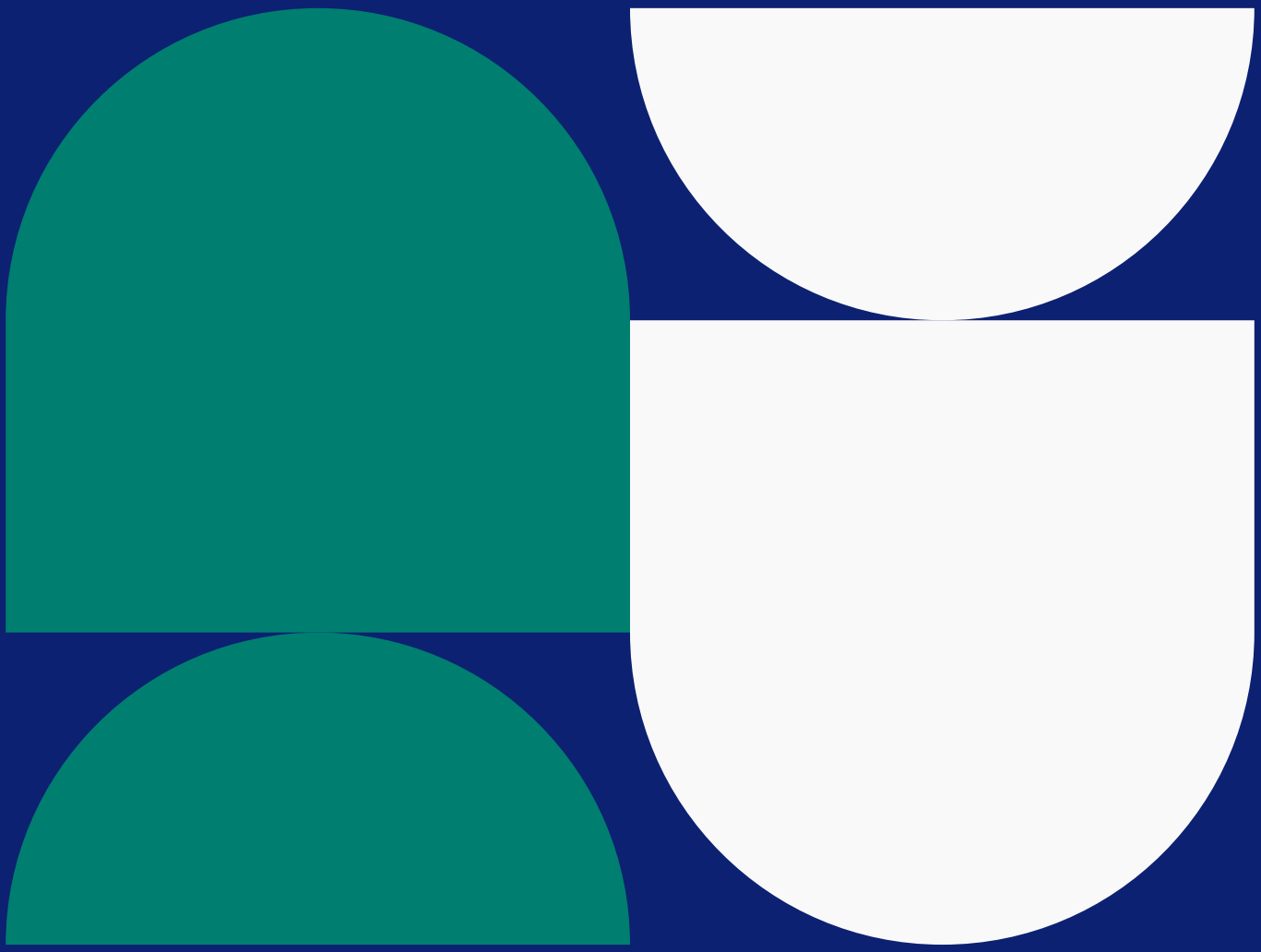
Quality and impact of research in basic medicine in Sweden



Vetenskapsrådet

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Quality and impact of research in basic medicine in Sweden

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Vetenskapsrådet förord

Vetenskapsrådet har låtit utvärdera forskningsområdet medicinska och farmaceutiska grundvetenskaper utifrån sin modell för nationella utvärderingar av forskningsämnen. Modellen har utarbetats i samverkan med en rådgivande grupp med representanter från Sveriges universitets- och högskoleförbund och Universitetskanslersämbetet. Utvärderingsmodellen utgår från regeringens instruktion till Vetenskapsrådet, som bland annat innehåller uppdraget att ”utvärdera forskning och bedöma forskningen och dess vetenskapliga kvalitet och betydelse” (§1:6).

