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THE CONTAMINATED LIBRARY

Locunt.

Microbes in book culture

Nicole C. Karafyllis, Jörg Overmann, Ulrich Johannes Schneider and Christoph Mackert (Eds.)

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PREFACE – THE NATURAL HISTORY OF BOOK CULTURE

In libraries, microbes try to decompose the very items that are supposed to be meticulously preserved there. Seen from this angle, microbes are clearly troublemakers disrupting a well-ordered culture. In the library's collection, they're instances of a history of decay – a process which in the natural world ultimately always prevails over human culture. Therefore, in order to prolong the lifetime of the library's dead objects, these organisms hostile to books are attacked with biocides. What's more, their bad reputation isn't confined to collections. By and large, bacteria have the worst image of nearly all life forms, second only to viruses.

On the other hand, contrary to the idea of destructive contamination, can microbes in historical books also be regarded as belonging to them? Should a microbe be viewed as part of the biography of an old book – something with a semiotic character? Does it act like a probe by providing information about a manuscript's previous locations and users? Just as the microbe is an instance of the origins of the natural world and its biological realms, might it also be an instance shedding light on the history of a book, perhaps even the library where it was once kept? How have microbial communities been altered by factors such as different bindings, types of paper and ink, not to mention changing habits and hygiene? How do microbes vary within an individual manuscript, in a codex, in a library, even among readers – including with respect to historical epidemics? Do microbes in a book have to 'fight' or collaborate with other organisms such as insects and fungi? And what's the structure of the microbiome of a book?

PREFACE – THE NATURAL HISTORY OF BOOK CULTURE

These questions are addressed by the interdisciplinary research project MIKROBIB, which produced this publication and the accompanying website. The project considers the book as a habitat of diverse organisms and life forms jointly populating it (as a microbiome), some of which have survived until the present day. Analysing the 'language of microbes' from a philosophical, cultural, and microbiological viewpoint, the three subprojects are based at the Philosophy Institute of the Technische Universität Braunschweig, the Leipzig University Library, and the Leibniz Institute DSMZ - German Collection of Microorganisms and Cell Cultures in Braunschweig.

The project's object of reflection and empirical study is the historical book. To this end, microbiological analyses were conducted on late medieval codices (c. 1250–1500 CE) now preserved by Leipzig University Library, and the findings combined and compared with studies of the history of individual books. The samples underwent molecular biological analyses at the DSMZ using state-of-the-art high-throughput sequencing methods in order to identify the microorganisms. The DSMZ has one of the world's largest microbial collections, comprising almost 50,000 microbial isolates from over 15,000 species.

This collaborative research project thus brings together two distinct types of collections: the traditional library (Leipzig University Library) and the high-tech microbial bank (DSMZ). This living collection embodies the other side, semantically speaking, of the debate about infection and contamination. It represents the view that microbes are useful and should be preserved as a future resource, for example as an object of research, a biotechnological agent, or to produce antibiotics. Disciplinary perspectives are altered by the interaction (both

PREFACE – THE NATURAL HISTORY OF BOOK CULTURE

material and semantic) between the classification schemes applied to the different collections, each of which has its own concept of world knowledge. While the living collection maintains the eternal presence of some of the 'living dead' of natural history, the dead collection embodies history in the diversity of its cultural narratives. Since these dead objects constitute both a habitat and food for microbes, the combination of book and microbe in the library enables the historicity of life to be traced in two ways: life as an object (the microbe) and life as a subject (the reader). The contaminated library imagines a legible world that remains so despite disruption. In this approach, our planet with its celestial dome isn't an archive, but a vast reading room open day and night – even and especially during a pandemic.

Nicole C. Karafyllis

Institute of Philosophy, Technische Universität Braunschweig

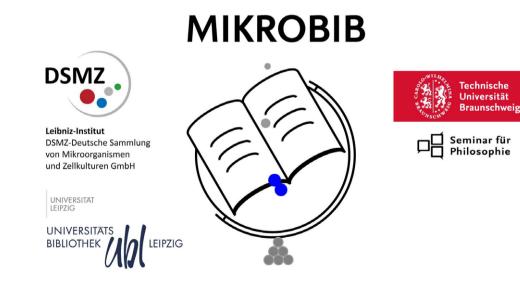
Jörg Overmann

Leibniz Institute DSMZ – German Collection of Microorganisms and Cell Cultures, Braunschweig, Department of Microbial Ecology and Diversity Research

Ulrich Johannes Schneider

Leipzig University Library, also the Institute of Cultural Studies, Leipzig University

The logo of the collaborative research project MIKROBIB combines the conceptual structures and objects of its three subprojects: books, microbes, and the collected knowledge of the world. The open book in the centre is immediately apparent, but it takes a fertile imagination to decipher the logo in full. Is that a Petri dish used in microbiology surrounding the book? Or does the circle represent the frame of a globe? And are those dots in the logo spherical bacteria? What about those lines on the pages – are they writing or spiral-shaped bacteria? Does the triangular axis supporting the globe consist of Staphylococci? The logo is a stylized view of the theoretical and practical interplay between bibliography, microbiology and philosophy – three disciplines exploring the legibility of the world and its collected holdings in order to push the boundaries of knowledge.



SUBPROJECT A:

The contaminated 'world as a book' – the referentiality of knowledge systems of dead and living collections using the example of a library and a microbe bank

Using the example of the Leibniz Institute DSMZ – German Collection of Microorganisms and Cell Cultures, Subproject A – which dealt with the philosophy of science and technology – started by analysing the special institutional form of the microbial collection, namely the order and semantics of its objects, forms of knowledge, and the associated purification, isolation and cultivation techniques.

With the 'contaminated book' and the newly conceived 'microbiome of the book' (Subproject C) in mind, classification schemes and concepts of world knowledge were elicited. Taking into account the history of concepts and ideas, research was also conducted into what material objects in the collections of interest could be used to make what world(s) legible (or not). The result was a classification matrix, rather resembling a topology. Only on its various levels could it be decided whether any contamination takes place and who contaminates whom. The figure of contamination was regarded here as the 'inclusion of the excluded'. In particular, the concept of the microbe as a cosmopolitan was addressed, while the cosmos was regarded according to the ancient model as a world that's beautiful, despite owing itself to chaos. The negotiation processes of the distinctions between nature, culture and technology inherent to research were elaborated in relation to the concept of the "legibility of the world" (to quote the philosopher Hans Blumenberg).

Principal Investigator and Project Coordinator of MIKROBIB: Professor Nicole C. Karafyllis, Institute of Philosophy, Technische Universität Braunschweig, Germany; co-workers: Dr Alexander Waszynski, Uwe Lammers

SUBPROJECT B:

Microbes as probes of a book's biography – cultural studies of late medieval sammelbands preserved at Leipzig University Library

The cultural studies subproject called into question the category of 'organisms hostile to books' used in conservation, and compiled biographies of individual books using medieval sammelbands (books made up of separately written works) in the holdings of Leipzig University Library. Volumes were selected together with Subproject C. The circumstances of their access, acquisition and production were researched, shedding light on the journey taken by each book and its texts over the centuries – a type of research that can only be conducted on the original book itself.

In addition, books were physically examined to see what factors ensured or endangered their 'survival': their cover, the lock or clasp (if present), the binding, pages added from different manuscripts, shelf marks, woodworm tunnels, mould infestation, etc. Particular attention was paid to the cover, which is still mainly studied under the lens of art history research and only slowly being addressed by aspects of book research concerned with cultural studies. Book histories were analysed in order to compile their biographies, an area which was also relevant to Subproject C concerning microbiology.

Principal Investigator: Professor Ulrich Johannes Schneider, Leipzig University Library (director), also the Institute of Cultural Studies, Leipzig University; project coordinator: Dr Christoph Mackert, also head of Leipzig University Library's Manuscript Centre; co-workers: Katharina Gietkowski, Dr Regina Jucknies, Katrin Sturm

SUBPROJECT C: The microbiome of the book – archaeomicrobiological analyses

The work carried out in the microbiological subproject can be described as empirical and analytical as well as theoretical and synthetic. First of all, the methods to be employed were determined on the basis of literature research and preliminary experimental work, while the sorts of microorganisms which might be found in books were elucidated. In the empirical part, which was carried out in conjunction with Subproject B, selected medieval volumes from Leipzig University Library with different origins and comprising different materials underwent microbiological and molecular genetic analysis in order to determine the microbiome in each case.

Suitable non-destructive sampling methods were developed. Cultivation techniques for newly discovered, representative microbes were also worked out. It was assumed that most of the microbes in a book would be dead or only exist in the form of spores, and that only a few would still be metabolically active. Microorganisms were identified by means of molecular biological analysis of the samples at the DSMZ using the latest high-throughput sequencing methods. Where possible, differences in the microbiomes relating to materials or media were explained ecophysiologically in order to better understand the biotope diversity of books and to enable their biographies to be analysed. Microbes that could thrive on the materials contained in shelf marks and bindings, or tolerate the presence of lead and potential toxins were considered as potential research findings as well.

Principal Investigator: Professor Jörg Overmann, Scientific Director of the Leibniz Institute DSMZ – German Collection of Microorganisms and Cell Cultures; also Institute of Microbiology, Technical University of Braunschweig; co-worker: Dr Cecilia G. Flocco

WORLDS OF MICROBES

Nicole C. Karafyllis, Alexander Waszynski, Uwe Lammers

1. V. Globator . 1/3 ". n. V. aureus_1/3 ". nr. V. stellatus_1/3 ".

BOOKS, INSECTS AND MICROBES: GLOBETROTTERS

These days, libraries are regarded as static entities: as collections, as books' final destinations, as temples of systematic knowledge of the world. Yet far from being static, collections of books were on the move for very long periods of time, along with the knowledge they contained. And they were joined by travelling companions and highwaymen, namely microbes, a term stemming from the Greek words for 'small' and 'life'. They, too, feasted on reading material. Because a fascination with reading was accompanied by a desire to own books, which not infrequently resulted in their theft, books have always been kept safe in unusual places. The Greek geographer Strabo, for example, told of the ancient library of Aristotle (384–322 BCE), which was temporarily buried to save it from book-mad rulers. This led to damage caused by insects and their larvae ('worms') - the smallest living creatures visible to the naked eye. But instead of a grave for the books, earthen burial meant the survival of knowledge and also its transformation, for the gaps in the text caused by worms were later filled by copyists, in some cases rather creatively.

The problem of contamination described above affects all objects in collections. It's viewed today as if through a magnifying glass – because what a 'microbe' is turns out to be smaller and smaller. Thanks to microscopes with increasingly high resolutions, human observation has advanced from insects to infusoria, bacteria, viruses and prions. The systematics of Aristotle's *History of Animals*, which embodied the foundation of biology and was one of the most widely read books for almost 2,000 years, have broadened and deepened since antiquity. The world has become more diverse and more biodiverse – both on the planet and in individual objects. Living creatures are everywhere; we are never alone. Absolute purity is just as utopian as the eternity of a collection's holdings.

Strabo's geography: Those who dig a pit for others ...

The historian and geographer Strabo (63 BCE– 23 CE) delivered a wide-ranging description of the ancient world. He praised Aristotle as "the first person with whom we are acquainted who made a collection of books." After his death. it passed through various hands and places, via Turkey to Rome. The scrolls survived inhospitable conditions "in an excavation underground; at length, but not before they had been injured by damp and worms ...". It is said of a later purchaser and owner of Aristotle's library that he "attempted to restore the parts which had been eaten and corroded by worms, he made alterations in the original text and introduced them into new copies; he moreover supplied the defective parts unskilfully, and published the books full of errors."

Strabo: Allgemeine Erdbeschreibung ('Geographica') in three volumes, Lemgo, Meyer, 1777 [UBL: Geogr.gr.108].

In the third volume of the German edition of Geographica, Aristotle's library is mentioned as an outstanding source of knowledge in antiquity [UBL: Geogr. gr.108:3, p.1667].

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Drengehntes Buch bes griechifchen Tertes. 1667

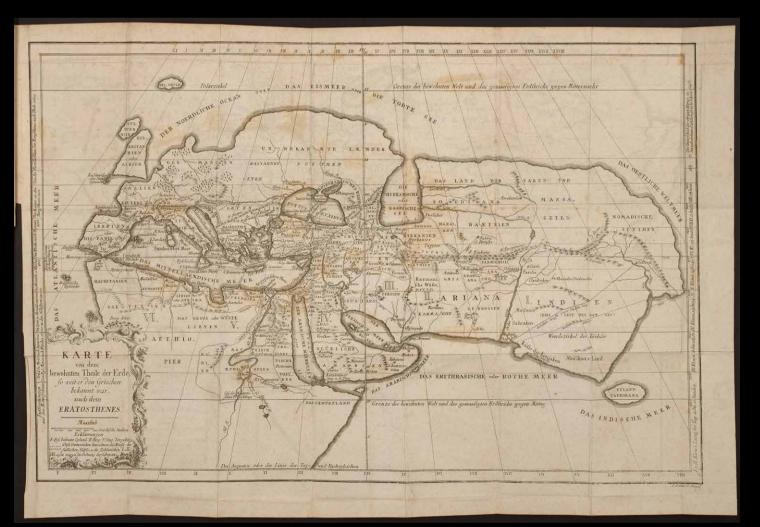
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The map depicts the known world of the ancient Greeks according to 18th-century knowledge [UBL: Geogr. gr. 108:1].



Aristotle's entomology: Cosmic rather than revolting

As well as being a philosopher, Aristotle was also a keen observer of nature who was interested in materials and their decomposers. He wrote in his History of Animals that the larvae found in scrolls resembled worms occurring in garments (Hist. an. V.32, 557b1-10). He was probably referring to the larvae of the clothes moth, which didn't even spurn tattered paper. Being bloodless animals, he placed insects right at the bottom of his zoological systematics; to this day we still use the term 'lower animals', which are far removed from the highest animal, the human being. But this is only true because of the lack of similarity, not in everyday life. Aristotle considered the smallest living being or microbe to be the cheese mite, which is still used nowadays to produce exquisite cheeses. Living, eating and reading formed a cosmic totality in Aristotle's view of biology, and biodiversity was regarded as normal. There was no friend-or-foe mindset yet; different forms of life coexisted side by side and no one felt sick at the sight of microbes. In Aristotle's day, 'cosmic' also meant beautiful, hence the derivation of the word 'cosmetics'.

Aristoteles' Naturgeschichte der Thiere (Aristotle: 'History of Animals'), Frankfurt am Main, Hermannsche Buchhandlung, 1816 [UBL: Arist.198f]. German translation of History of Animals by Aristotle [UBL: Arist.198f, title page].

Aristoteles

Naturgeschichte der Thiere

überfest und mit Anmerfungen begleitet

von

Dr. Friedrich Strad,

Professor der Naturgeschichte und der alten Sprachen am Gymnasium zu Duffeldorf.

BIRI

VNIVERS.

LIPS.

Frankfurt am Main 1816. Joh. Chrift. Hermanniche Buchhandlung. Aristotle also noted that other minute animals were to be found in books. He was probably referring to papyrus scrolls [UBL: Arist.198f, p.278].

278 Sünftes Buch.

von den vielfüßigen Kelleresen (Uffeln), nur mit dem Unterschied, daß sie platte Schwänze haben. Uebrigens seugen sich überall, besonders an den Seebarben (Trigla.) Ulle haben viele Füße, sind ohne Blut, und gehören zu den Infekten. Der Düstos am Thunstich erzeugt sich an den Floßen, bat die Gestalt eines Scorpions, und die Größe einer Spinne. In dem Meere zwischen Eyrene und Megopten giebt es auch einen Filch, den man die Laus nennt; dieser begleitet immer den Delphin, und wird außerordentlich fett, weil ihm bei den Jagden des Delphin ebenfalls reichliche Nahrung zu Theil wird.

Cap. 26.

Noch erzeugen sich einige andere Thierarten, wie schon gesagt worden ist, 5. B. in der Wolle, und was sonst aus Wolle gemacht wird, die Motten; besonders wenn die Wolle staubig wird; am allerstärksten aber dann, wenn eine Spinne zugleich mit eingeschlossen ist; diese nehmlich trinkt die Feuchtigkeit, die etwa noch darin vorbanden ist, und trocknet sie dadurch. Dieser Burm erzeugt sich sibrigens in einer Art von Kleid. Unch in alten Wachstafeln, so wie auch im Hols, entschen Thierchen, die unter allen die kleinsten zu seven sichen werben, weiß sind, und Milben genannt werden. So anch findet sich in Büchern eine Art von Wärmern, die denen in den Rieidern nicht unähnlich ist, und eine Cap. 26.

270

9

andere , bie ben Scorpionen gleicht , jedoch teinen Schwang bat, und nur von geringer Größe ift. Und fo fann man fagen, daß in allen trockenen Rörpern, wenn fe feucht, und allen feuchten Rörpern, wenn fie troden werden , in fo weit fie nehmlich Dabrung hergeben. Noch giebt es eine andere Art Bürmer, 181) bie fogenannten Solgträger, gemiß eins ber fonderbarften Befcopfe, Geinen buntfarbigen Ropf ftredt es aus einer Sulie bervor, und bat feine Suffe vorn, fo wie andere Bürmer ; der übrige Rörper ftedt in einer Spinnweben ähnlichen Sulle, um welche Spänchen feit fiten, fo daß es, wenn es friecht , baran ju bangen icheint. Diefe Sulle ift aber mit dem Burme felbit verwachfen, und zwar, wie die Mufchel mit ihrer Schale, fo bier ber gange Burm mit feiner Befleidung , baber er fie auch nicht ableat, fondern nur gewaltsam davon getrenne werden tann. Beschieht diefes aber, fo ftirbt ber 2Burm, und ift eben fo unbrauchbar , wie die Muschel ohne ihre Schale. Mit ber Zeit verwandelt fich diefer 2Burm in

181) Alle hier genannten Bürmer find nicht ichmer, ihren Sattungen nach, zu erfennen; jene Motte ift entweder Tinea pellionella, ober T. sarcitella; bie Milbe, griedijd Acari, ein Acarus; der britte, in Büchern lebende, mahrichtnlich Dermestes pellio und D. lardarius; dann folgt das Phalangium cancroides, und endlich die holgträger fub entweber Raupen von irgend einem Heinen Sodfträger, a. G. Tinea graminella, T. lichenella, T. silophorus, ober eine Lerve von irgend einer Phryganea. Blinius wiederholt unfern Bhilosphen nur II., 41. p. 243.

