Content

This document is meant to give a short overview of a discipline's characteristics, publication culture, and common practices. This is to help researchers review and asses the quality of work done of others outside their own field of research.

Astronomy

Astronomy includes not just observing the sky with (ground- or space-based) telescopes, but also physical interpretation and theoretical modelling, increasingly involving high-performance computing (HPC).

- In astronomy/astrophysics, research may be conducted within small groups of only a few individuals or in large consortia involving up to more than a thousand people, or anywhere in between. The larger consortia are typically centred around a particular observing facility.
- The overall research themes addressed by large consortia are often broad and may encompass multiple specific research topics carried out within smaller sub-units (Science Working Groups). This can still leave ample room for individual scientists to define their own unique projects.
- Research questions are mostly fundamental/curiosity driven, however the processing of large data sets, space technology, optics/detector development and signal processing have valorisation channels. Astronomy/astrophysics is very popular with the public and children, and thus social impact is often considered one of our other forms of valorisation.
- Exploitation of data archives plays an increasingly important role for many projects. Some facilities are entirely devoted to public surveys whose data can be freely accessed by the community, while others release their data after a proprietary period (typically 6-12 months). It is common for observatories/facilities to have open calls (once or twice per year) for new observations where individual research groups/teams submit proposals that are judged and allocated via peer review. These facilities are often oversubscribed by factors of a few to >10, and are thus highly competitive. It is also common for consortia that build instruments to be compensated in part through guaranteed time observations. Thus, to a great extent, data are a form of currency in our field.
- Time scales of research projects vary enormously. A relatively fast turn-around is possible in some cases (e.g. when based on public data, archival research), while somewhat longer for observational projects published at the end of a proprietary period, and can take several years or even decades for the largest and most complex projects (e.g. involving new facilities or new methods).
- Because astronomical facilities are expensive (millions to billions of €), many facilities are international thus our field really knows no borders.
- Time scales for building and operating large international facilities are often much longer (decades) than a grant cycle. Finding ways to ensure long-term stability to fund such projects over their lifetime is a major challenge for our field, particularly because funding agencies tend to distinguish between *building* infrastructure, covering the costs of *operations*, and enabling *science exploitation*.
- Most processes studied in modern astrophysics are highly complex and nonlinear, thus modelling increasingly relies on semi-analytical and numerical approaches. The increasing use of large-scale HPC facilities is a transition in our field, and brings us closer to efforts in, e.g., informatics, physics and theoretical molecular chemistry.
- Our field has many cross-disciplinary links: in addition to HPC and informatics, examples are common in physics and mathematics (e.g., on topics such as general relativity / black holes / gravitational waves and astroparticle physics via CAN, the *Committee for Astroparticle physics in the Netherlands*), as well as chemistry, biology, and earth sciences (e.g., planetary science, via programmes like the *Dutch Astrochemistry Network*, DAN, and the *Planetary and Exo-planetary programme*, PEPSCi).

Publication culture:

Most of our research is published in a relatively small number of equally high-quality journals: Astronomy & Astrophysics (A&A), the Astronomical Journal (AJ), The Astrophysical Journal (ApJ), the Monthly Notices of the Royal Astronomical Society (MNRAS), and their *Letter* variants (for relatively rapid publication of results with an expected high impact). Publication in A&A is free of charge for authors from sponsoring countries (including the

NL and many other European countries). Some researchers choose to submit expected high-impact results to Nature (or Nature Astronomy) or Science, but while a publication in Nature or Science may be considered high-impact, there are many high-impact results that are not published in these journals. For research areas on the interface with physics (astroparticle physics, cosmology, gravitational waves), the Physical Review Journals, the Journal of Cosmology and Astroparticle Physics (JCAP), and the Astroparticle Physics Journal are relevant. In addition, there are some smaller-scale journals that focus on specific research areas, such as Astronomy & Computing (for work with astronomy, computer science, and information technology aspects).

New results are usually published through peer-reviewed journal articles, not through conference contributions. An exception, to some extent, is astronomical instrumentation, where contributions to the SPIE (International Society for Optics and Photonics) conferences, which report on the state of affairs and the progress of instrumentation projects, can be important for acquiring / continuing project funding.