Det övergripande syftet med utvärderingen är att bidra till att stärka svensk forskning. Utvärderingen är utformad för bedömning av forskningens vetenskapliga kvalitet och dess betydelse för det omgivande samhället i ett internationellt perspektiv. Genom att lyfta fram såväl styrkor som svagheter kan utvärderingen utgöra underlag för att stärka forskningen; åtgärder kan vidtas av relevanta aktörer, så som såväl lärosäten som finansiärer och regering.

Utvärderingen har utförts av en oberoende expertpanel. Vetenskapsrådet tackar panelen för deras betydelsefulla och mycket väl utförda arbete med att teckna en nationell bild av forskningens kvalitet och betydelse inom medicinska och farmaceutiska grundvetenskaper i Sverige.

Stockholm, 31 mars 2025

Katarina Bjelke

Generaldirektör, Vetenskapsrådet

Vetenskapsrådets sammanfattning

Regeringens forskningspolitiska mål är att Sverige ska vara bland världens ledande forsknings- och innovationsländer. För att bevara och stärka Sveriges ställning som en framstående forskningsnation är kvalitetssäkring av den forskning som utförs i Sverige av yttersta vikt. Medicinsk grundforskning är ett område som erhåller betydande finansiering i Sverige, varför syftet med denna utvärdering var att ge en övergripande bild av resultatet av forskningen inom de medicinska och farmaceutiska grundvetenskaperna i Sverige.

En internationell expertpanel har utvärderat vetenskaplig kvalitet och genomslag i samhället av de medicinska och farmaceutiska grundvetenskaperna enligt en modell utvecklad av Vetenskapsrådet. De sju svenska lärosäten som har en medicinsk fakultet utvärderades av 15 panelmedlemmar tillsammans med 48 externa granskare. Underlaget till panelen har bestått av ett urval av toppublikationer och fallstudier från lärosätena samt omfattande statistik och bibliometriska analyser sammanställda av Vetenskapsrådet.

Panelen konstaterar att den medicinska grundforskningen i Sverige uppvisar prov på hög vetenskaplig kvalitet, banbrytande forskningsresultat samt robusta samarbetsnätverk, vilka har genererat betydande samhällseffekter.

Panelen anser att den starka forskningsprestationen stöds av robust forsknings- och utvecklingsfinansiering (FoU-finansiering), gemensamma plattformar för avancerad teknik och väldokumenterade kliniska kohorter som underlättar den snabba överföringen av grundvetenskapliga rön till klinisk praxis. Synergin mellan grundläggande och klinisk forskning, tillsammans med samarbetsinsatser, tillgång till innovativa metoder och teknologier, har lett till ökad forskningskvalitet, produktivitet och genomslag. Dessutom framhöll panelen vikten av en stark forskningsinfrastruktur som har implementerats framgångsrikt i Sverige. En annan avgörande faktor för den höga forskningskvaliteten är de omfattande internationella samarbetena och rekryteringen av internationella forskare. Utöver forskningens höga kvalitet var panelen också positiv till det svenska forskningssamhällets öppna och samarbetsinriktade forskningskultur.

Den vetenskapliga kvaliteten på toppublikationerna ansågs vara mycket hög och uppvisade både banbrytande och inkrementell forskning. Toppublikationerna uppvisar innovativ forskning och användning av spjutspetsteknologier, med banbrytande upptäckter som resultat inom alla utvärderade forskningsämnen. Endast topp 1,5 procent av publikationerna från lärosätena bedömdes genom granskning i utvärderingen och därmed fanns det också en förväntan på att kvaliteten på det utvärderade materialet skulle vara hög. Likaväl drog panelen slutsatsen att Sverige betraktas som en nyckelaktör inom vissa av de utvärderade forskningsämnena.