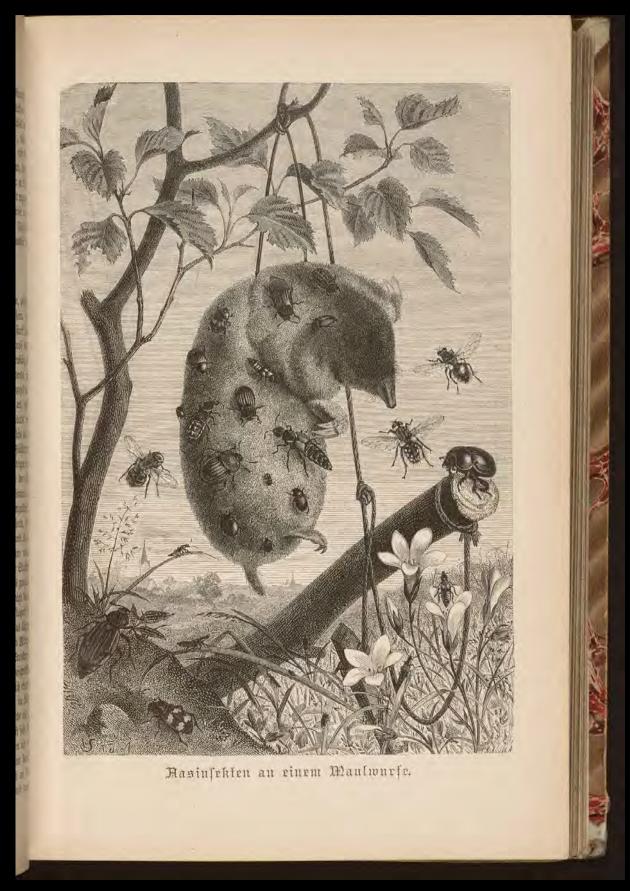
Cosmopolitan or criminal?

The encyclopaedia *Brehm's Animal Life* declares both humans (lovers of books) and larder beetles (books' enemies) to be equally cosmopolitan: "Because the food of beetles, especially of their larvae (for they themselves are more frugal), consists in the preferably dry parts of animal substances of all kinds, they're also found everywhere, outside in the open air, in our dwellings, on ships, on skins, collections of naturalia, etc., they travel around the world, and some of them become citizens of the world in the fullest sense of the word." (Vol. 9, p. 74, transl. by the authors)

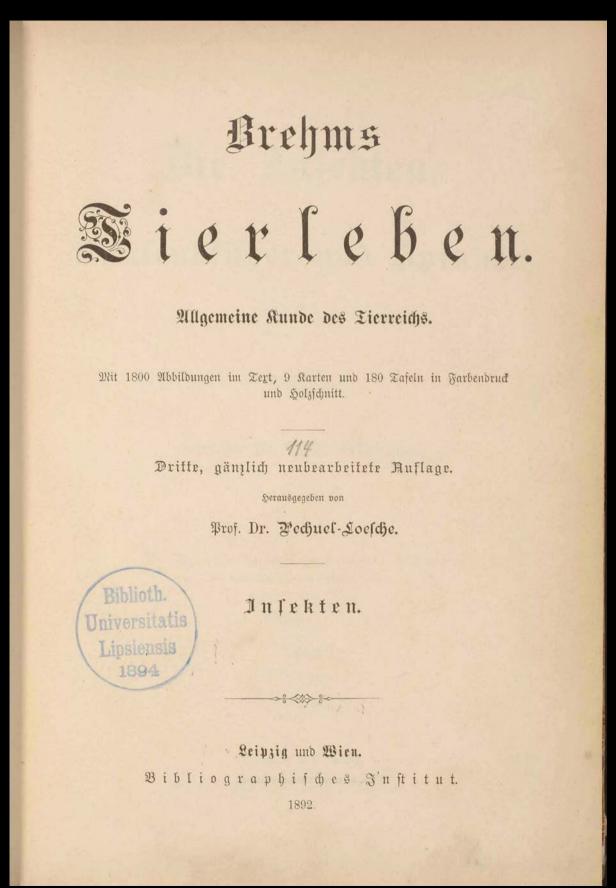
However, the larder beetle also belongs to the carrion insects, to the citizens of the shadow world, which are depicted in textbook fashion on a decaying mole. In corpses, the number and forms of insects can be read like a book. Meanwhile, the book itself is also a potential corpse, gnawed by the ravages of time.

The study of decomposition processes led to two new sciences at the end of the nineteenth century: ecology and entomological forensics (criminal biology). Insects on corpses are traces that can be read to reconstruct the crime. Today, microbial traces are also evaluated in forensics, such as individual bacterial flora on a fingerprint.

Brehms Tierleben ('Brehm's Animal Life'), vol. 9: Insekten ('Insects'), 3rd edition, Leipzig and Vienna, Bibliographisches Institut, 1892 [UBL: Zool.131n:9]. 'Carrion insects on a mole', plate V from *Brehm's Animal Life*, vol. 9 [UBL: Zool.131n:9, p.71].



Brehm's Animal Life was republished several times over in quick succession [UBL: Zool.1311:9, title page].



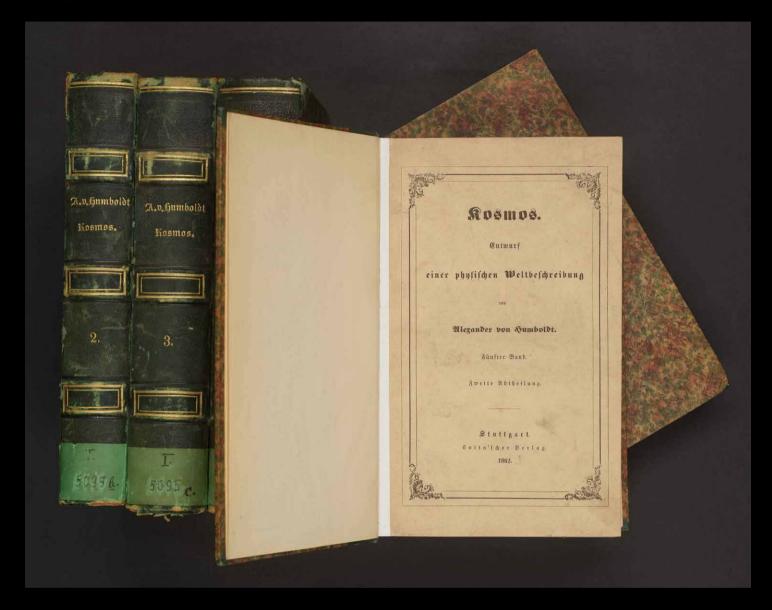
FROM COSMOS

Alexander von Humboldt's monumental encyclopaedia entitled Cosmos: A Sketch of a Physical Description of the Universe (1845ff.) was intended as a physical contemplation of nothing less than the entire universe. The knowledge of a natural whole was gained not only by collecting, surveying, mapping and describing, but also by recourse to the history of "the endeavours of man to conceive and comprehend the concurrent action of natural forces on the earth and in the regions of space ...". (Alexander von Humboldt, Cosmos, Vol. II, London 1848, p. 101) Humboldt was inspired by early authors of encyclopaedias such as Aristotle, Strabo and Albertus Magnus to develop a concept of a total unity that turned the traditional idea contained in Conrad of Megenberg's Buch der Natur upside down. The philosopher Hans Blumenberg (1981) quoted a letter by Humboldt, according to which he wanted to call his encyclopaedia "... The Book of Nature, after the one that Albertus Magnus wrote in the Middle Ages. But all this is uncertain. Now my title is: Cosmos." (translated by Helmut de Terra, The Life and Times of Alexander von Humboldt 1769–1859, New York 1955, p. 320.)

Alexander von Humboldt (1769–1859): The new organs of the cosmos

Humboldt distinguished between three aspects in which the world conceptually fitted into a whole: "1. the efforts of reason to attain the knowledge of natural laws ...; 2. events in the world's history which have suddenly enlarged the horizon of observation; 3. the discovery of new means of perception through the senses, whereby observations are varied, multiplied, and rendered more accurate, and men are brought into closer communication both with terrestrial objects and with the most distant regions of space." (Humboldt, Cosmos, Vol. II, p. 104)

Alexander von Humboldt, *Kosmos* ('Cosmos'), five volumes, Stuttgart, Cotta'scher Verlag, 1845–1862 [UBL: KHS.7450: 1-4, I 5095-e-f]. German edition of *Cosmos* in five volumes: The natural world classified encyclopaedically [UBL: KHS.7450:1-4, I 509<u>5-e-f].</u>



First German edition of Alexander von Humboldt's *Cosmos*, vol. 1, 1845 [UBL: KHS.7450:1, title page].

Kosmos.

Entwurf

einer phyfifden Beltbefdreibung

Alexander von humboldt.

bou

Erfter Band.

Naturae vero rerum vis atque majestas in omnibus momentis fide caret, si quis modo partes ejus ac non totam complectatur animo. Plin. H. N. lib. 7 c. 4.

Stuttgart und Augsburg.

3. G. Cotta'f der Berlag. 1845. An English-language edition was already published in its fourth edition as early as 1849 [UBL: 47-8-351:1, title page].

COSMOS: SKETCH

OF A PHYSICAL DESCRIPTION OF THE UNIVERSE.

BY ALEXANDER VON HUMBOLDT.

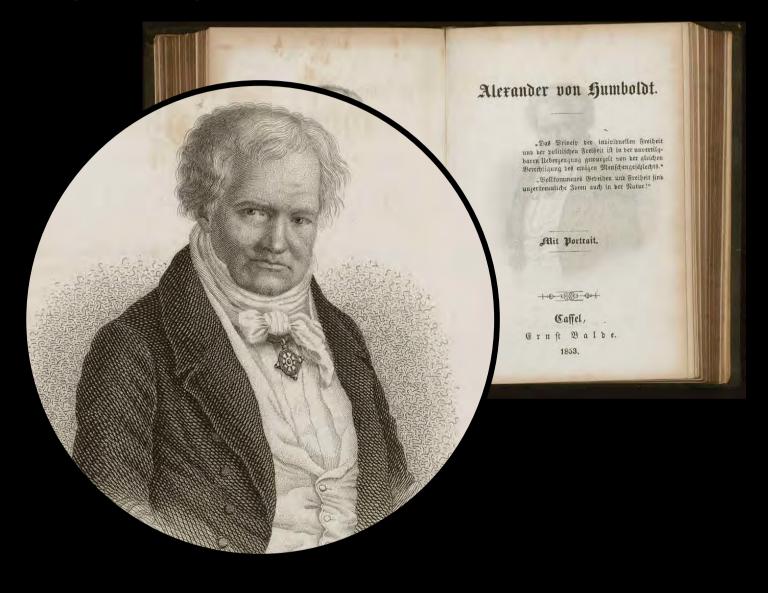
Vol. I.

Natura vero rerum vis atque majestas in omnibus momentis fide caret, si quis modo partes ejus de non totam complectatur animo.–Plus, H. N. lib, vil. v. 1.

TRANSLATED UNDER THE SUPERINTENDENCE OF LIEUT.-COL. EDWARD SABINE, R.A., For. Sec. R.S.

Fourth Edition.

LONDON: FRINTED FOR LONGMAN, BROWN, GREEN, AND LONGMANS, FATHERNOFTER HOW; AND JOHN MURRAY, ALBEMARLE STREET. 1849. "Noticing here only those instruments which mark great epochs in the history of the knowledge of nature, we may name the telescope, and ... the compound microscope, which affords us the means of following the processes of development in organization (the formative activity, the origin of being or production, as Aristotle finely says) ...". (Cosmos, Vol. II, p. 109) It's no wonder that in the twentieth century, a series of teaching aids for science lessons was called Kosmos or that a microscope for pupils was named after Humboldt. The Humboldt microscope enabled people to read *The Book of Nature* in a new way. Portrait of Alexander von Humboldt contained in *Moderne Klassiker* ('Modern classics'), Cassel: Ernst Balde 1853, vol. 9, frontispiece [UBL: Lit.germ.A702i-5-9].



Kosmos Humboldt microscope shown in an old brochure [private collection].

KOSMOS-MIKROSKOP HUMBOLDT

Ein ausbaufähiges Arbeitsmikroskop, das sich durch seine gediegene Ausführung und gute Ausrüstung bei Untersuchungen im Labor, für den Mediziner und Biologen, beim Unterricht in Schulen, Instituten und Lehrgängen, sowie bei der Liebhaberarbeit zahlreicher Naturfreunde bestens bewährt und vielfache Anerkennung gefunden hat.

Die nebenstehende Abbildung zeigt das Kosmos-Mikroskop Humboldt, ausgebaut mit 3teiligem Revolver.

Technische Ausstattung

Stabiler Fuß mit festem Stand. Tubusträger bis zu 90° umlegbar, dadurch für Mikro-Projektion und – Fotografie geeignet. Grobeinstellung mit Zahn und Trieb. Beiderseitige Feineinstel-

lung durch Mikrometerschraube (1 Teilstrich = $\frac{1}{1000}$ mm). Feststehender Objekttisch 110 x 110 mm mit 2 Objektklammern. Irisblende mit ausschwenkbarer Auflage für Blau- oder Mattscheibe, in Kondensorfassung mit Gewinde für Kondensorlinsen (siehe Seite 2).

Optische Ausstattung

Plan- und Hohlspiegel von 50 mm \mathcal{D} , 2 achromatische Objektive mit einer Eigenvergrößerung von 10:1 und 50:1, und 2 Huygens-Okulare mit 5- und 12 facher Eigenvergrößerung.

Dadurch sind mikroskopische Vergrößerungen folgender Werte möglich: 50-, 120-, 250- und 600 fach. Durch zusätzliche Objektive und Okulare (siehe Seite 4) ist ein Ausbau auf stärkere Vergrößerungen jederzeit möglich.

Kosmos-Mikroskop Humboldt wie oben beschrieben in verschließbarem, poliertem Holzschrank mit Aufbewahrungsleisten für Objektive und Okulare, sowie einem Testpräparat; ohne Objektiv-Revolver DM 264.—,

für Kosmos- und Mikrokosmos-Mitglieder DM 256.-..

Das gleiche Modell mit Objektiv-Revolver für drei Objektive (siehe obige Abbildung)

für Kosmos- und Mikrokosmos-Mitglieder DM 281.-..

Für den weiteren Ausbau des Kosmos-Mikroskopes HUMBOLDT steht eine große Anzahl passender Zusatzteile zur Verfügung.

FRANCKH'SCHE VERLAGSHANDLUNG STUTTGART ABT. KOSMOS-LEHRMITTEL

DM 289 .-.

The spherical algae Volvox globator

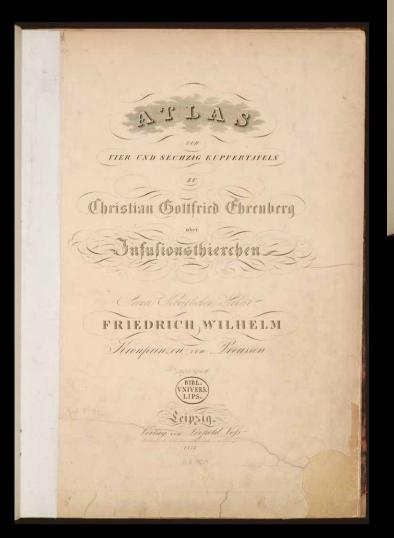
On 24 July 1838, Alexander von Humboldt wrote to the botanist and his expedition companion Christian Gottfried Ehrenberg: "I am pleased with you, for you and for natural science, which – after Cuvier's death – you are the <u>only</u> one to have mastered in its entirety (and to a far greater extent than he), that [your] great infusorial work is being published. It will be epoch-making and be monumental alongside your travel research. I consider you fortunate that you have discovered an independent region. The discovery of the preservation of infusoria will have great consequences. Where would botany be if everything could only be seen in fresh plants?"

http://telota.bbaw.de/AvHBriefedition/#/101, accessed 11 January 2021, translation by the author

Ehrenberg's major work *Die Infusionsthierchen als vollkommene Organismen* ('Infusion animals as perfect organisms', 1838) had just been published. This made him the founder of microbiology, which he connected to the microgeological exploration of the Earth. At that time, 'infusoria' was a collective term for microorganisms such as bacteria, microalgae and zooplankton. They were collected using an infusion method in order to view them under the microscope, including the spherical algae *Volvox globator* from Ehrenberg's illustrated atlas. The cosmos was joined by a microcosm that left nothing to be desired in terms of diversity.

Humboldt congratulated his travelling companion on having discovered this "independent region" of the natural world. As with the cosmos, the breadth and depth of this underworld now had to be explored. Soon, it was understood as a world of the precursors of plants and animals ('protists'), and a separate realm – bacteria – was demerged.

Christian Gottfried Ehrenberg, Die Infusionsthierchen als vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur ('Infusion animalcules as perfect organisms. A glimpse into the deeper organic life of nature'), Leipzig, Voß, 1838 [UBL: Gr.Fol.932:1, Gr.Fol.932:2]. Title pages of Ehrenberg's treatise and the accompanying atlas [UBL: Gr.Fol.932:1, Gr.Fol.932:2].



DIE

INFUSIONSTHIERCHEN

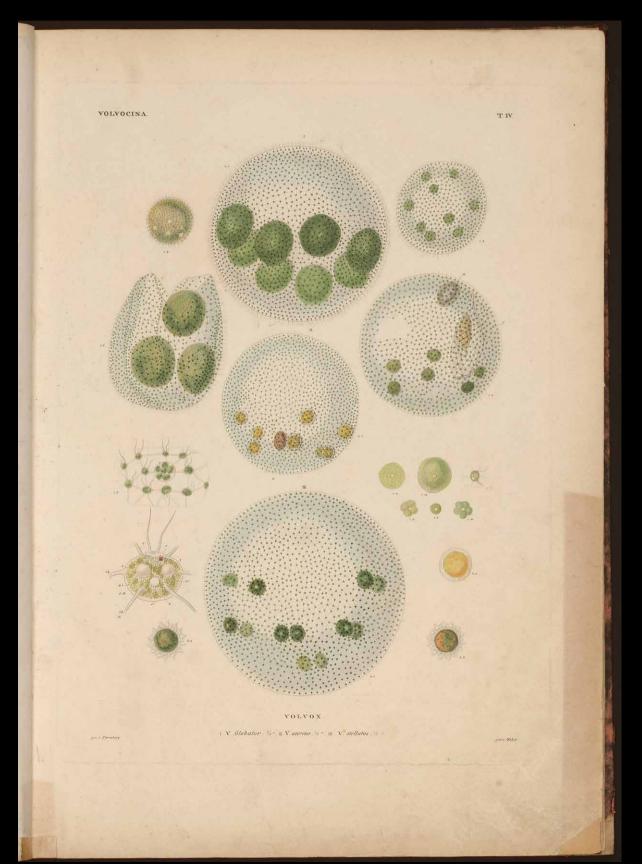
ALS

VOLLKOMMENE ORGANISMEN.

EIN BLICK IN DAS TIEFERE ORGANISCHE LEBEN DER NATUR.