Besides journal papers, important output indicators include: invited talks and invited review articles or chapters (e.g. in books); software or databases that are made publicly available via e.g. Github (including supporting tutorials) and the Astrophysics Source Code Library (ASCL.net); and original or innovative public-outreach or citizen-science initiatives. Another form of (non-refereed) output are short messages for the rapid communication of results concerning events of a temporary nature (for example, a just-discovered supernova), called “transients”. An example is The Astronomer’s Telegram (ATel). These messages contribute to a rapid and coordinated response with other observational facilities (on Earth or in space) and may be listed on a researcher’s CV along with publications, as they signal discoveries.

Publication quantity varies by sub discipline. Observational papers on existing data can move fast, and more observationally oriented scientists in large teams may have 10s of papers per year (not all as first/lead author). Theoretical papers or papers involving the development of new analysis methods and/or codes can sometimes take years. Scientists focusing more on theoretical/computational projects, and/or working in smaller groups/collaborations, may have fewer publications per year.

The order of authors on a paper is often an indication of their contribution, with the first author(s) having done most of the work. For papers with long author lists, a first set of authors may be ordered by decreasing contribution, followed by an alphabetical list of co-authors who made relatively minor contributions. Work by a PhD student or postdoc will often have the supervisor listed as second author (or the first author after a list of PhDs/PDs in the group), who is then recognised as a leading author. In some subfields (for example astronomical instrumentation) the last author is the lead PI, who has taken leadership in supervision and/or financing throughout the project.

In recent years, large collaborations have become increasingly important, and articles with hundreds to thousands of authors are no longer unusual. Publications of such large collaborations often use a strictly alphabetical order of authors, which can make it difficult to distinguish an individual’s work. For those cases we often rely on indicators such as corresponding author or internal notes. Letters of recommendation that explain the contributions of individuals for a team can also be important.

Almost all papers are posted on the arXiv pre-print service after, and sometimes before, publication. The NASA Astrophysics Data System (ADS) is a very extensive bibliographic database that is indispensable for the astronomy community world-wide. Citation metrics will commonly be given based on ADS, rather than other services (such as Google Scholar) that may be less complete.

Chemistry

Background: the main purpose of this document is to assist reviewers and NWO panel members, who are not chemists themselves, to assess the quality of research proposals and CVs within chemistry. The document lists a number of characteristics of chemistry as a scientific discipline, including its publication culture.

In chemistry the properties, behaviour and transformation of matter are studied. The elements that make up matter are atoms, molecules and ions. Chemistry studies their composition, structure, properties, behaviour and the changes they undergo during a reaction with other substances. Also the nature of the chemical bonds within and between chemical compounds is addressed.