Den bibliometriska analysen visar på varierande citeringsgenomslag för svensk medicinsk grundforskning. Generellt sett har Sveriges citeringsgenomslag inom området legat runt världsgenomsnittet de senaste åren, även om det finns noterbara skillnader mellan olika forskningsämnen. Den högsta andelen högciterade publikationer återfinns inom medicinsk genetik, följt av cellbiologi och mikrobiologi. Svenska publikationer inom immunologi och fysiologi har dock ett citeringsgenomslag som ligger under världsgenomsnittet. Deltagande av medförfattare från andra länder ökar tydligt citeringsgenomslaget. Karolinska Institutet är generellt sett det svenska lärosäte som har högst citeringsgenomslag. Inom vissa forskningsämnen uppvisar dock även Göteborgs universitet, Uppsala universitet och Lunds universitet ett imponerande citeringsgenomslag.

Den nationella statistiken visade en balanserad könsfördelning inom de flesta anställningskategorier, med det anmärkningsvärda undantaget för professurer, där män utgör en betydande majoritet vid lärosätena (70 till 80 procent). Panelen drar slutsatsen att denna diskrepans tyder på en könsbias på professorsnivå, vilket kräver framtida åtgärder.

Bedömningen av fallstudierna visade flera utmärkta exempel på samhällelig betydelse av forskning. Många fallstudier beskrev dock potentiella eller vetenskapliga effekter snarare än konkreta samhälleliga effekter, vilket faller utanför ramen för utvärderingen. Vissa fallstudier saknade också tillräckligt med bevis för att verifiera forskningens effekter. Inte desto mindre ansågs mer än hälften av de 57 fallstudierna visa på forskning som haft enastående eller mycket betydande räckvidd och betydelse för samhället utanför akademin.

Panelen betonade flera viktiga faktorer som är nödvändiga för att upprätthålla forskning av hög kvalitet. En nyckelfaktor är vikten av att bedriva och utveckla multidisciplinär forskning. För vissa forskningsämnen föreslog panelen att framtida forskning skulle kunna dra nytta av ökad användning av Sveriges omfattande dataresurser, särskilt i hypotesdrivna studier. Dessutom rekommenderade panelen att lärosätena ökar interaktionen mellan sjukhus och forskare för att maximera kunskapen om de underliggande mekanismerna i kliniska frågor.

Vidare påtalar panelen att lärosätena bör uppmuntra forskare att ytterligare stärka sina ansträngningar att erhålla konkurrensutsatt finansiering utöver nuvarande nivåer, för att kontinuerligt förbättra kvaliteten i forskningen. Detta gäller särskilt för forskare tidigt i och i mitten av karriären och inkluderar såväl nationell och som internationell finansiering. Finansieringsmöjligheter från organisationer som Europeiska forskningsrådet (ERC) och Europeiska innovationsrådet (EIC) bör uppmuntras och aktivt eftersträvas.

Panelen betonade att betydande samhälleliga effekter inte kan uppnås utan medicinsk grundforskning. Det är därför avgörande med fortsatt effektivt finansieringsstöd till området. Panelen rekommenderade också att fortsätta och vidareutveckla framgångsrika nationella och internationella samarbeten.

Baserat på resultaten i denna utvärdering drar Vetenskapsrådet slutsatsen att medicinsk grundforskning har bidragit med framstående exempel på forskning av hög kvalitet och effektfulla lösningar på samhällsutmaningar, särskilt inom hälsoområdet. Vetenskapsrådet anser att det är viktigt att

- säkerställa det stabila ekonomiska resurser för forskning och forskningsinfrastruktur
- åtgärda könsobalansen bland professorer
- stödja och främja forskare tidigt i karriären
- främja internationellt samarbete
- värna öppenheten i forskningsgenomförande inom det svenska forskningssystemet
- arbeta tvärvetenskapligt för att möta framtidens utmaningar
- aktivt rekrytera forskare med nyckelkompetenser, särskilt inom framväxande teknologier
- särskilt mindre lärosäten identifierar och prioriterar sina styrkeområden för att uppnå större genomslag i forskningen och i samhället.

Att ta itu med dessa frågor är nödvändigt för att säkerställa den fortsatta utvecklingen av de medicinska och farmaceutiska grundvetenskaperna och deras förmåga att leverera banbrytande forskning och tillhandahålla innovativa och avgörande lösningar på samhällets utmaningar.