VON D. CHRISTIAN GOTTFRIED EHRENBERG ZU WERLAN

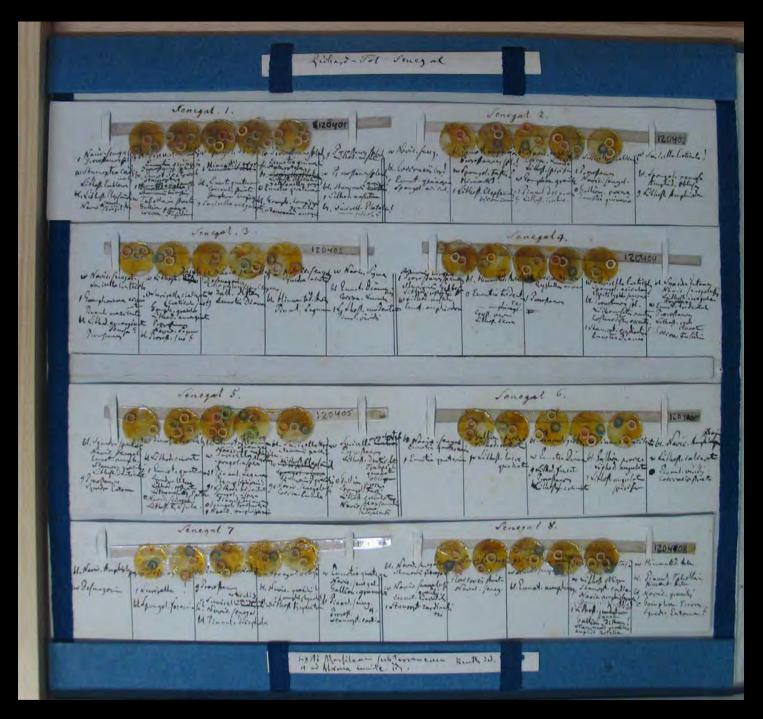
NEEST LINEN ATLAS VON VIERUNDSECHSZIG COLORIATES KUPPERTAFELS. GEZEICHNET TOH VERUNSER UNIVERS LIPS LEIPZIG, VERLAG VON LEOPOLD VOSS. TORALDE ALON LEOPOLD VOSS. INTERNATION LEOPOLD VOSS. The spherical algae Volvox in Ehrenberg's Die Infusionsthierchen als vollkommene Organismen ('Infusion animalcules as perfect organisms') [UBL: Gr.Fol.932:2, Atlas, plate IV].



Collecting microbes: Zombies under glass

Microbial diversity prompted the question of new forms of collecting. Humboldt referred to herbaria with dried plants, books of nature that were often collected in libraries. But how can bacteria and algae be preserved? Can they be preserved dead, or must they be collected alive? In this regard, neither the library nor the botanical garden are suitable forms of knowledge storage. Ehrenberg was only acquainted with the method of collecting dead specimens in the form of microscope slides, which he himself helped to develop. However, experimenting with these specimens was no longer possible.

Christian Gottfried Ehrenberg, Mittheilung einer sehr einfachen Methode zum Festhalten, Vergleichen und Aufbewahren der feinsten und vergänglichsten mikroskopischen Objecte ('A very simple method for capturing, comparing and preserving the most delicate and perishable microscopic objects'), Berlin, Verlag der Königlichen Akademie der Wissenschaften in Berlin, 1837 [UBL: Ges.-Schr.164:1835]. Microscopic long-term specimens by C. G. Ehrenberg [photo: Museum für Naturkunde Berlin]



Ehrenberg's treatise on "microscopic objects" [UBL: Ges.-Schr.164:1835].

Mittheilung

sehr einfachen Methode zum Festhalten, Vergleichen und Aufbewahren der feinsten und vergänglichsten mikroskopischen Objecte.

Von H^{rn.} EHRENBERG.

[Gelesen in der Akademie der Wissenschaften am 21. Mai 1835.]

mmmmm

Die von mir der Akademie seit einer Reihe von Jahren in einer allgemeineren Beziehung vorgetragenen Organisations-Verhältnisse mikroskopischer Organismen haben, obschon meine Darstellung das Vertrauen sorgfältiger Beobachter gewonnen hat, doch auch hie und da Widerspruch erweckt. Ein individuelles peinigendes Gefühl, die obschon zu oft wiederholten Malen beobachteten Gegenstände doch zuweilen nur allein, oder nur mit einem und dem andern Beobachter übereinstimmend zu sehen, hatte mich früher zunächst zu den Versuchen angetrieben durch farbige Nahrung die von mir schon lange Zeit erkannte sehr zusammengesetzte Structur der Infusorien einigermaßen zur allgemeineren Ansicht zu bringen. Jene Versuche gelangen erst spät, aber vollständig, und es sind bereits so viele bestätigende Zeugnisse sorgfältiger Beobachter zur öffentlichen Kenntniß gekommen, daß über das Ernährungssystem der mikroskopischen und gallertigen Thiere späterhin nicht leicht mehr bedeutende Differenzen sich lange halten können (¹). Anders verhielt es sich aber immer noch mit den andern Ergebnis-

⁽¹⁾ Auch der neuliche lebhafte Widerspruch der Herren Dujardin und Peltier in Paris über die Ernährungsorgane der Infusorien, zeigt sich nur als eine Folge individueller Schwierigkeit in der Behandlung des Mikroskops. Ich halte nicht für nöthig dagegen speciell etwas zu erinnern, denn die Farbenspectra des Mikroskops darf man freilich nicht, wie Herr Peltier, mit den durch Indigo oder Carmin gefärbten inneren Canälen verwechseln, auch ist es ein individueller, die Sache gar nicht berührender Irrthum, wenn Herr Dujardin die Bläschen in der Körpersubstanz der Eingeweidewürmer, welche mit dem Ernährungsgeschäft, wozu

Potato cultures

At the end of the nineteenth century, the first collection of microbes with live cultures was set up at the German University in Prague. The storage medium of knowledge was no longer parchment or paper, but glass. Bacteria are also stored in ampoules in today's microbe banks, albeit freeze-dried as granules (see Fig. p. 178). These 'living dead' are in a state of latent life that can be resurrected. Before this possibility existed, microbial strains were cultivated alive on beet slices or potatoes cut in half ('potato cultures'), which quickly led to contamination.

Karl B. Lehmann, Rudolf Neumann, Atlas und Grundriss der Bakteriologie. Teil I: Atlas ('Atlas and outline of bacteriology. Part I: Atlas'), München, J.F. Lehmann, 1899 [UBL: Allg.med.Lit.1231-gb:10,1]. Title page of the German edition of Karl B. Lehmann's Atlas and Principles of Bacteriology, 1899 [UBL: Allg. med.Lit.1231-gb:10,1].

LEHMANN'S MEDICIN. H A N D A T L A N T E N. BAND X.

ATLAS UND GRUNDRISS DER BAKTERIOLOGIE UND LEHRBUCH

DER

SPEZIELLEN BAKTERIOLOGISCHEN DIAGNOSTIK. TEIL I: ATLAS.

VON

PROF. DR. K. B. LEHMANN VORSTAND DES HYGIENISCHEN INSTITUTS IN WÜRZBURG

UND

DR. PHIL. & MED. R. O. NEUMANN ASSISTENT AM HYGIENISCHEN INSTITUT IN WÜRZBURG.

2. VERMEHRTE UND VERBESSERTE AUFLAGE.





MÜNCHEN. VERLAG VON J. F. LEHMANN. 1899. Bacillus anthracis, Fig. IX: Potato culture after 6 days at 22°C – actual size [UBL: Allg.med.Lit.1231-gb:10,1, Tab. 8 (first edition, Tab. 1)].

Editio II. Tab. 8. (Editio 1. Tab. 1.) Tab. 8. Micrococcus pyogenes a. aureus. (Rosenbach.) Lehm, et Neum. (Staphylococcus aureus Ros.) I. Gelatine Stichkultur 6 Tage bei 22°. I. Gelatine Stichkultur 5 Tage bei 22°.
II. Agar Strichkultur 5 Tage bei 22°.
III. Agar Stichkultur 5 Tage bei 22°. Stichkanal.
IV. Agar Stichkultur 5 Tage bei 22°. Oberfläche.
V. Agar Plattenkultur bei natürlicher Grösse 6 Tage bei 22°. Aufliegende und tiefliegende Kolonien.
III. Dittee Charge Carge bei 22°. Aufliegende kleinere VI Agar Platte 6 Tage bei 22º 4. Aufliegende kleinere Kolonie. VII. Gelatine Platte bei natürlicher Grösse 4 Tage. Aufliegende und tiefliegende Kolonien bei 22º. M. VIII. Gelatine Platte 4 Tage bei 22º 4ª. Aufliegende und III . tiefliegende Kolonie. IX. Kartoffelkultur 6 Tage bei 22⁰. X. Mikroskopisches Präparat ¹⁹⁹⁹ von Agarkultur 2 Tage bei 22% XI, Mikroskopisches Praparat, Einzelne Kokken vor während und nach der Teilung ^{Lä}r^{0,0}. IX. XI Aur: 45 x VIII Lich Jan v. F. Heinhold , Munchen

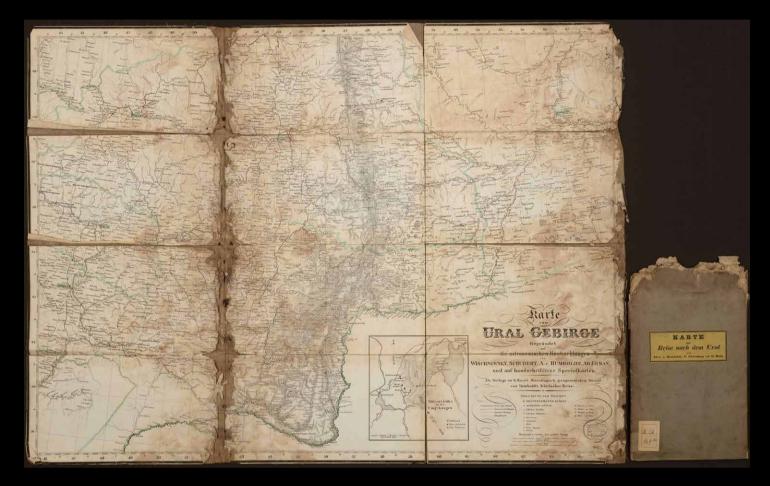
The 'Siberian plague'

Ehrenberg and the mineralogist Gustav Rose joined Humboldt on his great expedition to explore the eastern hemisphere which would take them to the far reaches of Russia, when suddenly their path was crossed by the 'Siberian plague'. On arriving in Kainsk (now Kuybyshev) in western Siberia, Ehrenberg noted in his journal on 29 July 1829: "Nasty news of plague cases ... The town authorities do not consider it necessary to alter the route, but to exercise caution."

Edition Humboldt digital: <u>https://edition-humboldt.de/themen/</u> <u>detail.xql?id=Hoo16785&view=l&l=de</u>, accessed 11 January 2021, translation by the author

The local doctor called the disease *Synochus putridus*, the name of a nervous fever similar to typhoid. "Insect bites, according to his theory, are supposed to make openings in the skin which facilitate the direct action of the noxious atmosphere on the blood vessels." (Ibid., pp. 39v; translation by the author.) The three scientists underwent mobile quarantine and hardly ever left their carriage. They avoided contact and refused to drink water from unknown sources. At the beginning of August 1829, they left the epidemic area unharmed without knowing exactly what the 'Siberian plague' was. It turned out to be anthrax, which was long thought to be a fly-borne cattle disease.

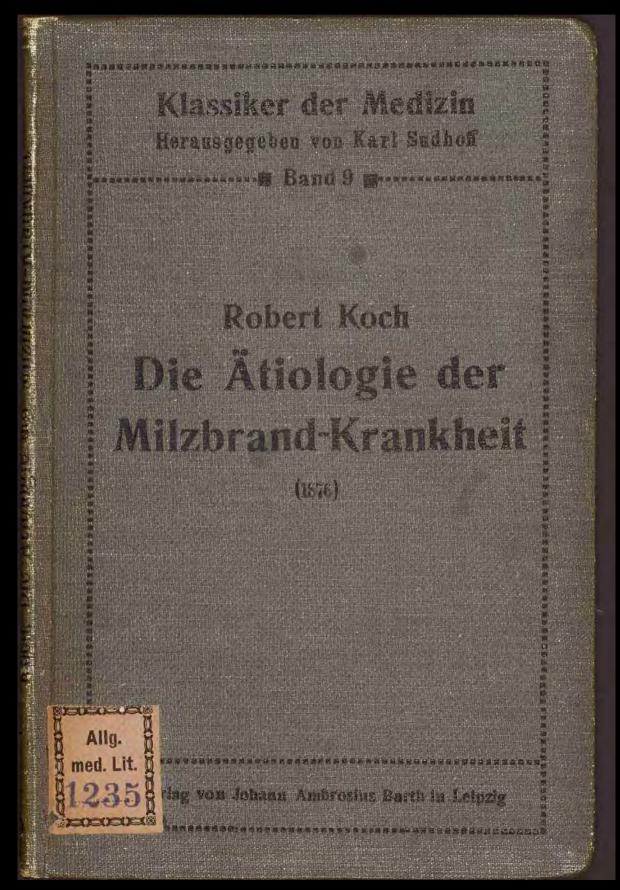
Gustav Rose, Mineralogisch-geognostische Reise nach dem Ural, dem Altai und dem Kaspischen Meere ('Mineralogical-geognostic expedition to the Urals, the Altai and the Caspian Sea'), vol. 2, Berlin, Sander, 1842 [UBL: Geol.878v:2]. Object decay is accelerated not only by microbes, but also by being touched by users. Map from 1842 showing Rose, Ehrenberg und Humboldt's expedition to the Urals in 1829 [UBL: L.Ch.167a].



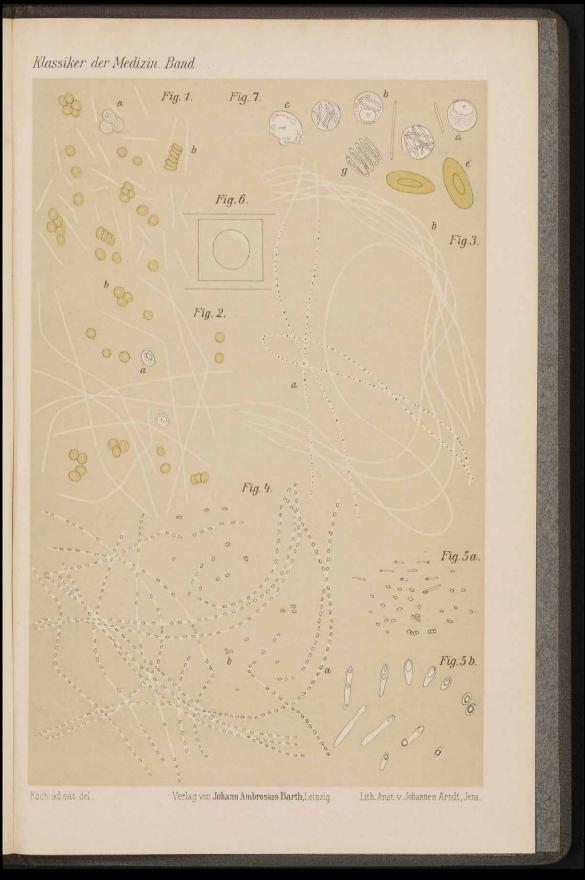
The experimental detection of anthrax: Robert Koch

It wasn't until 1876 that the young district physician Robert Koch (1843–1910) delivered complete experimental proof of the cause of anthrax and the life cycle of its pathogen (*Bacillus anthracis*), including spore formation. The bacilli (rod-shaped bacteria) require blood containing oxygen and so can only survive for a short time in cadavers, which is why they'd rarely been found previously by pathologists. Conducting experiments on bovine blood, Koch showed that the bacilli form long chains. Seen under the microscope, the surviving spores look like glowing dots.

Robert Koch, Die Aetiologie der Milzbrand-Krankheit, begründet auf die Entwicklungsgeschichte des Bacillus Anthracis ('The aetiology of anthrax disease based on the evolutionary history of Bacillus anthracis'), in: Beiträge zur Biologie der Pflanzen, Ferdinand Cohn (ed.), vol. 2, Breslau, Kern, 1877 [UBL: Allg. med.Lit.1235]. Cover of the Die Aetiologie der Milzbrand-Krankheit ('The cause of anthrax') [UBL: Allg.med.Lit.1235].



Illustrations of *Bacillus anthracis* as white rods, partly with spores, in Kochs *Aetiology* [UBL: Allg.med.Lit.1235].



It was only about three decades after Ehrenberg and Humboldt that bacteriology was hived off from botany and protist science as a branch in its own right, for bacteria turned out to be fundamentally different from plants and animals. In the space of a few years, 'the microbe' went from being an admired ancestor of human life on Earth like the diatom to an enemy – and it was hygiene's job to fight it.

But Ehrenberg was still unaware of this development. On 12 September 1829, he examined a lake near the town of Kyshtym in the southern Urals and wrote in his journal: "Observations of infusoria and confervae. Humboldt conducting magnetic observations." Below, he listed his aquatic finds: the microscopic spherical alga *Volvox globata* and "syphilitic Tatar skull from the lake". Two days later, having reached the Miass ironworks, he "revised his drawings of infusoria".

Edition Humboldt digital: <u>https://edition-humboldt.de/</u> <u>themen/detail.xql?id=H0016785&l=de</u>, *Tagebuch der russischsibirischen Reise 1829* ('Journal of the voyage across Russia and Siberia 1829'), fols. 53r, 53v, accessed 12 July 2021

Nowadays, much of the expedition area has been contaminated by strontium-90 and caesium-137 since the explosion of a tank containing nuclear liquid waste at the Mayak nuclear facility on 29 September 1957. The Kyshtym disaster is the third-biggest nuclear incident ever after Chernobyl and Fukushima. Long concealed, it was only revealed to the rest of the world by Soviet dissident Zhores Medvedev in his 1979 publication *The Nuclear Disaster in the Urals*, although he was initially disbelieved by members of the Western nuclear industry.

THE LEGIBILITY OF THE WORLD

Are books and other written documents the only things we can read? Evidently not, if we think beyond alphabetic scripts and associate legibility more generally with the ability to interpret signs and symbols. One impressive example is the historical use of hieroglyphics – incised writing consisting of depictions of natural objects carved into a writing medium such as stone or bone. However, the meaning of a hieroglyph doesn't necessarily follow from the image. Instead, these pictographic characters often represent a pronounced sound or syllable. The relationship between picture, writing and sign is complicated and can be read in different ways. To put it more simply, if we can read clouds, why not microbes?

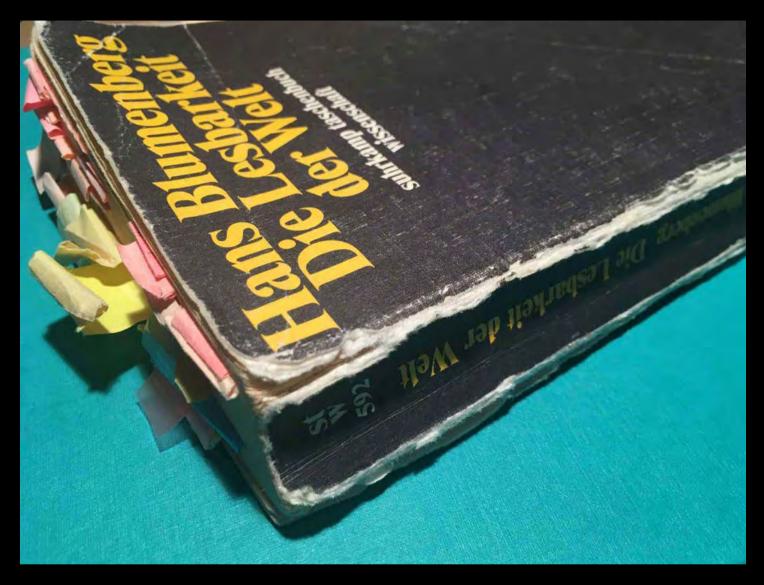
Microbiologists also produce something like incised writing. After sampling a medieval book, the cotton swabs are smeared on culture medium in the laboratory, where they are repeatedly inoculated using a metal loop, i.e. embedded in the agar medium so that they can inscribe themselves onto it. Each individual colony that develops in this way is a sign of, say, a human hand touching the book or a change of location. Any such action leaves traces on the book, placing a human bacterial signature over the writing which can be revealed by experiments.