- Chemistry is also called the central science, because it forms the connection between physics and biology/life sciences. This also becomes evident in the various chemical sub-disciplines, which typically are classified by the type of molecules or materials that are synthesized and studied, such as carbon-based compounds (organic chemistry), compounds without carbon (inorganic chemistry), systems involving very large molecules or collections of molecules (polymer and supramolecular chemistry), the molecular basis of life (biochemistry), materials in the solid-state (materials or solid-state chemistry) or compounds that accelerate chemical reactions (catalysis). Due to its abundance of connections with other fields, many sub-disciplines also sit at the interface with other scientific specialties, most notably, physical chemistry, chemical biology, analytical chemistry, astrochemistry, electrochemistry, environmental chemistry, medicinal chemistry, colloid and interface science, food chemistry, chemical engineering, geochemistry and structural biology. In theoretical/computational chemistry a first principles approach is taken. Due to this wide variation in the discipline, there is also a broad diversity of working, publication, and recognition cultures.
- That chemistry is a central science also becomes apparent when the length scales at which chemistry operates are considered: from (sub)nanometer to meter, and from atoms or single molecules to industrial scale. The topics chemists work on vary from fundamental to highly applied. Chemistry is essential to achieve many of the sustainability goals, e.g., clean water, affordable clean energy, sustainable consumption and production patterns, good health and well-being, and industry, innovation and infrastructure.
- Chemical research requires research infrastructure and supporting personnel, which is dependent on the sub-discipline. Experimental chemists make use of laboratories, where compounds and samples are synthesized and/or prepared, and subsequently characterised. These labs need to fulfill certain safety requirements, e.g., when volatile solvents are used fume hoods are required, for biohazard samples laminar flow cabinets are used. Preparation/synthesis of compounds requires i) chemicals, varying from inexpensive solvents to very expensive specialty chemicals, ii) custom glassware and iii) consumables, that can only be used for a certain amount of time, like gloves, syringes and pipette tips. The characterisation of compounds requires technical instrumentation, which vary from simple and inexpensive to sophisticated and expensive. Many chemistry groups/departments have their own instrumentation, which requires maintenance to keep it working and up-to-date. Technicians are responsible for the group/departmental research infrastructure, both the labs and the instrumentation. In some cases, research technicians work on a dedicated project. For some research instrumentation such as electron microscopes, mass spectrometers and cleanroom facilities, operation by trained technicians is required and user-fees are often requested. Theoretical chemists often use department-owned Beowulf clusters, which are small parallel supercomputers. In addition, chemists make use of large-scale infrastructure like neutron and x-ray beamlines, and the national super computer, in which chemists have the proportionally largest share in allotted time. To obtain access to these facilities, researchers have to apply for time, and successful applications can be seen as a type of research funding. Also, large scale equipment on pilot scale is being used for scale-up development activities to simulate production scale.
- Many chemists are members of scientific societies, which award prizes that are regarded as being prestigious. The KNCV is the chemical professional organisation in the Netherlands. NextGenChem provides a platform to PIs in the first five years of their faculty position at a Dutch institution. The most important international scientific societies are the American Chemical Society (ACS), the Royal Society of Chemistry (RSC) and the Gesellschaft Deutscher Chemiker (GDCh).

- In terms of output, the most important items for academic chemistry are journal publications, invited talks and patents. The importance of contributions to a journal publication is reflected by author order in an 'inside to out' ranking where first and last authorships are the most important, next to the corresponding author, who commonly is the principal investigator. Shared first authorship and shared corresponding authorship are not uncommon. Both the ACS and RSC are also publishing companies, which are very important and highly regarded in the field. The key journals, also from other publishers (Elsevier, Wiley, CellPress, EMBO, Springer Nature and Science) vary widely by sub-discipline, and it is not uncommon to publish articles in interdisciplinary journals. Online publication of article preprints on websites (e.g. ChemRxiv) is growing, but is not common practice yet.
- Considering the breadth of the chemistry field and connected diversity of cultures, it is impossible to provide typical numbers for sizes of groups and collaborations, project time scales, number of co-authors per paper, and number of publications and citations per researcher. The quantities may vary considerably among sub-disciplines. It is also difficult to judge researcher independency based on these numbers only.

Computer Science

Background: The main purpose of this document is to assist reviewers who are involved in the appraisal of computer research proposals but are not computer scientists themselves. It might also be usable in other contexts. The document lists a number of characteristics of computer science (CS) as a scientific discipline, including its publication culture.

- The CS discipline is very broad. CS research can be fundamental in nature, as well as application-oriented. Within the CS discipline, a wide variety of sub-disciplines exist, many of which relate to other scientific disciplines, such as the life sciences, biology, mathematics, business administration, and the humanities. Research questions for computer scientists may arise from using CS in application domains, such as law or healthcare.
- CS is artifact-centric in the sense that much of its research is concerned with the design and evaluation of artifacts (algorithms/techniques/tools/methods/software/technology). The artifact is seen as of being of value in itself. The creation of an artifact demonstrates the feasibility of the underlying concepts and opens the way for practical application. This artifact-centricity of CS contrasts with disciplines where the development or testing of theory takes centre stage.
- Next to the purely theoretical CS research, many sub-disciplines within CS are practice-oriented. The uptake of CS artifacts in practice is seen as an important indicator for the impact that work has. Also, the study of how artifacts are used is an important aspect of CS research.
- Computer scientists publish much of their best work in the proceedings of scientific conferences. Acceptance rates for CS conferences can be very low, even lower than for some top CS journals. CS conferences are ranked, for example, by CORE Inc. and GII-GRIN-SCIE. Note that ISI's "Web of Science" is inadequate for most of CS, because it is mostly based on journal publications; Google Scholar and Semantic Scholar give a better overview of publications.
- It is an accepted practice that a paper that is presented at a CS conference is extended towards a submission for a scientific journal, in particular on the basis of an invitation for a special issue connected to the event in question. Extending one's work that is presented at a workshop or conference towards a journal article is not seen as an act of plagiarism.
- Computer scientists also often directly submit their work to a scientific journal, in particular when it is considered to be of archival value. Journal publications have a similar significance for quality evaluation as in many other disciplines.
- Since it is relevant for computer scientists to present their work at conferences, service as chairs or members of programme committees is held in high esteem. Such memberships reflect the recognition of computer scientists by their peers. Memberships of editorial boards are appraised similarly.
- There are different conventions for the listing of authors of CS papers. A common convention is to list as first author the person who is the most important contributor to the paper, as second author the person who is the second most important contributor, etc. A fully alphabetical ordering of authors is also an accepted practice. In either case, the last author can be but is not necessarily the group leader.