The Swedish Research Council's summary

The Government's research policy goal is for Sweden to be among the world's leading countries in research and innovation. Quality assurance of research carried out in Sweden is vital to maintain and develop Sweden's position as a successful research nation. The field of basic medicine is a significant recipient of funding in Sweden hence the aim of this evaluation was to provide a comprehensive overview of the outcome of basic medicine in Sweden.

A panel of international reviewers has evaluated the quality and societal impact of basic medical research in Sweden, using a model developed by the Swedish Research Council. The seven Swedish higher education institutions (HEIs) that have a medical faculty were evaluated by 15 panel members along with 48 external reviewers. The evaluation was based on material provided by the HEIs, including a selection of top publications and case studies. Additionally, comprehensive statistics and bibliometric analyses, compiled by the Swedish Research Council, were included.

The panel notes that basic medical research in Sweden demonstrates evidence of high scientific quality, groundbreaking research results, and robust collaborative networks, which have generated significant societal impact.

The panel concluded that the high performance of research in basic medicine in Sweden is supported by robust research and development (R&D) funding, shared platforms for advanced technologies, and well-documented clinical cohorts that facilitate the rapid translation of basic science findings to clinical practice. The synergy between fundamental and clinical research, along with collaborative efforts, access to innovative methodologies and technologies, are ultimately leading to enhanced research quality, productivity, and impact. In addition, the panel highlighted the importance of strong research infrastructure that is successfully implemented in Sweden. Another crucial factor for the high quality of basic medicine in Sweden is the rich international collaborations and the recruitment of international scholars. Beyond the high quality of the research, the panel expressed its positive assessment of the Swedish research community's open and collaborative research culture.

The scientific quality of the top publications was considered very high and demonstrated both groundbreaking and incremental research. The top publications demonstrate innovative research and the use of cutting-edge technologies, with evidence of groundbreaking discoveries across all subdisciplines in basic medicine. Only the top 1.5 per cent of the publications produced by the HEIs were assessed in the peer review, hence the quality of the evaluated material was expected to be high. Nevertheless, the panel concluded that Sweden is regarded as a key player in some of the evaluated subdisciplines.

The bibliometric analysis in this evaluation revealed a varied citation impact of Swedish research in basic medicine. Generally, the citation impact has been around the world average in recent years although there are notable differences across various subdisciplines. The highest proportion of highly cited publications was found for publications in genetics and heredity, followed by cell biology and microbiology. However, publications in immunology and physiology have a citation impact below world average. Participation of co-authors from other countries clearly increases the citation impact. In general, Karolinska Institutet is the Swedish university with the highest citation impact. However, in certain subdisciplines, University of Gothenburg, Uppsala University and Lund University also demonstrate impressive citation impact.

The national statistics revealed a balanced gender distribution across most occupational categories, with the notable exception of professorships, where males constitute a significant majority at the HEIs (70-80 per cent). The panel concludes that this discrepancy suggests a gender bias at the professorial level, necessitating future intervention.

The review of case studies presented several excellent examples of high societal impact. However, many case studies presented potential or scientific effects rather than concrete socio-economic benefits, which fall outside the intended scope of the evaluation. Some case studies also lacked sufficient evidence to verify their impact. Nonetheless, more than half of the 57 case studies were considered to have outstanding or very considerable impacts in terms of their reach and significance on society (outside academia).

The panel emphasized several critical factors necessary for maintaining high-quality research. One key factor is the importance of conducting and developing multidisciplinary research. For some subdisciplines, the panel suggested that future research could benefit from enhanced utilization of Sweden's extensive data resources, particularly in hypothesis-driven investigations. Furthermore, the panel recommended that the HEIs should increase the interactions between hospitals and researchers to maximize mechanistic insights into clinical issues.

Moreover, the panel suggests that HEIs should further improve the quality of research by encouraging researchers to strengthen their applications for competitive funding beyond current levels. This includes both national and international funding, especially for early and mid-career researchers, which is essential to maintain and further develop high scientific standards. Funding opportunities from organisations such as the European Research Council (ERC) and the European Innovation Council (EIC) should be encouraged and actively pursued.

The panel emphasized that significant societal impact cannot be achieved without basic science and discoveries in basic medicine. Therefore, it is crucial to continue providing efficient funding support for the field. The panel also advised continuing and further developing successful national and international collaborations.

