compound eyes. *Acta Physiol. Scand*. **56**, 385–386 (1962).	Turing's mechanism inspires and is utilized at every step of the current authors' work. The first described anti-reflective corneal nanocoating.
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Physics	Wang, Y., Yu, J., Mao, Y. *et al.* Stable, high-performance sodium-based plasmonic devices in the near infrared. *Nature* **581,** 401–405 (2020).	Smith, N. V. Optical constants of sodium and potassium from 0.5 to 4.0 eV by split-beam ellipsometry. *Phys. Rev*. **183**, 634–644 (1969).	After 50 years and requiring fifteen authors, Smith's experiments are built on to produce high performance plasmonic devices.