This creates a dual legibility of the world extending far beyond the library. For in addition to traditional access to world knowledge in the form of ordered books, reading acquires an alternative vista in the book of nature. And in the modern age, this no longer means classifying creation, but offers an experiential ocean of possibilities. Since reading, travel and cosmopolitanism all belong together, it's no wonder that microbes also travel the world – including as pandemics!

From measurement to touching and sharing the world

There's an old enmity between books and reality, wrote the philosopher Hans Blumenberg (1920-1996) in Die Lesbarkeit der Welt ('The legibility of the world'). Compared to worlds of dusty book, the observation and measurement of nature appear fresh, new and modern. However, it was only the medium of the book that enabled the idea of being able to read in nature in the first place. It's in this sense that Blumenberg pursues the metaphor of the 'book of nature': from Augustine to first Romanticism and then modern molecular genetics. What all the varieties have in common is that they hold out the prospect of access to a world-whole, and yet have disappointed us time and again. Accordingly, Blumenberg seeks answers to the question of what sort of world people could have: a measurable world of data ("Newton's world") or an experiential world of life ("Robinson's world")? A world that could be described – or perhaps formally derived ("world chronicle" vs. "world formula")? Or even, as Blumenberg adds, a microbial world?

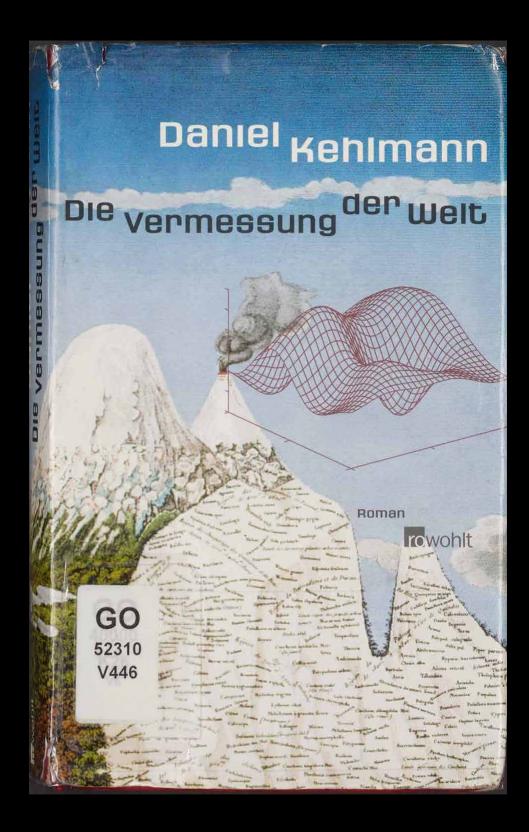
In the metaphor of the legibility of the world, theoretical curiosity is combined with the difficulty of not being able to directly access either the objects or the whole of this curiosity. Thus, Humboldt's treatise *Cosmos* was intended to create the impression that nature leaves on mankind in book form: "A book on nature as a book of nature". This encyclopaedia of nature turned the old enmity between books and reality into a new friendship. Yet Blumenberg and Humboldt said nothing about a certain alternative: reading in a book itself as in nature, i.e. in the microbial traces left by readers and insects on paper and parchment. The book of nature would thus be joined by a nature of the book on equal terms, a medium of legibility and a habitat of 'liveability'. After all, reading also means touching. Well-thumbed copy of Hans Blumenberg: *Die Lesbarkeit der Welt* ('The legibility of the world'). Frankfurt am Main: Suhrkamp 1981, paperback edition 1986 [photo: A. Waszynski].



Global success: Humboldt as a character in a novel

Almost half a century before the publication of Cosmos (1845 ff.), Alexander von Humboldt set out on his expedition to America, to the western hemisphere - half the world – accompanied by Aimé Bonpland (1773– 1858). They took an arsenal of instruments with them to precisely measure ocean currents, temperatures and magnetic fields. In Daniel Kehlmann's famous novel Measuring the World (2005), their explorations are portrayed in a parallel montage with the mathematical discoveries of Carl Friedrich Gauss (1777–1855), who was less fond of travelling but a genius when it came to geodetic surveying – a method used to determine the position of permanent points on the Earth's surface. As well as comparing two approaches to discovering the laws and irregularities of nature, Kehlmann primarily highlights the physical antecedents of the newly acquired knowledge of the world. As the physical bearer of curiosity, the body is susceptible to all kinds of adversities, especially on an exploratory expedition, such as disease, insect infestation and indigestible food. An ability to immediately turn adversity into an advantage – descriptions of new species, considerations regarding the world's future food supply – is all part and parcel of the scientific ethos of Humboldt's character in the novel. Behind the attention to natural detail is a philosophical holism which works as an epistemological antagonism. In Kehlmann's novel: "Nature is a whole," declares Humboldt, to which Father Zea, the well-equipped exegete of the first of the two books, replies: "Oh really?"

Daniel Kehlmann: Die Vermessung der Welt ('Measuring the World'), Reinbek bei Hamburg: Rowohlt 2005 [UBL: GO 52310 V446; photo: UBL, copyright Rowohlt Verlag GmbH].



Friend or foe – of books

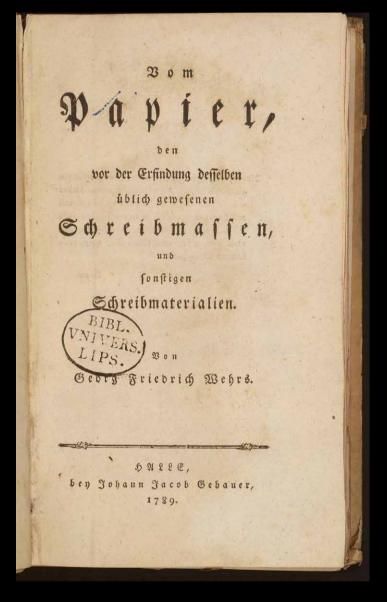
By the end of the nineteenth century, with most of the world having been surveyed and divided into dominions, it was time to sound out cultural and ideological borders, including those of language. The question of how coexistence was to be achieved became unavoilable. Fear of degeneration was rampant; hygiene became an emerging science. The book had become a mass product and spawned new diseases like addiction to reading as well as new species such as bookworms with their penchant for pulp fiction. The educated classes wanted to set themselves apart. So who were foes of books, who were their friends?

In the German dictionary compiled by the Grimm brothers, the terms Bücherfeind ('book-hater') and Bücherfreund ('book-lover') appear in the same column. The decisive difference is that the booklover, the bibliophile, is a human being, whereas the enemy of books is a beetle. The larder beetle (Dermestes lardarius) is about 8mm (nearly a third of an inch) long and is fond of human dwellings, being frequently found in homes and storage facilities. It lays its eggs on textiles and foodstuffs, and sometimes also on books and parchment. It is the beetle's larvae that are mainly responsible for the damage caused. According to Georg Friedrich Wehrs' standard work Vom Papier ('On Paper') published in 1789, what really attracts the larder beetle is shiny paper with a layer of grease. Although the greasing of paper has been

successively banned, all over the world the larder beetle lives off the fat of the paper, with or without reading matter.

Georg Friedrich Wehrs, Vom Papier, den vor der Erfindung desselben üblich gewesenen Schreibmassen, und sonstigen Schreibmaterialien ('On Paper, common writing materials before the invention of paper, and other writing materials'), Halle, Gebauer, 1789 [UBL-Sign.: Ökon.2206]. Jakob Grimm and Wilhelm nach funizia und eine bücheren Grimm: German Dictionary, BÜCHEREINBAND, m. involuc. vol. II, Leipzig: Hirzel 1860, BUCHERFEIND, m. dermestes lar col. 472 [UBL: Gr.ling. BÜCHERFLEISZ, m. ernstliches zeich rec.2320:2]. WEISE pol. näscher 171; dieser seltene schon dem allgemeinen studium slavische en über schichten mit genialem bücherfleisz und he E 58, 157. nachgegangen war. Göthe 45, 380. BÜCHERFREUND, m. bibliophilus. e breter zu BÜCHERGEBUND, m. was bücherbündel: dasz unter dem arm nicht du dein büchergebund schautragst, wie der baue BÜCHERGEWANDUNG, f. büchereinband. SSON. BÜCHERGEWERBE, n. bei ihrem weitläg werbe. HELFR. PETER STURZ schriften. Leipz. 17 en eichen ze dampf BÜCHERGLÜCK, n. fatum libelli. Log 7, 96 bücherglücke: hücher haben auch ihr glücke. wann sie faszt man dennoch gute würze, pfelfer o kümt es dir, ich bin zu friede, liebes b wann mit dir nur in geheime nieman DEUTSCHES BUCHERHAUF, m. beschränkt von dies WÖRTERBUCH den würme na VON JACOB GRIMM UND WILHELM GRIMM. ZWEITER BAND. BIERMÖRDER - D. LEIPZIG VERLAG VON S. HIRZEL Title page of the dictionary 1860. by the Grimm brothers, vol. II [UBL: Gr.ling.rec.2320:2].

Title page of Georg Friedrich Wehrs' *Vom Papier* ('On Paper'), 1789 [UBL-Sign.: Ökon.2206].



Wehrs also wrote about insects that damaged books [UBL-Sign.: Ökon.2206, p.691].

> schädlichen Infekten, und den Mitteln, folche theils davon abzuhalten, theils ju vertilgen. Die Ulten fuchten ihre Bucher gegen die Befchåbigung der Infekten badurch in Sicherheit zu stelten, daß fie folche nicht nur in festen Jutteralen verwahrten, fondern auch die beschriebenen Papiers

Funfzehntes Rapitel. 30n denen den Urfunden und Buchern

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bermahrten, fondern auch die beschriebenen Papiers und Pergamentrollen oder Blatter mit Ceber . und Citronenol, ober mit andern ftart riechenden Dins gen überftrichen. In neuern Zeiten bat man gum bfrern verschiedene Mittel wider bie fo mancher vors treflichen Bucherfammlung zum Berberb gereichen. ben Infetten vorgeschlagen, allein theils find biefe Mittel nicht hinlanglich befant geworben, theils aber haben fie bem gewünschten Erfolge nicht ents fprochen. Die fonigliche Societat ber Wiffen. fchaften in Gottingen hielt es baber für wichtig genug, in ihrer am 1oten Julius 1773 gehaltenen Berfammlung, für den Julius 1774 die Preis. frage aufzuwerfen : Die vielerlei Lirten von Ins feften 'es gebe, bie ben Urfunden und Buchern in Urchiven und Bibliothefen fchadlich waren? welchem Stude ber Materien, als Rleifter, Leber, Xr 2 Pape

Title page of Wehrs' supplementary volume [UBL-Sign.: Ökon.2206:Suppl.].

In the supplementary volume. Wehrs also wrote about paper-eating insects in the colonies [UBL-Sign.: Ökon.2206:Suppl., pp.160-161].

Supplemente ju bem voriges Jahr in Salle herausgefommenen Buche p o m â Γ, hen por der Erfindung desselben üblich gewefenen Schreibmassen, und fonftigen Schreibmaterialien. IVERS non Beorg Friedrich Behre, ordentlichen Mitgliede ber Königt. Brofbrit, Churfürfil. Braun-femwig Lineburgiden gateburtbichaftsgefellichaft in Zello, und der Churfürfilich Schaft den ebenmischen Societät m Leipig auständischem Schenmitgliede. Sannover in der helmingfchen 5 andlung, 1 7 9 0

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Baumrinde. - In ber Bibliothet au 2Bolfenbattef

ift eine in Birtenrinde gebundene Bibel vorhanden, phi-

Seite 692. Note zum erffen Ubfage im Terte.

Uuch bie philadelphifche Societat ber Biffenfchaften, warf auf Veranlaffung ibres Chrenmitgliedes, bes

herrn Françols von Deufchateau, weil alles Papier

in ben bortigen Rolonien fo febr bald burch bie Dafs

fe und fchablichen Infeften verborben mirb, in ihrer

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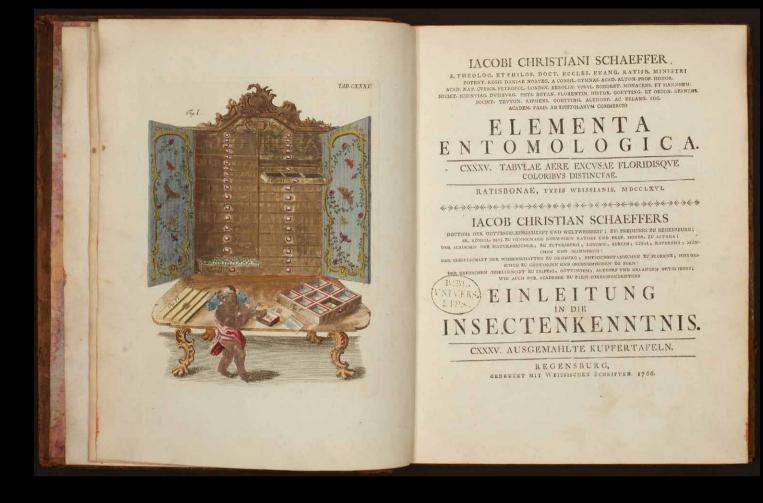
Edward Scissorhands: the house pseudoscorpion

Compared to the Darwinian struggle for existence in a finite habitat, the world opened its arms to animals in antiquity, including those in the book. One curious creature (Chelifer cancroides) known in German as a Bücherskorpion (book-spider) not only lived in books, but actually originated there - for according to Aristotle's doctrine of spontaneous generation, living beings could simply come into being as if from nothing. This small animal found its way into entomological works such as the hand-coloured book by Jacob Christian Schaeffer (1766), who called it a 'scorpion-spider'. Nowadays considered a pseudoscorpion, it didn't quite fit into biological systematics because of its unusual morphology, as Aristotle first noted: "Certain insects are furnished with prickers or stings. Some insects have the sting inside, as the bee and the wasp, others outside, as the scorpion; and, by the way, this is the only insect furnished with a long tail. And, further, the scorpion is furnished with claws, as is also the creature resembling a scorpion found within the pages of books."

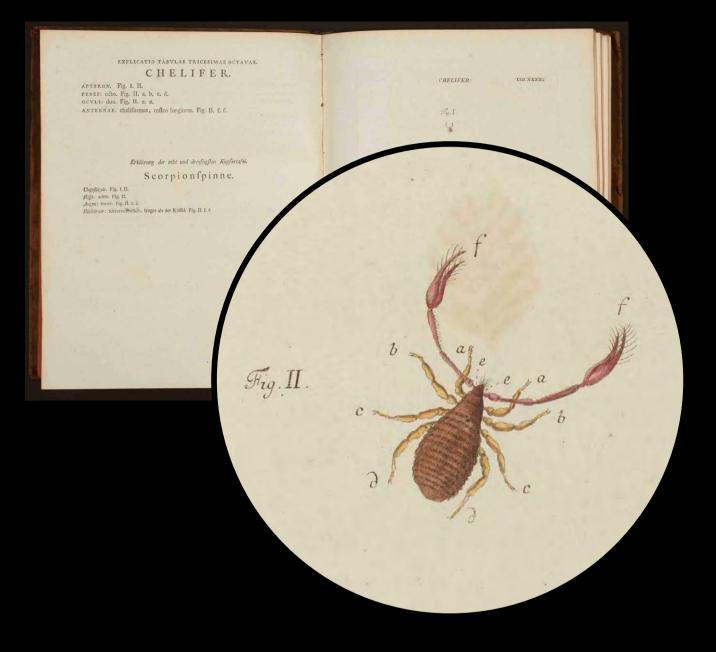
Hist. an. IV.7, 532a 14-18, English translation by D'Arcy Wentworth Thompson, cited from <u>https://penelope.uchicago.</u> <u>edu/aristotle/histanimals4.html</u>, accessed 12 July 2021

Although the house pseudoscorpion created disorder among the natural orders, Aristotle found it very useful to illustrate a basic principle of life, namely teleology – the view that anything coming into being has a purpose. This explains why the house pseudoscorpion has claws: because its biotope is the book, it needs organs that can cut paper.

Jacob Christian Schaeffer, Elementa entomologica. Einleitung in die Insectenkenntnis ('Introduction to Entomology'), Regensburg, Weiss, 1766 [UBL: Zool.236.1]. Title page of Schaeffer's Elementa entomologica with frontispiece [UBL: Zool.236.1, Tab. CXXXV].



The 'scorpion-spider' as shown in Schaeffer's book [UBL: Zool.236.1, Tab. XXXIIX].



SEARCHING FOR CLUES IN A BOOK'S BIOGRAPHY

Katharina Gietkowski Regina Jucknies Christoph Mackert Ulrich Johannes Schneider Katrin Sturm

SEARCHING FOR CLUES IN A BOOK'S BIOGRAPHY

Much changes about the history of books when microbes are taken into account. The perspective of creatures that live on, inside, with or from the book means attention has to be paid to more than just the text. We regard books differently as a cultural asset, we ask different questions, we're invited to consider books in an old library as objects made of natural materials such as parchment and paper, wood and leather, thread and glue. An interest in the history of ideas encourages us to read books. But if we adopt the viewpoint of microorganisms, we start to look more closely. What is this habitat for microbes? How do a book's production and use affect the microbial scene it contains?

The history of books is a field involving many aspects. Manuscripts, for example, are handcrafted artefacts made of different materials even before they've been bound. These aspects have been intensively studied many times over, and experts working in libraries and elsewhere have long required an understanding of material studies and the natural sciences. Yet when seen from the microbe's point of view, interest is intensified in everything which is considered a trace of nature (such as specifics of the material and damage), or which is indissolubly connected to the book block as a natural trace.

Manuscripts are individual historical items produced in diverse ways with all sorts of characteristics depending on where and why they were created. Throughout their lifetimes, they're affected by the long distances they cover. They pass through many hands leaving both visible and invisible traces. In collections and libraries, books acquire additional features such as shelf marks, annotations, and inscriptions of ownership. In many cases, the only way to determine when,

SEARCHING FOR CLUES IN A BOOK'S BIOGRAPHY

where and for whom a manuscript was produced or where it was taken is by means of circumstantial evidence concluded from its material condition. Today's researchers take all sorts of aspects into account and apply a wide range of methods as they coax historical books to speak.