Based on the results of this evaluation, the Swedish Research Council concludes that the field of basic medical research has produced substantial examples of high-quality research and impactful solutions to societal challenges, particularly in health issues. The Swedish Research Council considers it essential to

- safeguard the stable financial resources for research and research infrastructure
- develop effective mechanisms to address gender imbalances among professors
- support and promote early-career researchers
- promote international collaboration
- uphold the transparency in research practices within the Swedish research system
- enable HEIs to work interdisciplinarily to address future challenges
- actively recruit researcher with key competences, particularly in emerging technologies
- support smaller HEIs in identifying and prioritizing their areas of strength to achieve greater impact both in science and society.

Addressing these issues is imperative to ensure the continued advancement of basic medical research and its capacity to deliver cutting-edge research and provide innovative and vital solutions to societal challenges.

1 Introduction by the Swedish Research Council

This introduction serves to provide the context for the current evaluation, which has been conducted in accordance with an evaluation model developed by the Swedish Research Council. The subsequent sections elucidate the methodology of the evaluation as well as the criteria used for selection of evaluated research subjects, and higher education institutions (HEI). Supporting materials, including descriptive statistics and bibliometric data, are presented in chapter 2 Background material. Furthermore, the instructions issued to the HEIs, and the reviewers are provided in the appendices.

1.1 National quality assurance system

The Government's research policy goal is for Sweden to be among the world's leading countries in research and innovation, and a leading knowledge nation.[1] Quality assurance of research carried out at HEIs in Sweden is vital to maintain and develop Sweden's position as a successful research nation.

The primary responsibility for quality assurance lies with the HEIs themselves. According to the national system for quality assurance of higher education and research, the HEIs shall ensure that their research and research environments undergo regular peer reviews from a national and international perspective and systematically capture and address the recommendations arising from such reviews. The Swedish Higher Education Authority is since 2017 responsible for auditing the HEIs' own quality assurance of research.[2] In addition, the Swedish Research Council undertake comprehensive evaluations of a selection of research areas to assess the landscape of Swedish research and determine the scientific quality and societal impact.[3]

Consequently, the present evaluation performed by the Swedish Research Council is focused on the results of the research and shall provide a national overview of the scientific quality and societal impact of the research and is intended to complement the HEIs' own evaluations.

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[1] Proposition/Government Bill Prop. 2024/25:60, "Forskning och innovation för framtid, nyfikenhet och nytta". The Swedish Government's website.
[2] Proposition/Government Bill 2020/21:60, "Forskning, frihet, framtid – kunskap och innovation för Sverige", p. 150. The Swedish Government's website.
[3] Förordning (2009:975) med instruktion för Vetenskapsrådet/Ordinance with instructions to the Swedish Research Council, Clause 1:6, (our translation).

1.2 The Swedish Research Council's evaluation model

The Swedish Research Council has a governmental mandate to "evaluate research and assess its quality and impact"[4] at the HEIs in Sweden. In line with this mandate, the Swedish Research Council regularly evaluates the research results of Swedish HEIs.

In 2018-2019, the Swedish Research Council developed a model for national evaluations of research subjects and thematic (transdisciplinary) research domains.[5] Formalising the process in a model ensures a predictable evaluation format. The overall purpose is to contribute to improving the quality and impact of Swedish research. This purpose is fulfilled when the Swedish Research Council's evaluations provide input to quality-enhancing measures by HEIs, the Government, and funding bodies.

Through evaluations conducted in accordance with the model, the Swedish Research Council aims at providing a national overview of Swedish research within a research area, focusing on the quality and impact of research. This national overview is currently not provided elsewhere in the existing Swedish system for national quality assurance of research. The intention is not to use the model to evaluate all research subjects according to a set evaluation cycle. Rather, research subjects are selected based on where the Swedish Research Council finds it particularly important to conduct an evaluation.

International peer review forms the basis of the evaluation model. The evaluation panels should use their international experiences to suggest how quality and impact may be improved. The model balances the need to limit the workload of the HEIs, with the ambition of identifying possible areas for research development.