Earth and Environmental Sciences

Background: The goal of this document is to assist NWO panel members in assessing the quality of research proposals in the Earth and Environmental Sciences (EES). A key characteristic of research in EES is its extremely wide research spectrum.

The Earth Sciences cover a large range of independent scientific disciplines (e.g., Geology, Geography, Ocean & Atmosphere Sciences, and Hydrology). Each discipline can be subdivided into many subfields. This requires special attention for referee selection. While this is relatively easy for project proposals of which the scientific aims stay within a specific subfield, it is often problematic for those projects that involve research questions with cross-disciplinary aspects. For such projects much fewer international peers are available that are knowledgeable on all aspects of the proposed research. This may impact the evaluation of the proposed work, the workload, the scientific risks, and the value of preparatory work. International review is a necessity because of the limited national size of the field.

The Environmental Sciences include multi-, inter- and/or transdisciplinary fields to study the environment, including the causes and effects of environmental change, and the solutions to environmental problems. This implies integration of Life and Earth Sciences for studies on the environmental pressures, the state of the environment and the impacts of environmental change. To study drivers of, and solutions for environmental change, also social sciences need to be integrated. Environmental Sciences range from natural science-oriented studies to integrated, quantitative, and interdisciplinary system approaches. Research projects are practically all cross-disciplinary and hence the same problems are encountered as noted above for cross-disciplinary proposals in the Earth Sciences.

Depending on the subfield and topic the time it takes to produce publishable results for a PhD student can vary strongly. Some develop new technology in a lab or develop new numerical models, whereas others apply these tools. Consequently, the number of publishable papers comprising the final thesis cannot be a criterion for scientific quality. At the same time a PhD thesis without publication is more an exception than a rule.

In many sub-fields of Earth Sciences, fieldwork (on land, at sea) and/or experimental research in the laboratory or development of large computational codes can form a major component of a PhD project and can be very time-consuming. Fieldwork frequently requires teamwork and the resulting publications may involve large numbers of authors (~10-20 co-authors is not unusual). The same holds for multi-, inter-, and transdisciplinary studies in Environmental Sciences. There is a tendency for larger programmes in an international context running for 5-10 years' time. International collaboration is common practice.

The publication culture regarding the sequence of authors varies. One convention is to list as first author the person who is the most important contributor to the paper, often the PhD candidate or post-doc, as second author the person who is the second most important contributor, etc. Alternatively, the first and last author are the most important, with the last author being group leader and/or the second most important contributor. This implies that the group leader can be in any, or no, position on an authorship list. At postdoc or tenure track level, researchers are appreciated to publish independently from their PhD supervisors/head of the group. Recent journals in the field require an explicit author contribution statement.

Earth and Environmental scientists generally publish in peer-reviewed scientific journals. Subfields have their own high-level topical international journals. Publication is also sought in international fore-front journals that cover broad fields in Earth Sciences, or journals that publish from all scientific fields (e.g. Nature, Science, PNAS, Earth Future). Memberships of editorial boards of society journals are valued highly. For both Earth and Environmental Sciences, the range of journals is large, given the disciplinary spread of the researchers involved.