THE ELOQUENCE OF WRITING MATERIAL

Until well into the thirteenth century, parchment was the only writing material used for books in the West. Made from animal skin, its qualities varied depending on the type of animal, how it was made, and its quality. From the twelfth or thirteenth centuries onwards, paper made from plant fibres from the Islamic cultural regions reached the Christian world in southern Europe, where the production process was improved to make paper more resistant to insects. Watermarks began to be used to indicate the make and quality of paper, providing indications to modern-day scholars of when and where manuscripts were produced. Other clues about the production of a book are the ink and colours used.

Parchment: Different by nature

Parchment existed in the European Middle Ages (sixth to fifteenth centuries) in different qualities ranging from perfectly smooth and light to coarse sheets containing flaws, tears, and even holes. Whenever inferior parchment was used, the manuscript was clearly not important and merely an everyday item. Quite coarse pieces from the edge of the hide with cracks resulting during production were used for this Latin commentary on the Psalms, which was written in an eleventh-century monastery to give the monks a deeper understanding of the Holy Scriptures. There's even a particularly large hole in the middle of one page. Often, the scribe simply wrote around the hole, but in this case it was plugged with a small piece of parchment and then written upon.

Latin commentary on the Psalms, Germany, 11th century [UBL: Rep. II 33 (on loan from Leipzig Municipal Library)]. Double page 6v/7r with detail from Rep. II 33 with (left) a piece of parchment missing at the edge and (right) a plugged hole [UBL: Rep. II 33, fols. 6v/7r].

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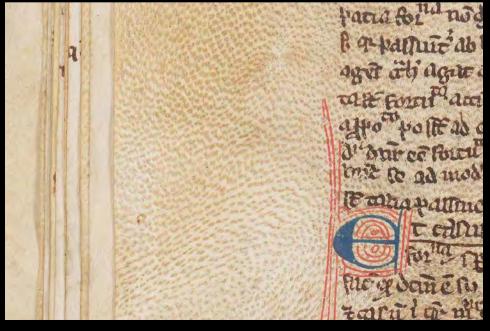
Animal hides tell of their origin

This volume provides a good example of just how much the quality of parchment varied. An owner had five different manuscripts bound together – probably from southern France, northern France and western Germany - and so combined parchment from different regions. Differences in the colour of the parchment and how it was made can be seen when comparing the individual parts. Dark parchment, where the pores of the animal skin are still clearly visible, came from Italy or southern France. Very fine, almost white parchment with no variation in colour usually originated in northern France. Evenly light, albeit less exquisite parchment was predominantly used in Germany and other northern Alpine regions. Juxtaposing parchment manuscripts from different countries was especially common in higher education since students and teachers travelled a lot.

Collection of writings on medicine and natural philosophy, France and Germany, 13th/14th centuries [UBL: Ms 1150]. Manuscript parts of different origin: southern parchment on the left, northern parchment on the right [Ms 1150, fols. 86v/87r].

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Clearly visible hair follicles on southern parchment [Ms 1408, fol. 23v].



Arabian paper – Latin texts – French insects

The book block of this manuscript is riddled with long, ramified feeding tunnels of the house longhorn beetle (Hylotrupes bajulus). This indicates the use of Arabian paper which, owing to its different composition, was more susceptible to insect damage than paper from Latin Europe. The Latin texts with scholarly treatises on medicine from the early fourteenth century contained in the volume point to the University of Montpellier in southern France. This is quite close to Spain which, being partly under Arab rule, was a place where Arabian paper was produced and sold.

Collection of medical texts, Montpellier, early 14th century [UBL: Ms 1116].

Long, ramified feeding tunnels in Ms 1116 [fols. 9v/10r, 182r].

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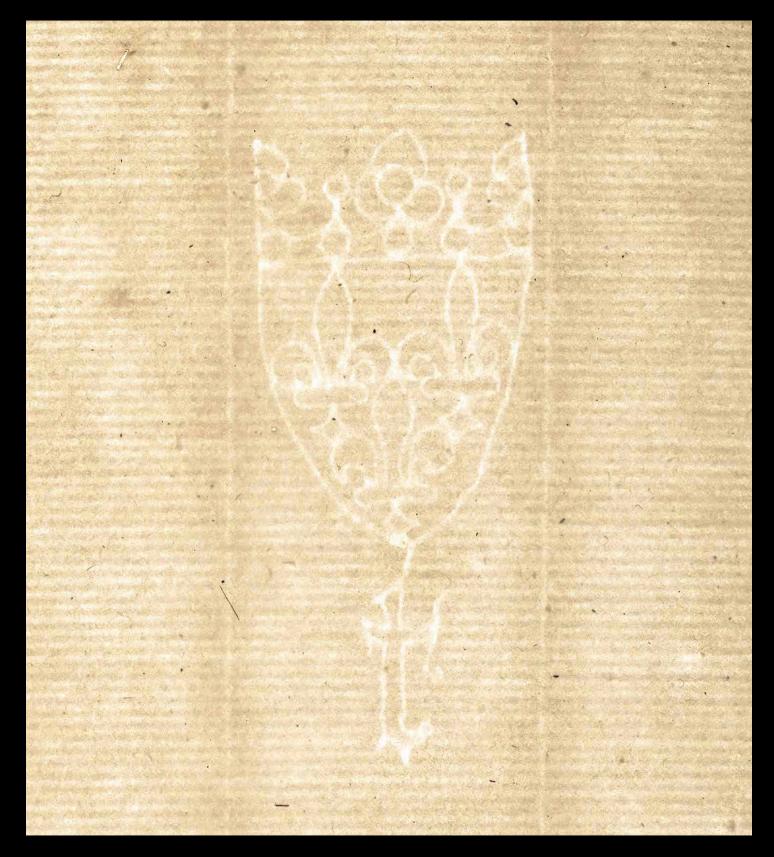
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Designs in paper

Watermarks typical of Western paper manuscripts primarily provide information about when a manuscript was written. It's often possible to narrow down the time of origin to within two years. In certain cases, the exact town or at least the area where the manuscript was made can also be identified from the watermark. In manuscript Ms 981 kept in Leipzig, for example, paper with the watermark known as 'Three Lilies in the Coat of Arms' was used. This type of paper was employed in the latter half of the fifteenth century, especially in the Lower Rhine region, and was probably produced in northern France. This corresponds to the information at the end of the volume that the manuscript was written in Aachen in 1464.

Canon law paper manuscript, Aachen, 1464 [UBL: Ms 981].

The watermark 'Three Lilies in the Coat of Arms' on an empty page in Ms 981.

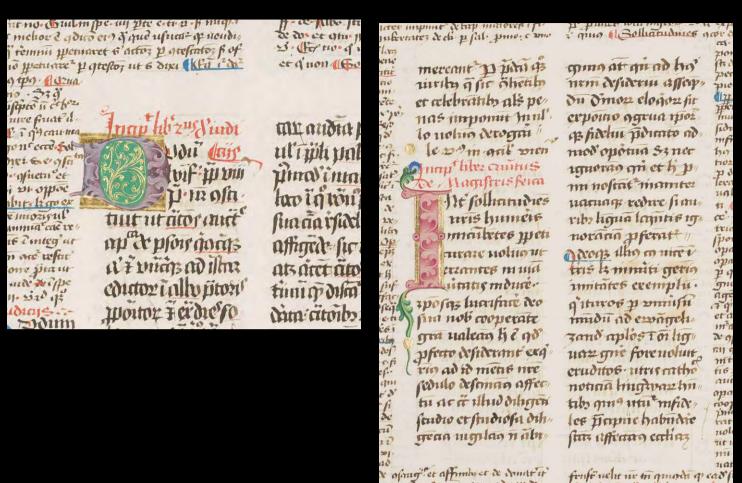


The watermark 'Three Lilies in the Coat of Arms' on a written page in Ms 981.

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Illuminated initial with gold [Ms 981, fol. 24v].

Illuminated initial with gold [Ms 981, fol. 77v].



Colophon showing the place and date of origin [Ms 981, fol. 104v].

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The colours of the south of France

The colours used to illuminate manuscripts have certain characteristics depending on the production process of the pigments used as well as regional preferences and fashions. A particularly striking example is the specific colouring of 'fleuronné initials' in southern France. Fleuronné is a form of ornamentation applied to initial letters that was widespread in the late Middle Ages, in which the letter is surrounded by filigree flowing lines. The traditional colours used for fleuronné are red and blue. In manuscripts produced in the south of France, however, the bluish decorative elements frequently stray into violet, as in this collection of medical texts from the early fourteenth century. Their origin in the south of France is confirmed by the other initials of the volume decorated with scenic illustrations due to the colours used and the typical tendril forms with pointed elements, which are known as thorn tendrils.

Medical manuscript from the south of France, first quarter of the 14th century [UBL: Ms 1189].

Initials with violet fleuronné [Ms 1189, fol. 24v].

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Initial adorned with thorn tendrils. Note the depiction of hair loss inside the initial [Ms 1189, fol. 40v].



BINDINGS

Binding is what turns a manuscript into a book. The nature of the binding reveals much about a book's intended purpose, ranging from cheap notebooks for study purposes to distinguished-looking wooden covers with embossing and decorative clasps. Over the centuries, bookbinders used various materials, including wood, leather, hemp, metal, parchment, paper, glue, and even recycled remnants of manuscripts. These materials provide valuable clues about the origin and history of individual volumes. Embossing on the cover identifies workshops where volumes were bound, while fragments used for binding shed light on a cover's origin. Often, diverse manuscripts, each with its own history, were combined between the covers. Many manuscripts were rebound, some more than once.

A collection of manuscripts between the covers

This sammelband poses a number of questions for researchers. It brings together a variety of manuscripts dealing with liturgical and related matters as well as the history of religious orders dating back to the late-fifteenth century and the first half of the sixteenth century, and which were probably bound together in the second quarter of the sixteenth century. Interestingly, the formats of the fascicles differ greatly, ranging from folio to small quarto so much so, in fact, that one has to wonder why the ecclesiastical institution that owned them (probably a Dominican convent, judging by the saints' feast days referred to) chose to have them bound in the same volume. It's also striking that the cover is disproportionately large. Small libraries with a unique profile can sometimes be discovered between two covers.

Liturgical sammelband, 15th/16th centuries [UBL: Ms 768].

Double page 56v/57r in Ms 768 with a view of other parts with a different format [Ms 768].

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Very differently sized fascicles in the rear of the volume [Ms 768].

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Paper recycling in the late Middle Ages

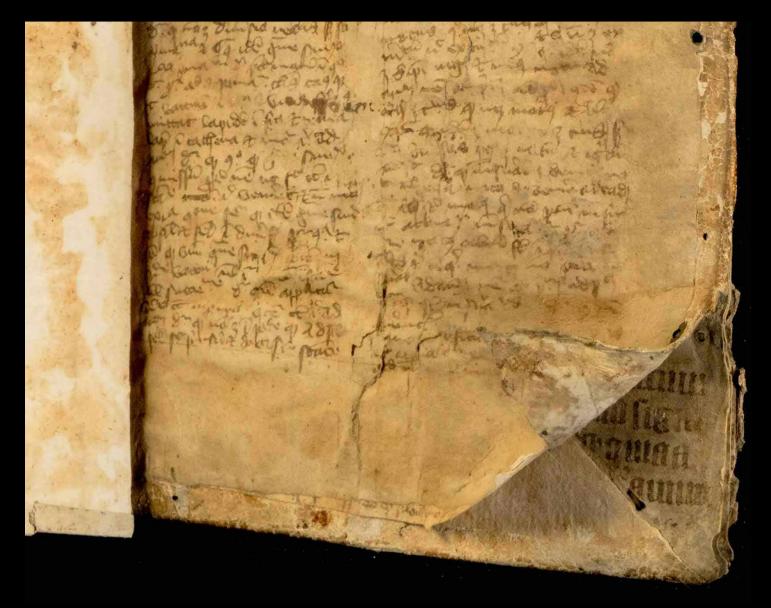
Because paper was expensive, it wasn't simply thrown away. Manuscripts, letters and bills that were no longer needed were used by bookbinders to line covers. By gluing together several sheets of paper, pasteboard was produced for covers, which made its way back into libraries as part of a new book. For this manuscript, pages from a manuscript from the early fifteenth century were used as the pastedown glued to the inside of the cover. Carefully peeling back the pastedowns reveals further handwritten material underneath, which was glued together to make pasteboard for the core of the cover. It includes fragments that are often found in recycled printer's waste, namely the standard Latin grammar of the Middle Ages, Ars minor by Aelius Donatus. Since this widespread work was used as a textbook for young pupils just getting to grips with the language, the copies used were well worn, and so old, tattered pages from it were often reused as printer's waste.

Manuscript fragments in the covers of a hagiographic manuscript, 14th/15th centuries [UBL: Ms 822].

Inside front cover with raised part of the cover lining [Ms 822].



Inside back cover with a view of a fragment from Aelius Donatus' Latin grammar [Ms 822].



The book cover – a miscellany of materials

The damage to this cover reveals the different materials used by bookbinders, and also tells us something about the history of manuscript storage. The function of wooden covers was to protect the contents. The weight of the wood and a metal clasp kept the parchment or paper flat and moisture out. Leather on the outside held the wooden covers together, while the parchment endsheet inside supported the connection between cover and book block, and also protected the first written page from the rough wood of the cover. At one time, metal bosses enabled books to be stored and moved without scratching the leather cover. This is because until the sixteenth century, books were stored horizontally on lecterns or in cupboards; only later were they arranged vertically side by side. Traces of the former metal clasps and the book chain are still visible here. A fragment of manuscript was glued on to prevent rust from the chain soiling the cover.

Late-mediaeval wooden cover, 14th century [UBL: Ms 66].

Front cover of half-binding [Ms 66].



Inside front cover with endpaper peeled back [Ms 66].



Inside back cover with a hole for the chain fastening at the top, leather on the cover peeled back to the left of it, and further down the visible bands [Ms 66].



Embossing as evidence

The Leipzig manuscript Ms 306 contains the Commentary on Job by Pope Gregory I, a fundamental work in medieval monasteries. Ms 306 was written in the early thirteenth century, probably in the then newly founded Altzella Abbey, a Cistercian monastery in Saxony, since the codex contains an inscription of ownership confirming its possession by the monastery from around the same time. However, the present cover is more recent, having been fitted when the manuscript was rebound almost 300 years later. We know from the embossing on the leather cover that it was made in the late fifteenth or early sixteenth century in the abbey's own bookbindery. The same embossing can also be seen on the cover of a fifteenth-century paper manuscript written between 1415 and 1424 in Thuringia, probably in Erfurt. Although there's no inscription of ownerships in this manuscript, the embossing indicates that it must also have been in Altzella around 1500. The binding used thus tells us where a manuscript was kept and where it went.

Two manuscripts from Altzelle, c. 1500 [UBL: Ms 306, Ms 687].

Inscription of ownership from Altzella in Ms 306 [fols. 1v/2r].

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Embossing on the back cover of Ms 306.



[Ms 306].

Rear cover of Ms 687 with Altzella embossing.



Inexpensive and used – a book's everyday attire

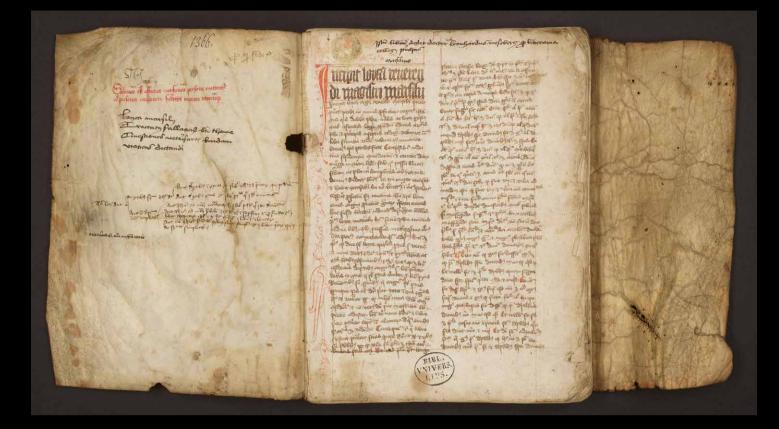
The first glance at the limp binding of this book already reveals a lot. The cover is made of wavy waste parchment, the spine is reinforced with strips of leather, and there's writing everywhere, inside and out. The comparatively cheap binding points to certain milieus in which such a manuscript must have been used, for instance in higher education. This is backed up by the fact that this volume contains texts on philosophy from the latter half of the fourteenth century; the University of Prague comes to mind. After the volume was taken to Leipzig in the fifteenth century, a local student listed the courses he'd attended right at the back. Nevertheless, a certain value was placed on the book's ornamentation: initials, rubrication, even a half-page illustration of the author adorn the texts of this utilitarian manuscript.

Philosophy sammelband with flexible binding, 14th century [UBL: Ms 1366].

Parchment cover and leather-reinforced spine of Ms 1366 with limp binding.



Front view of the open volume [Ms 1366].



Rear view of the open volume with a list of lectures attended on the left [Ms 1366].





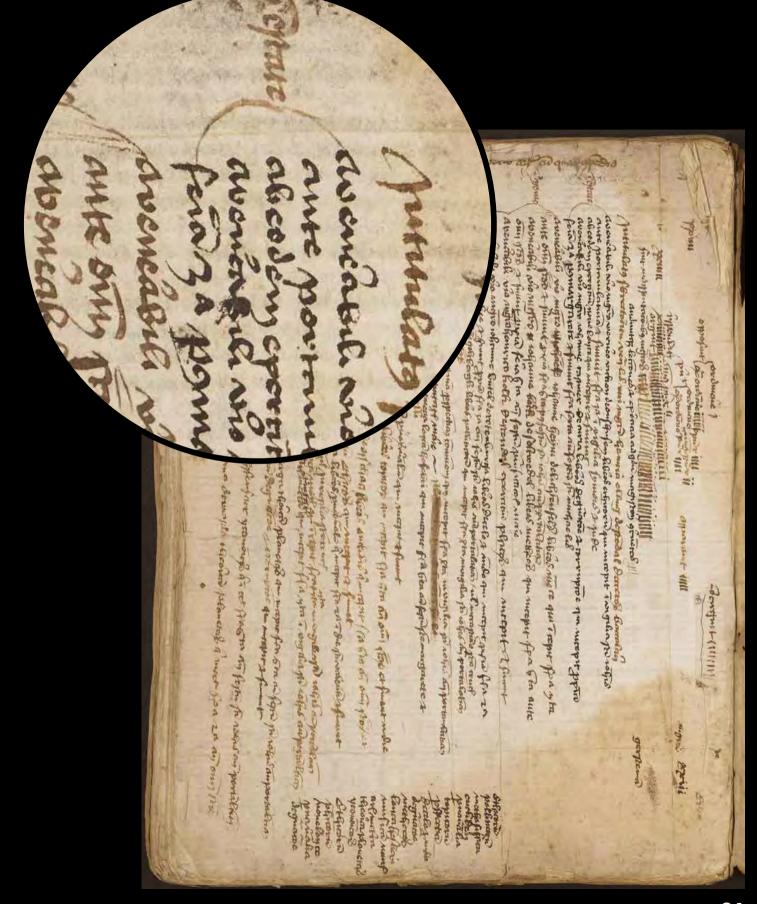


Illustration of the author, university scholar Marsilius of Inghen (d. 1396) [Ms 1366, fol. 53v].