Initially, a preliminary version of the model was developed in collaboration with an advisory group including representatives of HEIs as well as the Swedish Higher Education Authority. Subsequently, a revised model was tested in a pilot evaluation of research in political science. The principles for the implementation of the pilot evaluation are to be found in the report "Quality and impact of research in political science in Sweden", Swedish Research Council 2021.[6] After this pilot evaluation, lessons learnt and opinions on the model were gathered from several groups: the panel that conducted the evaluation, the HEIs included in the pilot evaluation, the original advisory group, and involved co-workers at the Swedish Research Council. Following this process, the evaluation model was subject to minor revisions.[7] In 2022, the evaluation model was once again

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[4] Förordning (2009:975) med instruktion för Vetenskapsrådet/Ordinance with instructions to the Swedish Research Council, Clause 1:6, (our translation).
[5] PM Vetenskapsrådets modell för ämnesvisa och tematiska utvärderingar. Preliminary version 2019-06-19.
[6] Quality and impact of research in political science in Sweden. Swedish Research Council, 2021.
[7] PM The Swedish Research Council's model for national research evaluations by subject, Reg.nr. 3.2-2018-00113.

employed to assess the scientific quality and impact, this time of physics research conducted in Sweden.[8] The insights gained from this application of the model contributed to its further refinement and improvement.

1.3 The present evaluation

This report presents the third evaluation using the evaluation model. The evaluation was launched in 2024 and was dedicated to the research subject of basic medicine.

The field of basic medicine is a significant recipient of funding within the field of medicine and health sciences in Sweden. This evaluation encompasses pre-clinical research and, together with evaluations of clinical research[9], provides a comprehensive overview of the outcome of medical research in Sweden.

The national evaluation of research in basic medicine is focused on the quality of scientific production and the significance of research's impact on society. Scientific quality is assessed primarily on peer review of cutting-edge publications and is complemented with bibliometric analyses on the total scientific production. The Swedish Research Council believes that scientific experts' assessments are essential for truly evaluating the scientific quality. While publications with many citations indicate significant impact within the research community, citations alone do not guarantee the most prominent and scientifically important research.

Societal impact is assessed by reviewing case studies that demonstrate the research's impact outside academia. The Swedish Research Council provided background documentation for the review, such as national statistics and bibliometrics, while HEIs provided documentation in the form of 403 cutting-edge scientific publications (1.5 per cent of their total production between 2018 to 2022) and 57 case studies. (More information about the evaluation model is given in Appendix 1).

1.4 The higher education institutions (HEIs)

The seven HEIs included in this evaluation were selected to represent research in basic medicine in Sweden, as they are the only HEIs with medical faculties. Together, these seven HEIs represent 97 per cent of all personnel involved in basic medicine and 100 per cent of all doctoral students in basic medicine in Sweden. These HEIs also account for 77 per cent of all Swedish publications in basic medicine between 2018-2022, according to Web of Science.

Several other Swedish universities also perform research and publish results within the field of basic medical sciences. However, these other universities do

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[8] Quality and impact of research in physics in Sweden. Swedish Research Council, 2023.
[9] Utvärdering av den kliniska forskningens kvalitet vid de regioner som omfattas av ALF-avtalet. Swedish Research Council, 2023

not have a medical faculty, and they report their statistics data, such as staff and expenditures, in categories like natural sciences instead of basic medicine.

The selected universities included in the evaluation are:

- Karolinska Institutet
- Linköping University
- Lund University
- Umeå University
- University of Gothenburg
- Uppsala University
- Örebro University.

1.5 The evaluation process

The evaluation panel consisted of 15 scientific experts from various European countries and different research subjects in basic medicine, with one serving as chair and one as vice chair. The purpose of having a diverse international panel was to get an overview of Swedish research from an international perspective. Twelve of the experts were recruited to assess scientific quality, and three experts were recruited to assess societal impact. The list of evaluation panel members as well as the instruction is shown in in Appendix 1. In addition, 48 external reviewers were assigned for the peer review of top publications.

The top publications from the HEIs were divided into eight subdisciplines. Correspondingly, the scientific experts and external reviewers were organized into eight subpanels. The publications were initially assessed by three experts and then discussed in subpanel meetings where consensus grades were established.

The case studies were assessed primarily by the societal impact experts in the panel, with support from appropriate scientific experts. The panel members attended a three-day meeting in Stockholm the 29th to 31st of January 2025. In preparation for the meeting all the background material described in this report was sent to the panel members. During and after the three-day meeting, all members of the panel participated in the writing of the report, presented in chapter 3.