Life Sciences

Background: It is important to note that the life sciences discipline encompasses many large sub disciplines that conduct research differently. This makes it difficult, even for life scientists in neighbouring fields, to understand and value each other's work. Confidence in expert judgements is therefore essential.

In general, the Life Sciences discipline is an extremely diverse research field that shares interfaces with many other disciplines. Life Sciences investigate all forms of life at all levels (from molecules to ecosystems) which makes it a very diverse research field. Due to its high integrative level, there is much interaction with all science fields; interaction occurs between the life sciences and other natural science-areas (e.g. Chemistry, Computer Sciences, Earth Sciences, Physics), as well as medical and social science-areas. This interdisciplinarity is reflected in research areas (e.g. biochemistry, biophysics, biopharmaceutics, bioinformatics and neuropsychology), but also in interdisciplinary endeavours of cooperating researchers. Table 1 provides a demarcation of the Life Sciences discipline.

Life scientists mostly publish articles in peer-reviewed international journals. (This accounts for about 85% of output.) The largest non-article output shares are from PhD theses, conference abstracts, and editorials/letters. Conference proceedings and book chapters make a relatively small contribution, except in Bioinformatics where conference proceedings are very important (c.f. Computer Sciences).

Time scales of research differ, for instance, controlled research environments often lead to shorter time scales compared to uncontrolled environments. However, the time scale of lab work increases dramatically when e.g. new technologies/approaches are developed or research animals are involved.

Although generally the number of publication outputs is highest in the Life Sciences, for research conducted on a longer time-scale it is common to write fewer in number, but more in-depth or comprehensive publications that cover a broader research subject. The type of journal affects the potential impact of an article, since in the sub disciplines some specialised journals have stricter review policies and higher prestige (but you have to be a researcher in the field to know which ones). Similarly, publications in more generalist journals in the field of biology tend to have a high prestige as this indicates that results are of interest also outside the sub discipline and usually reach a wider audience. It is now more custom in some sub disciplines to publish articles on online preprint websites (e.g. bioRxiv) before they are peer-reviewed and published in peer-reviewed journals.

The order of the authors in articles is of importance: The first author is the main contributor/executor of the study, whereas the last author is mostly the second active contributor or in some sub disciplines (e.g. biomedicine, biochemistry, molecular and cellular biology) the group leader and conceptual creator. Shared first-authorships and shared last-authorships are getting more common.

The number of contributors to an article as reflected in the number of authors can vary enormously: from a few to dozens. Collaborations are common in the Netherlands: Large consortia of >100 authors exist where each group provides data for analysis. Single-authorships occur usually only in reviews or editorials/letters. This way, papers from the Netherlands tend to have more authors, as well as more shared-first and shared-last authorships.

A Dutch PhD thesis is usually completed in 4-5 years, and consists typically of a general introduction/review and 3-5 chapters of original research by the candidate, written in manuscript form or as already published peer reviewed papers, followed by a general discussion (which is usually unpublished).

It is also increasingly common to make publications, data, and software available open access.
Disseminating output/ having impact via other means than peer-reviewed publications and dissertations is generally valued less, although this differs between sub disciplines and per type of output. Examples of other forms are presentations at conferences, work as a reviewer or committee member (including work for funders

and peer-review/editor work for scientific journals), teaching and mentoring students, policymaking, valorising science via patents or spin-offs, and (popular) science communication.

Several sub disciplines such as bioinformatics have a strong focus on the development and use of methods and technologies. Different sub disciplines use different methods (e.g. lab work versus fieldwork). Generally, most life scientists encounter and utilise large datasets.

The Life Sciences in the Netherlands know quite a lot of research institutes. Researchers working at these institutes have much more time for research than their colleagues at universities who have many teaching duties. This creates a difference in the amount of scientific output.

Table 1 - Demarcation of the life sciences field – left is the ERC panel classification, on the right the relevant sub disciplines, supplemented with sub disciplines as used by NWO insofar they were missing in the ERC classification. Note that the eight ERC panels that cover the Life Sciences also partly cover medical sciences. Medical sciences are beyond the scope of NWO-ENW.