OWNERS

Books are always owned by someone. Manuscripts were created for specific individuals, groups or institutions. Often, however, they changed hands over the centuries, and books belonged to various private or institutional collections. But a book normally outlives individuals, and monasteries don't last forever. Anyone owning a book usually left their mark on it in some way. Sometimes inscriptions of ownership and donation make it easier to track down previous owners. In other cases, it's the cover, the illumination or marginal notes that reveal a stage in the history of a book's ownership. Shelf marks and title plates record the collection to which a book once belonged and its position in the owner's system of knowledge.

Scars on the book block

Unusually, two title plates have been preserved here. On the one hand, there's a large paper title plate with an inscription in block capitals of the type affixed to all volumes in the original university collection during the tenure of Leipzig professor Caspar Borner, rector of the university in the mid-sixteenth century. On the other hand, remnants of an old title plate from the library of the Leipzig Dominicans, to which the codex originally belonged, are stuck to the upper margin on the left and right. The Dominican title plate was added to the volume in the fifteenth century, but was later covered up at the corners by new metal fittings at the time of the new library building around 1511. While most of the original plate was removed when the volume was acquired by Bibliotheca Paulina, the parts of the title plate concealed under the metal corners remained. The fact that they're visible again today is thanks to the librarian and Leipzig professor Joachim Feller, who had the fittings, bosses and chains removed from all the manuscripts in Leipzig University Library in the latter half of the seventeenth century.

Dual title plates [UBL: Ms 77].

Front cover with remnants of the Dominican title plate (top left and right) and large title label from Borner's era [Ms 77].



Reconstructing a book's biography

Several stages and locations can be identified in the long biography of this legal sammelband. The manuscript was produced in Italy in the early fourteenth century, as can be seen from the script and the illumination. However, by the fifteenth century it had already reached Germany, as revealed by an index added at the front. The fact that it was owned by Nikolaus Münzmeister from Dresden (later a physician in Freiberg) in the last third of the fifteenth century is indicated by two more additions: his coat of arms at the front and a note of sale at the back. Dr Münzmeister gifted the volume along with many of his other books to the Cistercian Altzella Abbey in the early sixteenth century. Although the abbey's usual inscription of donation is missing, the codex is listed in the Altzella library catalogue of 1514. In 1543, the manuscript was among the books from Altzella transferred to Leipzig University Library after the abbey had been dissolved.

Jurisprudence manuscript from Italy, 14th century [UBL: Ms 1075].

Double page 7v/8r with index and first page of text of the Italian fascicle [Ms 1075].



Coat of arms of Nikolaus Münzmeister [Ms 1075, fol. 1r].



Note of sale with Nikolaus Münzmeister mentioned by name on the rear endpaper [Ms 1075].

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All roads lead to Leipzig

This medical manuscript was also once owned by Nikolaus Münzmeister, although it reached him by a completely different route. The manuscript was written as early as 1169, as indicated by an unusual entry for the time on folio 94v, and probably in southern France, based on the parchment and illuminated initials. Although we don't know how the manuscript ended up in Germany, by the late fourteenth or early fifteenth century it was in Nienburg Abbey, a Benedictine monastery in the northern Saale valley. A subsequently erased inscription of ownership added by the abbey on the last page of the volume can be seen under ultraviolet light. Key parts of an older, similarly erased inscription of ownership on the first page, probably from the thirteenth century, are no longer decipherable, so it's unclear to whom it refers. The manuscript evidently remained in Nienburg until around 1500, because the deleted entry at the back was written over by a younger hand. However, there's no indication of how Münzmeister came to acquire the manuscript late in life. As early as 1506, he donated the volume to Altzella Abbey. The K on the upper margin of the first page is part of a very simple alphabetical ordering system for a small private book collection.

Medical manuscript from the south of France, 12th century [UBL: Ms 1131].

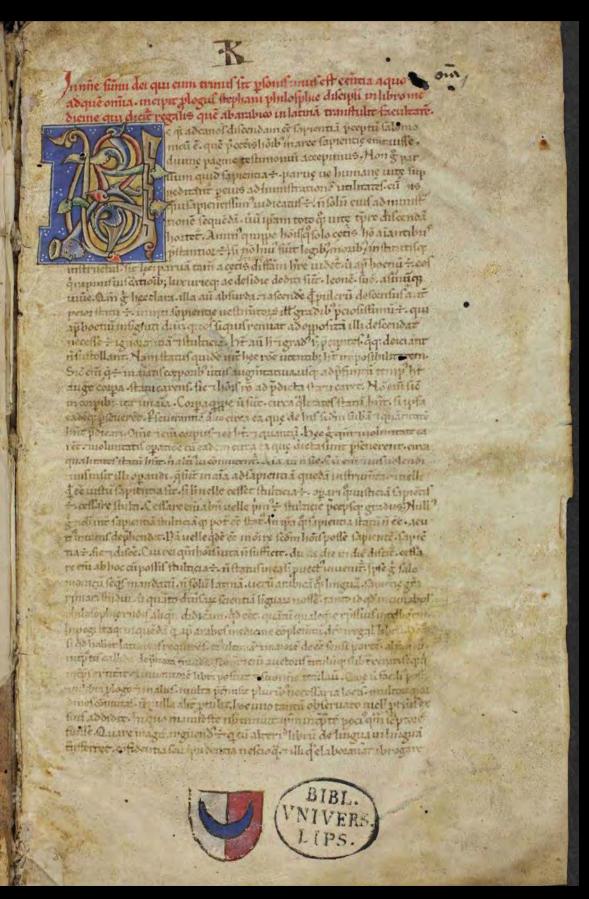
Double page 1v/2r with Altzella inscription of ownership dated 1506 mentioning that the volume had been received from Nikolaus Münzmeister [Ms 1131].

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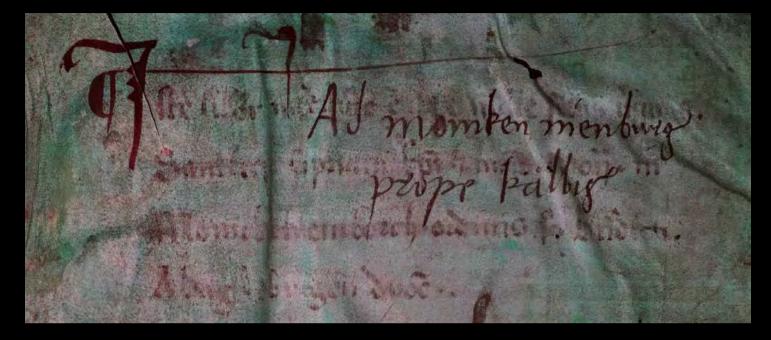
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First page of text with Münzmeister's coat of arms at the bottom and the shelf mark K in the top margin [Ms 1131, fol. 1r].



Nienburg Abbey's inscription of ownership seen under ultraviolet light [Ms 1131, fol. 162v].



Creating a library from books

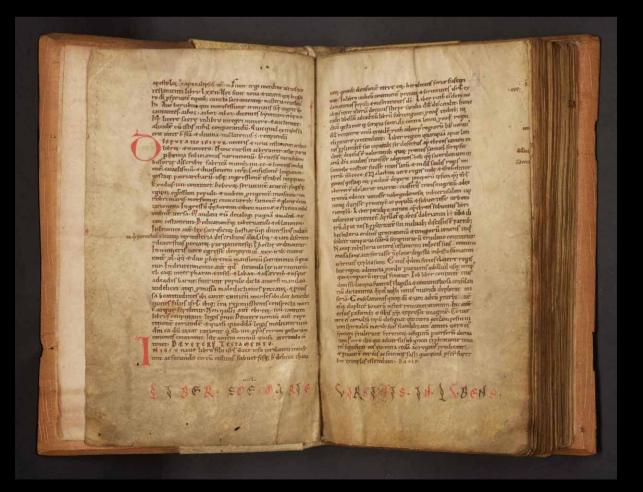
Andreas Rivinus (1601–1656, professor of poetry in Leipzig) had his books bound in the same way: with wooden covers, each half-covered with embossed light leather. This was a popular way for wealthy scholars to form a library out of the books they collected, books from very different sources being fitted with a common 'uniform'. However, the rebinding of these four medieval manuscripts for Rivinus makes it very difficult today to trace the path of the individual manuscripts before they were absorbed into the new book collection in the seventeenth century. Even so, an inscription of ownership of Leubus Abbey (a Cistercian monastery) has survived on some individual manuscripts. Rivinus also affixed uniform dedication plates inside all the volumes he bequeathed to Leipzig University Library (known at that time as Bibliotheca Paulina), documenting his generous donation for posterity.

Four volumes from a 17th-century private library [UBL: Ms 370, Ms 343, Ms 813, Ms 955].

Books owned by Rivinus with uniform binding [Ms 370, Ms 343, Ms 813, Ms 955].



Inscription of ownership of the Cistercian Leubus Abbey in Ms 343 [fols. 1v/2r].



Dedication by Rivinus in Ms 813 [fol. Ir].

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TRAVELLING BOOKS

Medieval manuscripts were often moved from one place to another, sometimes over great distances, as a result of being bought and sold, exchanged, or taken with their owners on their travels. In the event of substantial transactions, book blocks were sometimes detached from their cover and later rebound, a process which now and then involved the addition of other writings to form a new sammelband. Original temporary covers used as protection still bear witness to the method of transportation as well as locations where the manuscripts were exposed to water and fire, wind and weather. On their travels, the materials which books consisted of became a back door for nature.

Journey's end

Starting in the late seventeenth century, old manuscripts were collected for the newly established council library in Leipzig. Probably shortly after 1730, several manuscripts were rebound there with no regard for their provenance. Parchment folios from a distinguishedlooking liturgical manuscript from the early sixteenth century were used for the new covers. The previous covers were probably unsightly or flawed, which is why these precious manuscripts were given a more fitting exterior at the end of their journey. Despite their uniform appearance, their subject matter is very different. On opening the volumes, a German-language epic manuscript from the thirteenth or fourteenth century appears alongside a Latin history of Troy from 1461 and a Greek anthology of music theory from the mid-sixteenth century.

Three manuscripts in different languages and from different centuries [UBL: Rep. I 68b, Rep. II 66, Rep. II 127 (on loan from Leipzig Municipal Library)]. Three volumes with printer's waste taken from the same manuscript [Rep. I 68b, Rep. II 66, Rep. II 127].



Opening text in Rep. I 68b, Rep. II 66 and Rep. II 127 [Rep. I 68b, fol. 2r, Rep. II 66, fol. 1r, Rep. II 127, fol. 1r].



Causing mould, banishing mould

Considerable rot damage and traces of mould are visible on this paper manuscript, which was written in Italy around 1440–60. The damage probably occurred when the manuscript was taken over the Alps to Germany. At that time, books were transported in barrels and not infrequently packed very tightly, as freight prices were calculated per barrel. Any water penetrating the barrel created ideal conditions for mould to infest the cargo. Because this volume was precious to its owner, Freiberg physician Nikolaus Münzmeister, he repaired the rotten parts with large pieces of German-made paper and added the missing text.

Medical manuscript from Italy, 15th century [UBL: Ms 1206].

Mould stain in Ms 1206 [fol. 13v].

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Page with a large section repaired and writing replaced near the bottom [Ms 1206, fol. 4r].

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Don't judge a book by its cover

The board binding used here looks extremely plain and flimsy, the layers of parchment hanging almost loose. In addition, the parchment is very wavy, indicating severe exposure to moisture. This manuscript shares the fate of a large number of volumes from Paderborn Cathedral School, whose library was looted during the Thirty Years War (1618–48). Most of the captured codices were cut up and prepared for the antiquarian market. The council library in Leipzig acquired many of these outwardly nondescript volumes at the end of the seventeenth century. The simple appearance of this manuscript belies the fact that it contains an Augustine manuscript dating back to the second quarter of the ninth century. In fact, it's one of the oldest items in Leipzig Municipal Library's collection of manuscripts, which is now preserved by Leipzig University Library.

17th-century cardboard binding for a 9th-century text [UBL: Rep. II 43 (on loan from Leipzig Municipal Library)].

Very wavy parchment at the beginning of the text [Rep. II 43, fol. 1r].

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Manuscripts with 17th-century board binding owned by Leipzig Municipal Library.



Nearly destroyed by fire

The journey taken by this manuscript began around 1300 in the Upper Rhine valley with a copy of Willehalm by Wolfram von Eschenbach, which now forms the second part of this volume. In the second quarter of the fourteenth century, it was augmented by Willehalm's backstory as written by Ulrich von dem Türlin, actually an abridged version specially produced for this purpose (known as Leipziger Arabel). By this time, judging by the use of dialect in Arabel, the manuscript had already travelled further east into the Lake Constance region. All trace of the codex is lost for the next 350 years or so, until its appearance in the early eighteenth century in the library of Zacharias Konrad von Uffenbach (1683–1734), a book-lover, patrician and councillor from Frankfurt. Various notes in Uffenbach's handwriting can be seen on the margins. In 1731, it was part of a group of manuscripts sold by Uffenbach to the town council in Leipzig, where it was rebound. At some point, however, the volume must have suffered fire damage, for the upper edge of the book block has a wide hollow with fire-stained edges. The charred parts were carefully cut out by the Leipzig bookbinder, destroying part of Uffenbach's notes. At what point between Frankfurt and the Leipzig bookbinder the manuscript had its brush with fire is unknown.

Two courtly verse novels in a 13th/14th-century manuscript [UBL: Rep. II 127 (on loan from Leipzig Municipal Library)].

Transition from Leipziger Arabel to Willehalm [Rep. II 127, fols. 20v/21r].

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Long journey to Leipzig

This manuscript was produced in 1483, probably at St Mary's Dominican Convent in Upper Medlingen, which was located north of the Danube near Dillingen in Swabia. Folio 2r bears a contemporary inscription of ownership by the Medlingen nuns. The volume contains the Book of Offices by Johannes Meier, a standard text setting out the rules the Dominican nuns were expected to abide by. The convent offices dealt with include the sextoness, who is depicted in an initial with liturgical items and books in the sacristy, and the librarian, presented at her writing or reading desk surrounded by books, showing us where and how books were kept in convents and monasteries. However, the manuscript didn't remain in Medlingen for long. After the dissolution of the convent in 1555 following the Peace of Augsburg, the nuns fled to the nearby city of Augsburg, taking the manuscript with them to St Catherine's Dominican Convent. When this convent was also dissolved in 1802, the book probably came onto the antiquarian book market. In 1831, it was acquired by a member of the Bose family in Leipzig, who also added an inscription of ownership (folio 1r). It was later presented by the Bose family to Leipzig University Library. Like stamps in a passport, the inscriptions of ownership record the manuscript's whereabouts and changes of ownership over the years.

Manuscript from a convent in the south of Germany, 15th century [UBL: Ms 1548].

Inscription of ownership of the Dominican convent in Medlingen [Ms 1548, fol. 2r].

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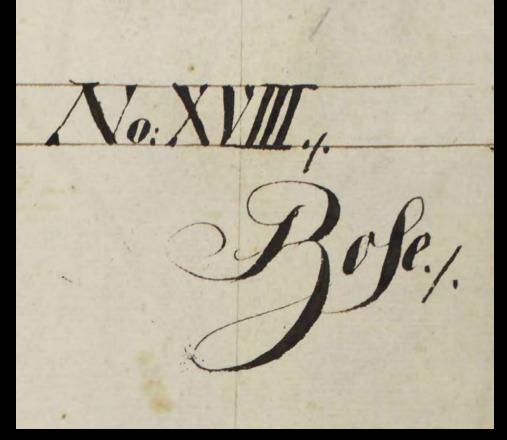
Initial showing the sextoness [Ms 1548, fol. 34v].



Initial showing the librarian [Ms 1548, fol. 89r].



Bose's inscription of ownership [Ms 1548, fol. 1r].



USERS

Historical manuscripts were not studied in climate-controlled reading rooms as they are today. Monks took literature into their cells, or read a book which had been chained to a lectern in a chilly library. A scholar might have drunk a glass of wine while reading in a heated parlour. A book may have been used in academic teaching, consulted as a medical manual in a practical setting, or kissed by a priest at mass. The way in which a book is read and used alters it as a natural habitat. Can traces in the book tell us stories about this? No one comes closer to a book than humans – with the exception of microbes.

Gifted, used, bequeathed

This volume was clearly once owned by Caspar Borner, a professor from Leipzig, as a string of entries in his handwriting confirm. He was given the book, as revealed by a note written by him on the front cover: "Ex Reineciana bibliotheca mihi donatum 1521" ("Presented to me from Reineck's library in 1521"). Borner made great use of his gift and worked his way through the collection of treatises dealing mainly with geometry and astronomy, inserting titles at the start of each text and compiling an index at the back – a keen reader's ultimate addition. Traces of use have been preserved at Leipzig University Library since the mid-sixteenth century, when Borner's private collection was donated to the library he founded and supported.

Sammelband covering aspects of astronomy, geometry and music theory, 15th century [UBL: Ms 1469].

Note by Borner on the front endpaper stating that the volume had been received as a gift [Ms 1469].

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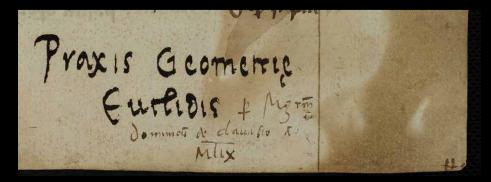
Treatise on altimetry [Ms 1469, fols. 135v/136r].

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Index in Borner's handwriting [Ms 1469, fol. 375v].

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Titles added by Borner of individual sections [Ms 1469, fol. 69r].



The book as a close companion

Several examples of this collection of Germanlanguage model sermons known to scholars as *Leipziger Predigten* ('Leipzig Sermons') have survived. They're named after this specimen, a copy from the first half of the fourteenth century. It bears numerous signs of use, implying its everyday function: the parchment is heavily worn in many places, has stains, and wool and straw remnants have accumulated in the fold area. Had a cleric perhaps read it on the straw sack in his cell? And does the large yellowishbrown oil or grease stain bear witness to a lamp being knocked over while reading in the evening or early morning? The close relationship between book and human is omnipresent.

Collection of model sermons in German, 14th century [UBL: Ms 760].

Stain on fol. 8v [Ms 760].

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Stains on the edge of a folio [Ms 760, fol. 170v].



Straw residue in the shoulder area [Ms 760, fols. 134v/135r].

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Oil stain [Ms 760, fols. 23v/24r].



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Writing on and in books

This manuscript containing numerous legal texts in German and Latin consists of various individual parts. It once belonged to Johannes Weisse (d. 1486), a professor at Leipzig University and a manic collector of texts. Weisse kept his books lying on his shelves, as was customary at the time, and wrote details on the edge of what each one contained – although such copious notes on the side of books were unusual. Weisse's surviving volumes have a uniform appearance and testify to a scholar who added substantial annotations to his manuscripts, including tables of contents and a tangle of entries written with distinctive dark brown ink and also lots of crimson. Weisse evidently didn't mind that this impaired the manuscripts' aesthetics. In Ms 951, for example, he interspersed text written beautifully by a professional scribe with his substantial notes, and also added a table of contents on the left.