2 Background material

2.1 Publications and case studies submitted by the HEIs

The number of publications assessed, for each HEI, was in proportion to their total number of publications within basic medicine published during the years 2018 to 2022 (see Table 1, column two).

Similarly, the number of case studies submitted by each HEI was based on their relative size in terms of research and teaching staff (full time equivalents, FTE) during the years 2018 to 2022 (see Table 1, column three). The HEIs with less than 20 FTE submitted at least one case and no HEI had to submit more than sixteen case studies. (See Table 1, column three). In addition, a flexibility was introduced to allow the HEIs some margin of manoeuvre in selecting relevant cases, while ensuring a reasonable number of cases providing enough material for the evaluation panel to base their conclusions on, and at the same time limiting the workload for everyone involved.

Table 1. Number of publications and case studies submitted by each HEI to this evaluation.

HEI	Publications	Case studies
Karolinska Institutet	147	15
Uppsala University	75	14
Lund University	61	11
University of Gothenburg	60	7
Linköping University	22	4
Umeå University	29	4
Örebro University	9	2
Total	**403**	**57**

2.2 Statistics of basic medicine in Sweden

In this section, the Swedish Research Council reports statistics of the Swedish HEIs conducting research in basic medicine. The statistics are mainly for the seven HEIs included in the evaluation. The total for the remaining HEIs is presented where applicable. The statistics were compiled with data reported to Statistic Sweden (SCB) and to the Swedish Higher Education Authority and presents the average number of full-time equivalents (FTEs) for the years 2018–2022.

2.2.1 Research and teaching staff in basic medicine

For the years 2018–2022, the seven HEIs included in the evaluation together account for all PhD students and 97 per cent of the reported research and teaching staff in basic medicine in Sweden. For specification per HEI, see Table 2 below. The table is sorted in descending order from highest number of research and teaching staff (FTE) as well as PhD students. Counts are average number of FTEs for the years 2018–2022. 'Staff' refers to research and teaching staff. 'Total' includes PhD students. 'Share all total' is share of the seven HEIs.

Table 2. Average number (FTE) of staff and PhD students at HEIs in basic medicine.

HEI	Staff (FTE)	PhD students (FTE)	Total (FTE)	Share all total
Karolinska Institutet	670	447	1117	35%
Uppsala University	562	220	782	25%
Lund University	359	122	481	15%
University of Gothenburg	321	124	445	14%
Linköping University	142	36	178	6%
Umeå University	64	52	116	4%
Örebro University	15	15	30	1%
Total	**2133**	**1016**	**3149**	

Figure 1 below illustrates the distribution of staff and PhD students (FTE) at each HEI. Karolinska Institutet as well as Umeå University and Örebro University have a more even distribution between research and teaching staff and PhD students than the other universities where research and teaching staff represents at least 70 per cent.

Figure 1. Distribution of staff and PhD students (FTE) at each HEI.