ERC panels (2022)	**NWO-ENW Life Sciences sub disciplines**
Molecules of Life: Biological Mechanisms, Structures and Functions	For all organisms: Molecular biology, biochemistry, structural biology, molecular biophysics, synthetic and chemical biology, drug design, innovative methods and modelling
Cellular, Developmental and Regenerative Biology	For all organisms: Structure and function of the cell, cellular biophysics, histology, cell-cell communication, embryogenesis, tissue differentiation, organogenesis, growth, development, evolution of development, organoids, stem cells, regeneration, biological basis for therapeutic approaches
Immunity, Infection and Immunotherapy	The immune system, related disorders and their mechanisms, biology of infectious agents or pathogens and infection, biological basis of prevention and treatment of infectious diseases, biological basis of innovative immunological tools and approaches.
Physiology in Health, Disease and Ageing	Organ and tissue physiology, comparative physiology, physiology of ageing, pathophysiology, interorgan and tissue communication, endocrinology, nutrition, metabolism, interaction with the microbiome, biological basis of non-communicable diseases including cancer (and except disorders of the nervous system and immunity-related diseases), toxicology
Integrative Biology: from Genes and Genomes to Systems	For all organisms: Genetics, epigenetics, genomics and other ‘omics studies, bioinformatics, systems biology, genetic diseases, gene editing, innovative methods and modelling, ‘omics for personalised medicine.
Neuroscience, Behaviour and Disorders of the Nervous System	Nervous system development, homeostasis and ageing, nervous system function and dysfunction, systems neuroscience and modelling, biological basis of cognitive processes and of behaviour, neurological and mental disorders
Environmental Biology, Ecology and Evolution	For all organisms: Ecology, biodiversity, taxonomy, environmental change, evolutionary biology, behavioural ecology, microbial ecology, marine biology, ecophysiology, theoretical developments and modelling
Environmental Biology, Ecology and Evolution	Biotechnology using all organisms, biotechnology for environment and food applications, applied plant and animal sciences, bioengineering and synthetic biology, biomass and biofuels, biohazards

Mathematics

Background: The goal of this document is to assist NWO panel members in gauging the quality of mathematical research proposals. By pointing out aspects in which research in mathematics may differ from research in other fields, we hope to prevent valuable research from being postponed for lack of funding.
One characterising aspect of research in mathematics is the extremely high level of specialisation it requires. This makes it difficult, even for mathematicians in neighbouring fields, to understand and value each other's work. Faith in expert judgements is crucial. The high level of specialisation is also the main reason for most characteristics listed below:

- Research mathematics tends to involve collaborations on a small scale (1-3 collaborators). Although there are large communities within mathematics that share a common language and common goals, a scientific breakthrough is usually obtained by two or three collaborators (e.g., a researcher with a PhD student/post-doc).
- Mathematics research tends to be on a long time scale. Even an excellent PhD student may take two, three, and sometimes even four years to obtain their first publishable results. Consequently, it is difficult to estimate the quality of a junior researcher based on their publications.
- University research groups tend to be based on common interests, not common goals. In particular, it is common for a junior researcher (assistant professor level) to be working on entirely different projects than the head of the group. This is valued and considered a sign of independence.
- Research in mathematics frequently contributes to a better understanding of phenomena studied in other sciences. However, to create a strong and healthy mathematical research environment, mathematics must also develop in its own right. Newly developed mathematical theory may initially only impact mathematics itself; its appreciation might be limited to a small circle of experts. Nevertheless, over a period of years (or decades) the impact will 'trickle down' to other fields.
- Regarding the publication culture: researchers in mathematics publish fewer papers than researchers in other fields. The order of authors is usually alphabetical. A paper can be anything between 5 and 150 pages in length. Some mathematicians never co-author papers with their PhD students, despite contributing. A single authored paper is seen as a sign of independence. The review process is generally slow: the time to publication may be a year, sometimes substantially more.
- Mathematicians usually publish in scientific journals, but some fields in mathematics have a publication culture comparable to that of Theoretical Computer Science with publications in competitive conference proceedings. In that case, researchers typically present the same result both in a conference proceeding and in a journal publication (the latter typically containing the full-length version).
- Next to publications in journals and conferences, some fields of mathematics rely on other forms of research output, such as algorithm implementations or software. Such contributions, also called artifacts, are highly valued and contribute significantly to the progress of a field.