Jurisprudence sammelband, 15th century [UBL: Ms 951].

Contents written on the top edges of volumes owned by Johannes Weisse [Ms 951, Ms 1348, Ms 1377, Ms 1400, Ms 1445].

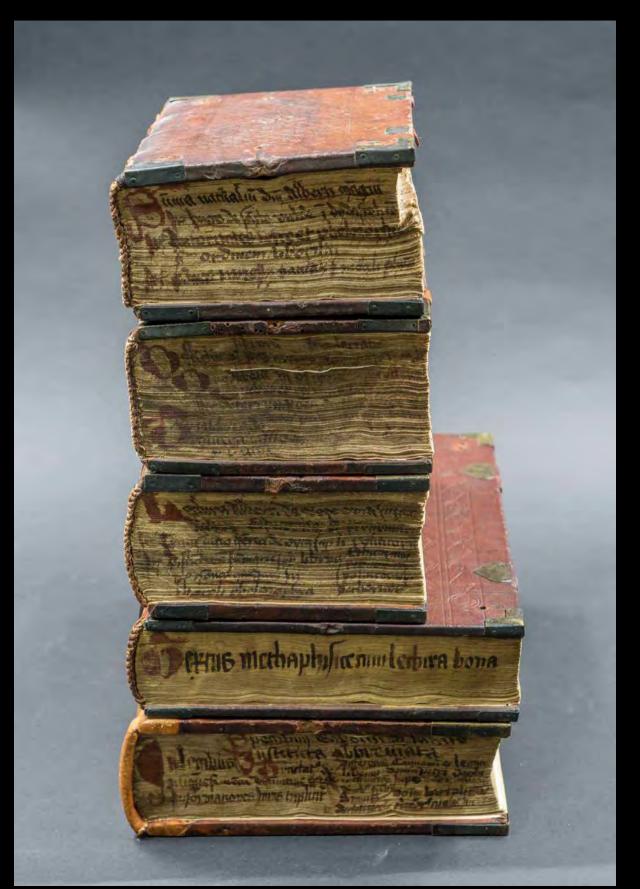


Table of contents handwritten by Weisse [Ms 951, fol. 1r].

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Double page with an outline of the text on the left, additions to the text on the right, and rubrication all handwritten by Weisse [Ms 951, fols. 61v/62r].

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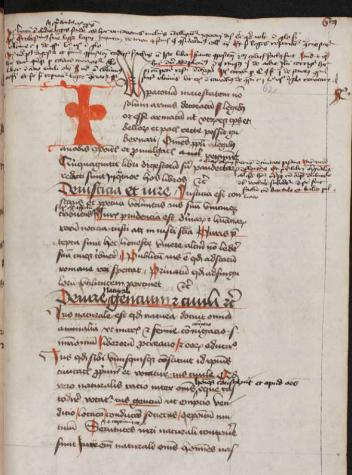
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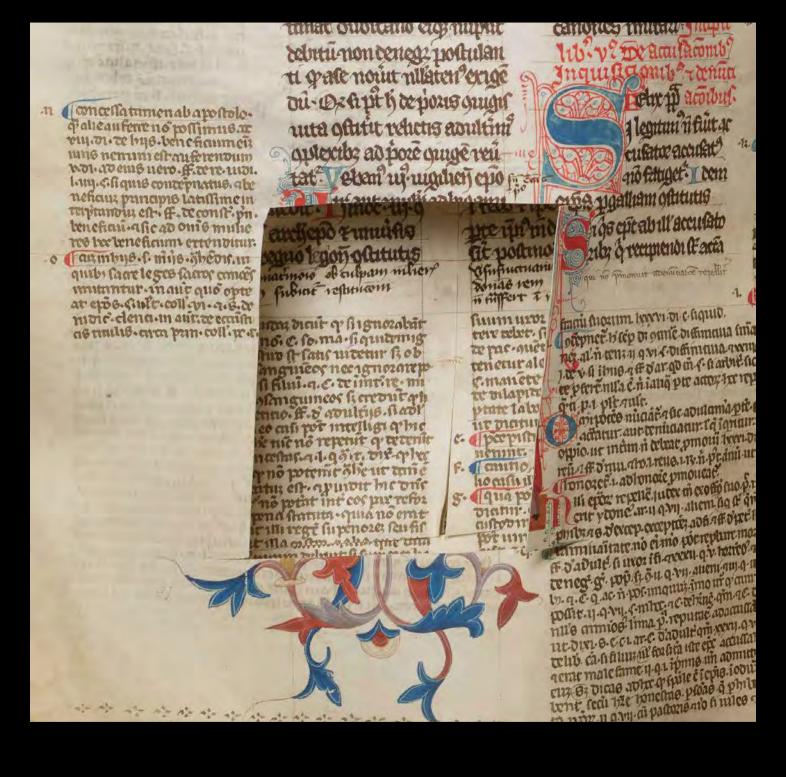
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The invasive user

Three manuscripts showing drastic signs of use are examples of parts of manuscripts being removed or added. In Ms 1075, illuminated initials have been cut out. This is something which is frequently encountered because later on illuminations were unscrupulously removed from books (and indeed still are) and sold separately on the antiquarian market. By contrast, Ms 1150 provides an example of how the aesthetics and content of manuscripts were sometimes updated, in this case by pasting a new historiated initial over an existing one as well as by cutting out and replacing pieces of parchment on folio margins to make space for new annotations. Finally, in Ms 852 (one of many examples), Wilhelm Bruno Lindner (d. 1876), a Leipzig professor of theology who was also a bibliomaniac and book thief, removed illuminated pages and tried to cover his tracks by replacing them with poor copies. They are now shown side by side in this volume.

Three manuscripts dating from the 13th to 15th centuries [UBL: Ms 1075, Ms 1150, Ms 852].

Initial cut out of Ms 1075 [fol. 278v].



Initial in Ms 1150 modernized by pasting a new one on top of it [fol. 1r].

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Pieces of parchment added for new marginal notes in Ms 1150 [fols. 47v/48r].

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Original (left) and Lindner's copy (right) of an illustration from Ms 852 [fols. 2r, 3r].



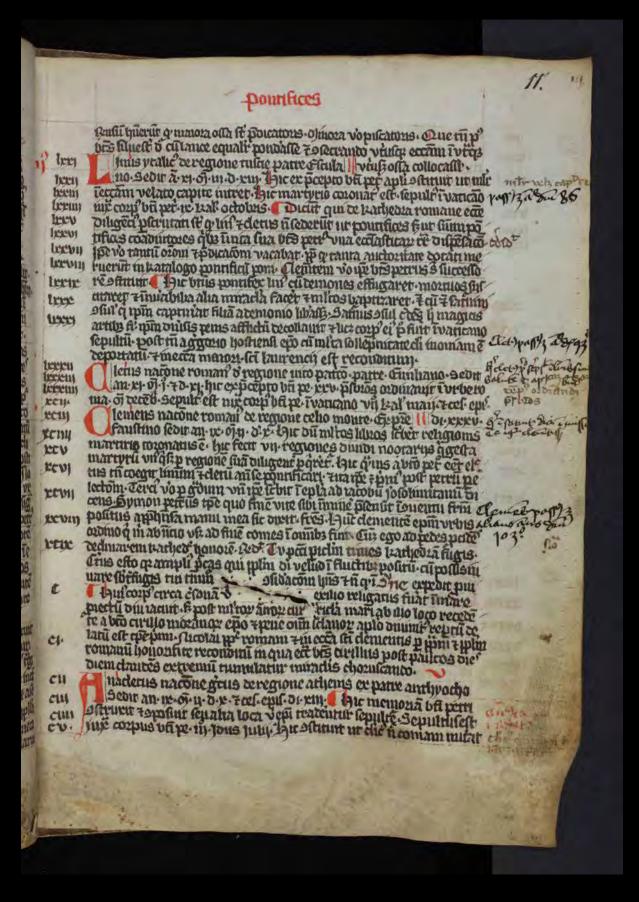
Has a book actually been read?

One question that's usually hard to answer is whether a book has been read, and if so, how often and by whom. After all, owning a book can also meaning leaving it untouched on the shelf for years. Soiling, especially on the corners and edges of a page, provides some indication of how often users have touched it, while notes in the margins attest to the way readers studied the text. Regarding this volume, we know from the coat of arms (fol. 1r) that it was owned by Nikolaus Münzmeister in the late fifteenth century, and there's also a typical inscription of ownership from Altzella Abbey spread over two pages (1v-2r) from the early sixteenth century. Moreover, there are numerous marginal notes written in a variety of hands from the fourteenth and fifteenth centuries. With this volume having been kept in Leipzig University Library since the 1540s, researchers' interest has at least been documented for the twentieth and twenty-first centuries, for since 1898, the use of manuscripts at the library has been recorded by slips of paper pasted into the book as shown here. Between 1905 and 2010, six readers signed their names.

German edition of *Chronicon pontificum et imperatorum* ('Chronicle of the Popes and Emperors'), Germany, 14th century [UBL: Ms 1313]. Nikolaus Münzmeister's coat of arms in Ms 1313 [fol. 1r].



Substantial annotations by readers in Ms 1313 [fol. 111].



Modern usage slip issued by Leipzig University Library from Ms 1313.

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MICROBIAL LIFE IN BOOKS

Cecilia G. Flocco, Jörg Overmann Manuscripts are an essential part of human cultural history and can be traced back as long as 5,000 years ago as papyrus scrolls. From the late antique period (from the fifth century onwards, to be exact) the form of the codex prevailed – a collection of manuscripts on parchment (or more rarely papyrus) stitched together between covers. In contrast, bacteria are thought to have existed on our planet for 3.5 billion years and colonized virtually all its habitats, including human dwellings and the air one breathes. Book-reading humans are actually a typical habitat for microorganisms, and one which has been colonized particularly densely. In fact, humans have significantly more microbial cells (collectively called microbiomes) than their own body cells. Therefore, it's almost inevitable for microorganisms to enter books, too, in various ways.

Nevertheless, only in the recent past have bacteria and many fungi been discovered in books. Although some microorganisms, for example certain fungi, can be seen with the naked eye as accumulations of cells (for instance mould stains or fruiting bodies of mushrooms), bacteria are usually invisible to the naked eye. It was only in 1675 that Antoni van Leeuwenhoek in Delft, having developed his own microscope, was able to obtain the first evidence of the existence of bacteria in water samples, human saliva and dental plaque. In his doctoral thesis written in 1818, Christian Gottfried Ehrenberg became the first to describe two paper-colonizing species of fungi (today known as Chaetomium chartrarum and Stilbospora chartrarum). After Louis Pasteur began developing germ theory in 1870, according to which diseases are caused by microorganisms and spread through interpersonal contact as well as contaminated food or water, and Robert Koch proved the existence of the first bacterial pathogen (the bacterium Bacillus anthracis, which causes anthrax) in 1877,

microbes were predominantly perceived as dangerous life forms. Only in the last three decades have microorganisms – especially bacteria – come to be regarded as being far more important for ecosystem functions, food and biotechnological products that are essential if mankind is to survive. These findings also raise new questions about microbial life in cultural assets like books. What types of microorganisms do occur in manuscripts? Where do they come from? How do the material properties of books, the conditions under which they're stored, their users and predominant mode of use determine their microbial colonization? Could these microorganisms provide new information about books – and perhaps even about important historical events?

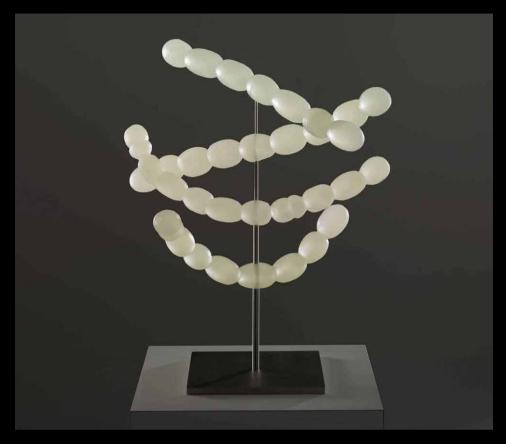
THE DIVERSITY OF MICROORGANISMS

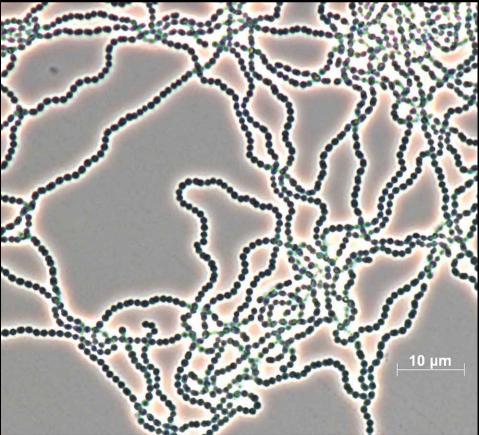
Over the course of their long evolution, microorganisms have developed enormous metabolic and biochemical diversity, far greater than that of plants and especially animals. Some bacteria can break down plastics and solvent residues, dissolve toxic heavy metal salts, and live in poisonous volcanic gases, on salt crystals in extraction ponds, at temperatures higher than 100°C or as cold as –18°C, at pH values of 0 (comparable to battery acid), and down to a depth of 2,000 metres in the Earth's crust.

Examining microorganisms under a microscope reveals often unexpected morphological versatility and a fascinating alien world. We can also study how such extremely tiny organisms are adapted to the conditions of their respective habitat.

A representative of the human skin microbiome

Streptococcus is a genus of spherical bacteria that grow in pairs and cell chains. It's part of the human salivary, skin and intestinal microbiome, and includes many non-pathogenic (commensal) species, some of which are used to make fermented dairy products. In addition, the genus also contains pathogenic representatives that cause lung, eye and skin infections. When examining the history of written documents, Streptococcus species can provide clues to a person's interaction with a book or manuscript, including traces left by the hands of readers, caused by sneezing onto a book's pages, or transmitted by a priest kissing sacred passages during devotions. A pure culture of *Streptococcus* – as a model and seen through a microscope [photos: DSMZ and I. Schroeder (DSMZ)].



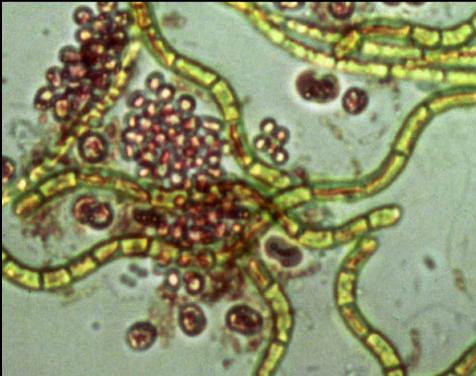


Photosynthetic inhabitants of oxygen-free water

In the case of bacteria of the genus Chloronema, adaptations to a completely different – and very specific – ecological niche are clearly depicted when observing their cellular characteristics. These bacteria occur in lakes and form cell chains up to a quarter of a millimetre in length. The cell filaments are mobile and contain photosynthetic pigments (bacteriochlorophylls) in small organelles (chlorosomes), which lie inside and against the cell envelope and give each cell its yellowish green hue. With the help of these photosynthetic pigments, Chloronema can use underwater light for growth. At the centre of each cell, there's also a collection of gas-filled vesicles. Appearing as continuous, elongated, pink-coloured structures when viewed under an optical microscope, they enable the cells to position themselves precisely in the required light conditions in the water column. The microbial model presented here combines the knowledge about the bacterium gained by using a wide variety of biochemical methods and scanning electron microscope techniques to reveal its main properties.

Images of a water sample with green cell filaments of *Chloronema* accompanied by groups of spherical purple sulphur bacteria from Mittlerer Buchensee, a lake near Constance – as a model and seen through a microscope [photos: DSMZ, J. Overmann].





Bacteria living off other bacteria

Myxobacteria are widespread soil microorganisms characterized by their ability to dissolve other, mainly wood-degrading bacteria and utilize them as food. Certain species can even break down cellulose, which is why myxobacteria are also found in the dung of herbivorous animals and on rotting wood. Many representatives of this bacterial group are valuable to humans because they have extraordinary biosynthetic abilities, like forming bioactive substances such as antibiotics and cytostatics. The social interaction of myxobacteria is also fascinating as they communicate via intercellular signals, move as a swarm towards prey bacteria or yeast fungi, and then work together to dissolve them into food. Whenever nutrient deficiency occurs, the cells migrate towards each other, form fruiting bodies in various colours and shapes, and then produce myxospores in those fruiting bodies, enabling myxobacteria to spread further in order to survive. Although paper as well as other paper-colonizing bacteria can create a possible habitat for myxobacteria, they haven't yet been found in books explored in this research project.

Fruiting body of *Chondromyces crocatus* – as a model and seen through a microscope [photos: DSMZ and H. Reichenbach (DSMZ)].

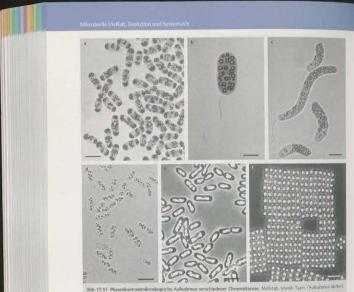




Reclassifying bacterial diversity

Unlike most multicellular plants and animals, microorganisms can't be identified and systematically classified solely on the basis of their morphological characteristics. In particular, many bacterial species have the same cell shape and are thus indistinguishable in this respect. Therefore, bacteria used to be characterized and distinguished based on their enormous metabolic diversity. However, over the past three decades, scientists have realized that bacteria and fungi can only be reliably classified by determining and comparing gene sequences. Mainly genes that code for nucleic acid molecules that are part of ribosomes are used for this purpose. Ribosomes are subcellular particles that are abundant in the cells of all living organisms and constitute the machinery for the formation of proteins. Because of this vital function, nucleic acid sequences in ribosomes only change slowly in the course of evolution due to mutations, making them ideal for classifying and identifying microorganisms.

German edition of Georg Fuchs's Allgemeine Mikrobiologie ("General Microbiology"), 10th edition, Stuttgart: Thieme 2017 [photo: private collection, copyright Georg Thieme Verlag KG].



Pfensig) - Alxbiomotium warmingel mit: Ablugenung von Schwelefgranulu an den Zellpolen. 5: Okonotiern einni. C. Thiosphillion giversie. 4: Albekonsettom veroram: 6: Thiodeghen zwars. 1: Thiospedia roses (Dunkelfeldaufnahme): Zentrale Uchtbecchende Zellbeeiche in e und f enthalten Garvesilet. 1: Thiospedia roses (Dunkelfeldaufnahme): Zentrale Uchtbecchende Zellbeeiche in e und f enthalten Garvesilet.

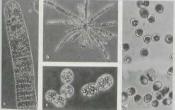
dans kann den pH-Wert bis auf einen Wert von 1,0 ver-ringern. A. Jerrooxidans oxidiert Fe(II) bei ebenfalls nied-rigen pH-Werten (* Abb. 12.15).

rigen pH-Werten (* Abb. 12.15). Die neutrophilen schwelloxidierenden Gammapro-trobacterä finden sich dagegen in die Ordnung Thiotri-chale. Sie wichtigsten Gatungen sind hier Beggidton (* Abb. 1732a. Abb. 334, Pits 12.1, Pits 124, Pits 18.11), Thioptoca (Plus 12.4, Pits 18.11), Thiothrix (* Abb. 1732b) und Actromatium (* Abb. 1732c). Es handelt sich hier um typische Gradientenorganismen, die

sich präzise in der Überlappungszone zwischen D, häh-sen und sallfdischen Schichten ansieden und daru sper-fische Anpassungsmechanismen wie gleitende Boer-eung, Chemotasis, sowie Spechen an Eistrumendunt-ren (Schwefelgranula) oder -akzeptoren (große Vazie-mit hohen Nitzkonzenztrationen), entwischet Inden. In-meisten dieser Bakretien sind schlecht oder bähr gu-nicht kultiverbar und daher nur nazureichend zuson-misch charakterisiert. Ebernfalls zu den Communacehologien obligen abl.

misch charakterisiert. Ebenfalls zu den Gammaproteobacteria gehören obli-gat symbiontische sulfidoxidierende Bakterien, die sch

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Hiomaryonita wanibien-	rlesiger Kokkus, bis 750 µm	-	7
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Ritle, Mollusca	Endosymbionten, Kiemengewebe	- 07	14



n über 100 Arten von marinen Wirbellosen finden. Ein 1995ches Beispiet sind die Endosymbionten des Riesen-föremwurns Riftia pachyptila (+ Abb. 12,14).

Methylococcales

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Standard von Cysten als Dauerformen. Essistiche Vertreter Inden sich in den Gattungen Methylobacter. Methylococcus und Methylomicrobium. Urauftris polyspora ist ein bereits 1870 beschriebenes. Magns Bakterium, dessen bis zu 5 µm breite Zellen in bis zu 10 mm langen organischen Scheiden stecken. Oft sind

die Scheiden an Oberflächen angehefter und mit Eisen-und/oder Manganoxiden hew. -hydroxiden inkrustiert. Diese Art kommt in nährstoffarmen Süßwasser vor. Dazu-zähen typisierweis auch Trinkussergewinnungsaha-gen und Wasserleitungen, weshab das Bakterium auch als. Berunnenden "bereinhen wird. Kurzitich wurde nachgewiesen, dass es auch Methan osidieren kann.

Abb. 17.52 Farblose, schweitelwasserstof oxidierende Bakterien an Begiotos gionikur mit Schweitelein-schützisch, Helfeldaufnahme, 200fach, (Aufnahme K. Schmid) b. Rösette wor Thioffin, Phaseikontrasi-aufnahme. 200fach. (Aufnahme D. Clava)

Clical Clical Achoronatian coefficienti mit Euschild aus Calchamcarbonat und Schwefel 2006ach. (Aufrahme K. Schmielt)
 Thioxidum mit Schwefeleinschilssen 1000fach. (Aufrahme J. W. M. La Ni und H. Schuur)

Pseudomonadales

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Die Pseudomonadales sind vorwiegend stäbchenförmige, aerobe Bakterien mit Atmungsstoffwechsel. In dieser Ordnung finden sich wichtige Bodenbakterien, aber auch opportunistische Humanpathogene.

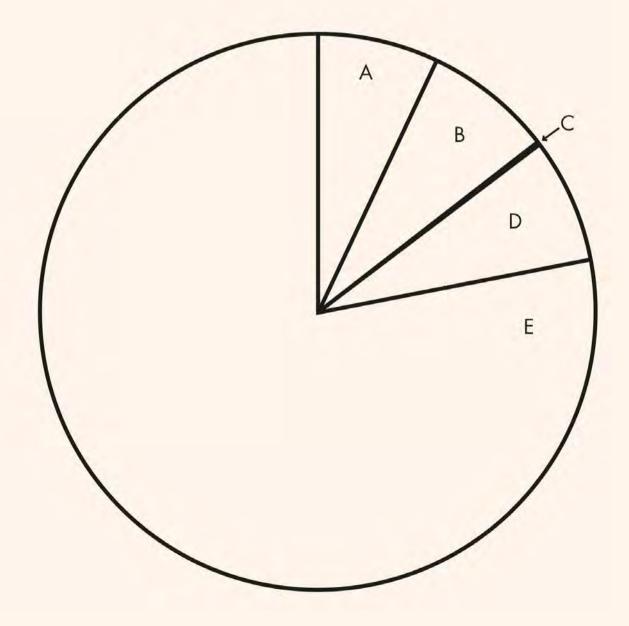
Pseudomonas: Die sehr artenreiche Gattung Pseudo-monas ist philnotypisch charakterisiert (und unterschei-der sich von Enterobacteriaceae) durch die polare Bege-Belung, das Fehlen von Gärungsstöffwerskel, Indol- und Acetoinbildung, das Auftreten des KDPG-Weg der Zucker-

A teaspoon of microbial diversity

Before the introduction of genetic approaches, for over a century the only way to identify microorganisms was the original method of isolating and characterizing pure cultures, which was established by Robert Koch in the nineteenth century. This entails isolating individual bacterial cells from their accompanying organisms in nutrient media in the laboratory and cultivating them. About 17,000 different bacterial species have been described in this way to date, a number which, given the known species diversity of animals and plants, seems surprisingly small. However, when gene sequences in natural soil or water samples were directly examined, scientists discovered a totally unexpected variety of unknown sequence types. For example, a teaspoon of soil can contain about 50,000 different species of bacteria. All in all, based on culture-independent molecular data, there are now estimated to exist 1.7 billion species of bacteria and 160 million species of fungi on Earth. The majority of this vast amount of information can't yet be read or even rudimentarily understood. It's particularly remarkable that, according to our current level of knowledge, only a tiny minority of 550 bacterial species and 320 fungal species are pathogens.

Are there any species of bacteria and fungi that are adapted to books as a habitat? How did these microorganisms become so? And how significant are they? Are they contaminants, in other words dangerous impurities caused by pathogens or pests – or something else?

A	Animals7,3%
В	Fungi
С	Plants0,02%
	Protists
Е	Bacteria



MICROORGANISMS AND BOOKS

Initially, from 1879 until after 1914, and partly even until 1940, virtually all microorganisms discovered in books in public libraries were almost exclusively deemed to be potential causes of dangerous infectious diseases such as tuberculosis, smallpox and scarlet fever – and even of cancer. Despite the lack of scientific evidence that books were sources of infection, they were nonetheless disinfected with toxic fumes (phenol or formaldehyde) or even burned. But mould is known to act as a pathogen, as a source of healthendangering mycotoxins, or as an allergen, and can even occur under certain circumstances in book archives. These days, bacteria and fungi are mainly perceived as detrimental because they affect paper and parchment in books – either aesthetically by discoloration, or structurally by breaking down both the pages and the binding agents in ink. To date, only 11 different genera of bacteria and just over 40 species of fungi have been identified on paper and parchment, and little is known about the overall microbial diversity in books. Since certain bacteria (e.g. Bacillus species) can remain viable for millennia by lying dormant, these bacterial species in books may even be able to provide information about past events.

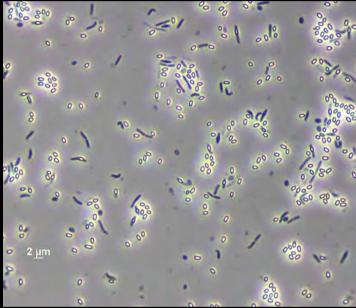
Microbial infestation of manuscripts

This photo of a *Bacillus* culture taken with a phase-contrast microscope clearly shows the formation of endospores as light-coloured, highly refractive inclusions in the dark grey vegetative mother cells. Following the death of the mother cell, these endospores can survive for thousands of years in a viable state. After being transferred to suitable growth conditions, the endospores become metabolically active, grow into vegetative cells, and multiply into macroscopically visible colonies.

View of a manuscript with fungal contamination [UBL: Ms 1395].



Two images of a *Bacillus* culture: endospores seen through the phase contrast microscope and colonies growing on an agar plate [C. Flocco (DSMZ)]





MICROORGANISMS IN BOOKS: AN ARCHIVE WITHIN AN ARCHIVE

The book manufacturing process and the properties of the materials involved create a very specific microbial habitat only colonizable by species adapted to it. For example, in order to make medieval parchment, hides from goats, sheep or calves underwent various forms of chemical treatment. They were placed into a lime bath to remove flesh rests, hair and fat, transforming the skin into a material that could be written on. Preservatives and binders such as salts and albumin as well as inks and pigments containing heavy metals also created a very specific physicochemical environment which is clearly extreme. Microorganisms in books must be adapted to these conditions such that they can either grow or at least survive in some other way. These microorganisms are sources of information in books which have barely been explored - so how can we tap them? And as well as telling us something about the physicochemical condition of a book, can they also provide information about the history of its storage and usage? To this end, late medieval manuscripts in Leipzig University Library were analysed with a combination of methods from microbiology, book biography, and the philosophy of science.

Largely undisturbed historical microbes

Leipzig University Library has one of the largest collections of medieval Western manuscripts in Germany. Seventy-five percent of them are still in their original binding, making them particularly suitable candidates for microbiological archaeology. Of particular interest are the late Roman manuscripts from the end of the twelfth and the early thirteenth centuries. After preliminary examinations, suitable specimens were jointly selected by library and life science researchers based on the manuscripts' specific history.

Scientifically analysed manuscripts [UBL: Ms 11, Ms 12].



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Apart from when it was catalogued by Rudolf Helssig in the 1920s, the two-volume Bible Ms 11 and Ms 12 has probably hardly been used since the latter half of the sixteenth century as it hasn't been digitized, restored, or requested by scholars. Accordingly, this manuscript makes an eminently suitable case study for the research of historical microbes. Thought to have been created in the Benedictine monastery in Pegau, it was written there around the period from 1310 to 1330. It features the typical archaic book ornamentation seen in many other Pegau manuscripts from this period with large palmettes running down the initials.

A doctor's handbook?

Manuscript Ms 1491 consists of five originally independent sections written between the mid-fourteenth century and the latter half of the fifteenth century containing astronomical, astrological and medical texts. Once again, clear differences exist in the format of the individual parts. It's also apparent that the volume has been well used. One striking element is a double folio of early paper (fols. 142/143), which was probably written in the middle of the fourteenth century and includes for instance a prescription against 'falling sickness' (epilepsy). Assuming the prescription was used by a doctor, it begs the question of whether special types of microbes can be found here.

Sammelband from the 14–15th centuries [UBL: Ms 1491].



A minimally invasive sampling method for manuscripts

In order to carry out appropriate microbiological and molecular biology analyses, a nondestructive, minimally invasive sampling method was developed that doesn't damage precious artefacts. Forensic swabs were used to aseptically sample both text passages which appeared not to have been frequently touched (as indicated by the lack of smearing) and areas near the edges of the parchment pages with clear signs of significant use. The microorganisms picked up by the swabs were placed on Petri dishes containing various agar-solidified culture media.

Dr Cecilia G. Flocco analysing a Bible in the laboratory [photo: DSMZ].

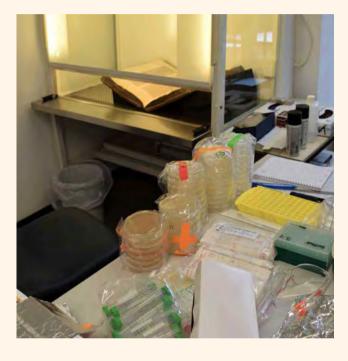


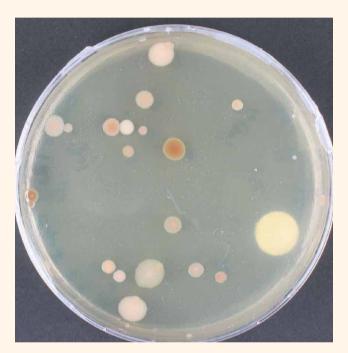
Steps in the experimental workflow

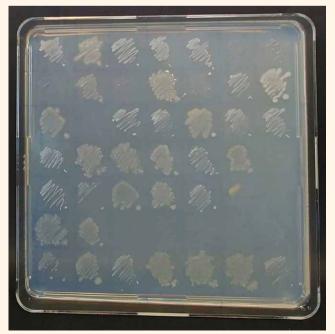
Since the genetic material of microorganisms in books contains a particularly large amount of information, it amounts to a potential archive that has barely been explored yet. Modern methods in molecular biology enable the genome sequences in sample material to be acquired directly and extremely rapidly. The downside is that there's nothing to which many of the genes found in these genomes can be compared, and so their function can't yet be interpreted. Therefore, in order to find out as much as possible about the metabolic properties of selected microorganisms in books, attempts are also being made - in parallel to the molecular approach - to isolate the main unknown species in the laboratory and characterize them more precisely. The bacterial colonies cultivated on agar plates were further cultivated so that they could be isolated, identified and archived. Bacterial cells from purified colonies were examined under a microscope, DNA from the colonies was extracted directly, and the 16S rRNA gene was amplified by polymerase chain reaction and sequenced using the Sanger method. The sequences were then compared to reference sequences in databases (SILVA, BLAST) and classified based on their sequence similarity. To visualize the relationship with bacteria which are already known, a phylogenetic tree was derived from the similarity values.

Stages in the evaluation of sampled manuscripts [photos: C. Flocco (DSMZ)].

- 1. Object selection and sampling strategy
- 2. Microbial Cultivation
- 3. Isolation and polyphasic identification
- 4. Bioresources preservation/archiving





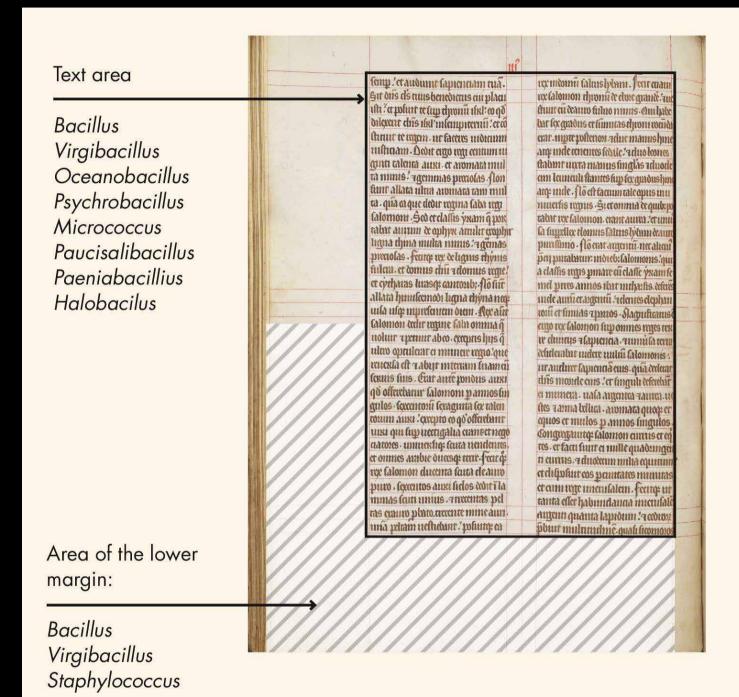




Microbial colonizers of books

Using non-invasive microbiological methods, numerous representatives of several bacterial species from the parchment manuscript Ms 12 were cultivated. They were found to include some unknown species. Above all, endosporeforming bacteria of the genus Bacillus and related genera were isolated. In addition, bacteria of the genus Staphylococcus, typical of the microbiome of human skin, were cultivated. Staphylococcus was already known to occur in books; in fact, it's one of the most widespread bacterial genera in medieval manuscripts. However, one new finding in these investigations was that whereas Staphylococcus was isolated from the frequently touched edges of pages, whereas Bacillus and similar bacteria were isolated prevailingly from the written part in the centre. The latter are related to bacterial species (the genera Bacillus, Virgibacillus, Oceanobacillus, Paenibacillus) previously found in saline soils and lakes, fermented foods, caves and monuments. This suggests that parchment manuscripts provide habitat conditions (for example high salinity or low water availability) similar to those bound to the environments from which such species were detected. Interestingly, no fungi were detected with the methods used.

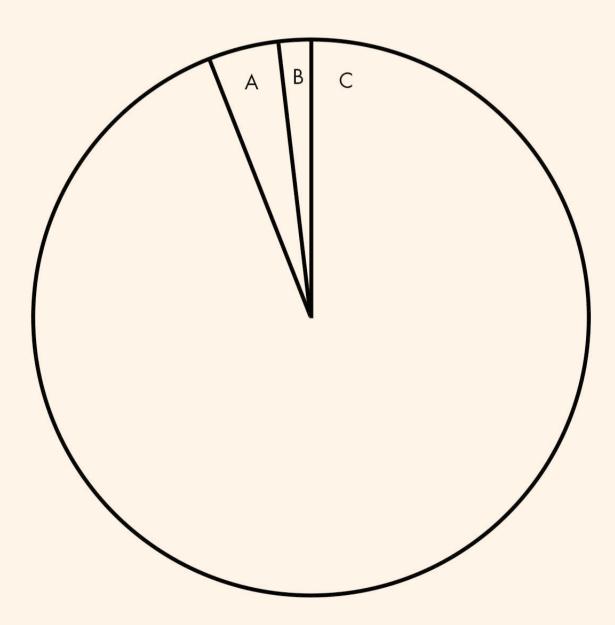
Depiction of the main microbial genera detected on the text and on the margins of the manuscript The microbial world of the manuscript [UBL: Ms 12].



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B Actinobacteria: Micrococcales (Dermacoccus, Kocuria, Micrococcus) 5% C Firmicutes: Bacillales (Bacillaceae, Paenibacillaceae,



Scanning electron micrograph of *Bacillus* sp. cells [photo: C. Flocco (DMSZ)/M. Rhode (HZI)] 3µm

Colonies of Staphylococcus sp. growing in agar [photo: C. Flocco (DSMZ)]



DSMZ – a living archive of microorganisms

The biochemical, physiological and ecological diversity of microbial life on Earth can only be revealed by comparing species found in books with the inventory of previously characterized species. Even though bacteria were initially archived in the nineteenth century on microscope slides for later comparison, morphological examinations can't distinguish bacteria from each other with sufficient accuracy. Moreover, the relevant properties of a microorganism can't be deduced from its distribution patterns alone, nor from its gene sequences - at least, not yet. Instead, the metabolic properties of unknown genes or the way in which they function have to be determined by means of tests with living cells. Accordingly, characterized microbial laboratory cultures (strains), each containing only genetically identical cells, are always needed in the form of physiologically active cultures for follow-up investigations. Since isolating exactly the same, genetically identical bacterium from the environment a second time is extremely unlikely, isolated bacterial cultures must be permanently preserved in a viable state for as long as possible. Microorganisms are therefore stored in a living archive.

Some 370,000 glass ampoules containing freeze-dried samples of individual bacterial strains are stored at the Leibniz Institute DSMZ German Collection of Microorganisms and Cell Cultures [photo: DSMZ].



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