Physics

Background: The main purpose of this document is to assist reviewers who are involved in the appraisal of Physics research proposals but are not physicists themselves. It might also be usable in other contexts. The document lists a number of characteristics of physics as a scientific discipline, including its publication culture.
Research in physics is largely fundamental in its motivation and approach, but often with clear and strong links to applications.

The approach to research in terms of collaboration scale in physics varies significantly by subfield. At the small scale, high-impact research projects can be executed in the research group of a single principal investigator. Collaborations between theorists and experimentalists occur frequently, and in some cases, collaborations can extend to a handful of other research groups. On a medium scale, physicists work collaboratively through infrastructure-oriented institutes, such as beamlines and reactors, where individual or small scale collaborative experiments are executed using infrastructure shared among hundreds of researchers. At the largest scale, in high energy physics, where a single output, such as a publication, is the direct collaborative effort of tens up to thousands of international researchers.

Physics has strong links and borders with a large number of other disciplines, such as chemistry, biology, mathematics, astronomy and computer science as well as with many of the engineering fields. In some sub disciplines, this collaboration extends into life science and medicine.

All subfields of physics are involved in very strong, very frequent, and absolutely essential international collaborations, across Europe, North America, Asia, and worldwide. Physics transcends borders and International collaboration is a fundamental cornerstone of the research process in physics.

A large fraction of physics research relies crucially on the use and development of advanced infrastructure, required to push the boundaries of knowledge in physics. A key process in physics research is the development of new advances in infrastructure and detector technology, which nearly always goes hand-in-hand with the fundamental research.

Dutch physics groups range in size from a few people to typically about 20 people. In some fields and institutes, principal investigators (professors, associate professors, assistant professors) take an independent leading role in the research group (the “independent PI” model). These PIs themselves define the research direction in the group and directly supervise PhDs and postdoctoral researchers. In this context, a typical successful experimental group would be 4-10 PhDs/postdocs, plus the PI, in steady state. Theory groups can be smaller, consisting of a PI and a few students. In both cases, some groups can become quite large (> 20 PhDs postdocs per PI). In this context, researchers at all levels work together through bottom-up initiatives and collaborative grants. Larger research groups in which several senior physicists are in one group together with a common theme can also occur.

It is common in physics that papers from smaller-scale collaborations of works from individual research groups could have on the order 3 to 15 authors. At the large-scale end, especially in particle and astroparticle experimental physics, publications can include hundreds to thousands of authors recognising the contribution of all scientists in designing, building and analysing data from these large experiments. In many fields of physics, a “parabola order” list construction is employed, with the first author the one who was most directly involved in execution of the work, often a PhD / postdoc, proceeding with decreasing contribution for subsequent junior authors. Principle investigators are then listed in reverse order of contribution to the direction and supervision of the project, with the last author being the primary PI who was leading the project. This is not uniform across all subfields of physics, with a particular exception for the case of “big science” work in particle and astroparticle physics in which authors are listed alphabetically by last name.

The physics discipline is highly active in the dissemination of publications via the arXiv preprint server. In many fields, all publications are shared and disseminated via the arXiv, although in the vast majority of those cases, the work on the arXiv is later published in peer-reviewed journals. The arXiv is also used as resource for demonstrating the order in which results are disseminated, bypassing delays in peer review. Conference proceedings in physics existed in the past, but little weight was given to them as a dissemination resource, with most of the important work disseminated via peer-reviewed journals and the arXiv. In fields of physics closer to applications, patents may also be an important medium for dissemination of results. In some subfields, publications in general journals like Science or Nature are not common and more weight is given to specialised journals.

In physics, developing new instruments, research infrastructure, highly complex experimental setups, and also new theoretical frameworks, can require a significant amount of time, and as a result, the publication output in some physics fields involving such development can be lower than average in the discipline, and sometimes vastly lower than in other disciplines. One significant difference we believe compared to many other disciplines is the high rate of embracement of the arXiv as a dissemination tool. Another significant difference, especially compared to biological disciplines, is in grant structure, where physicists are more likely to propose exploratory projects that can be judged on the strength of the ideas and the overall direction rather than preliminary data.