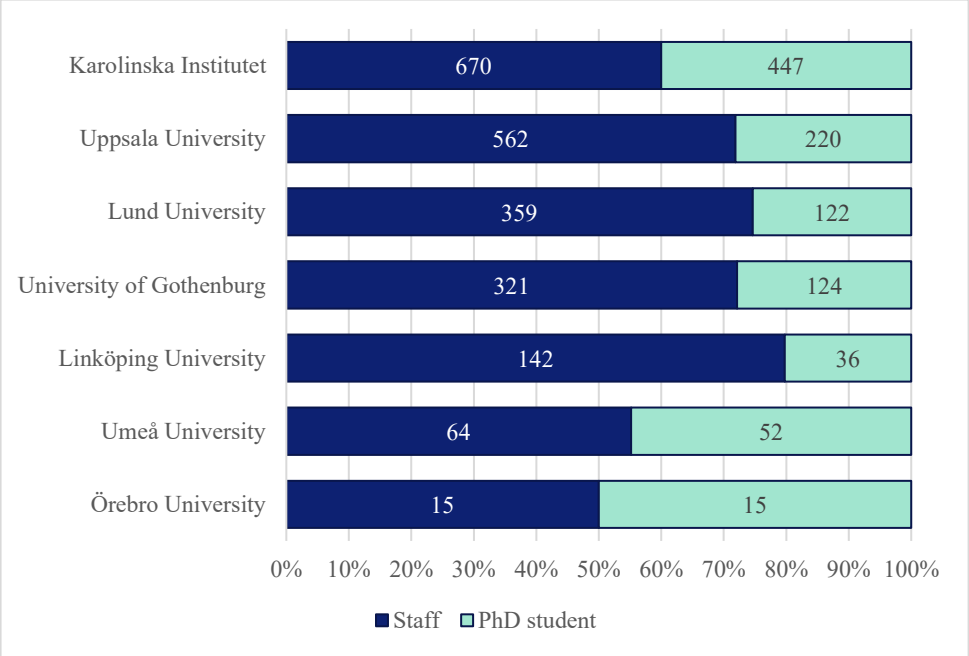


Figure 2 below illustrates the distribution of different positions (FTE) within the universities in per cent and total number. Karolinska Institutet has the highest number of postdoctoral positions and professors. The high number of postdoctoral positions at Karolinska Institutet stands out compared to the other HEIs. In terms of the number of professors in relation to other position categories all universities except Örebro University are comparable.

Figure 2. Average distribution of different positions (FTE) at the HEIs, in per cent and total numbers.

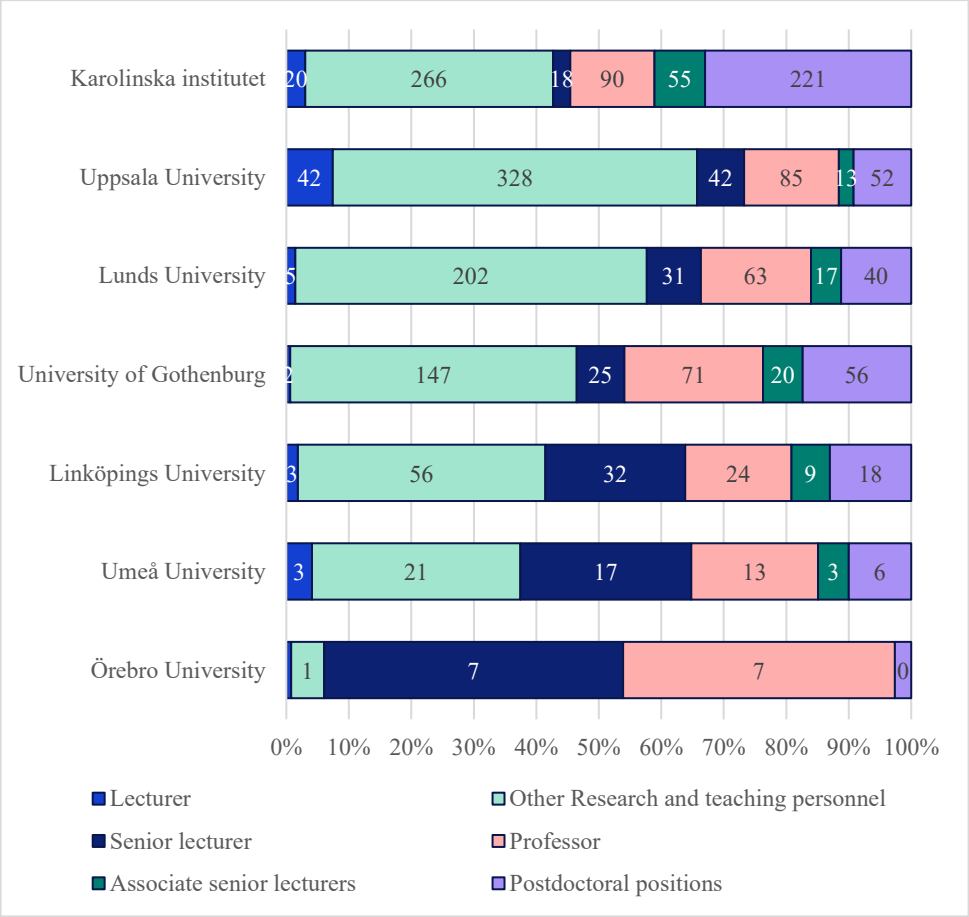


Figure 3 below presents the distribution of FTE PhD students at the seven HEIs distributed by gender. All the universities have a gender balance within 40–60 per cent, except for Örebro University and Linköping University where the number of women is just above 60 per cent.

Figure 3. Average distribution of PhD students (FTE) distributed by gender among the HEIs, in per cent and total numbers.

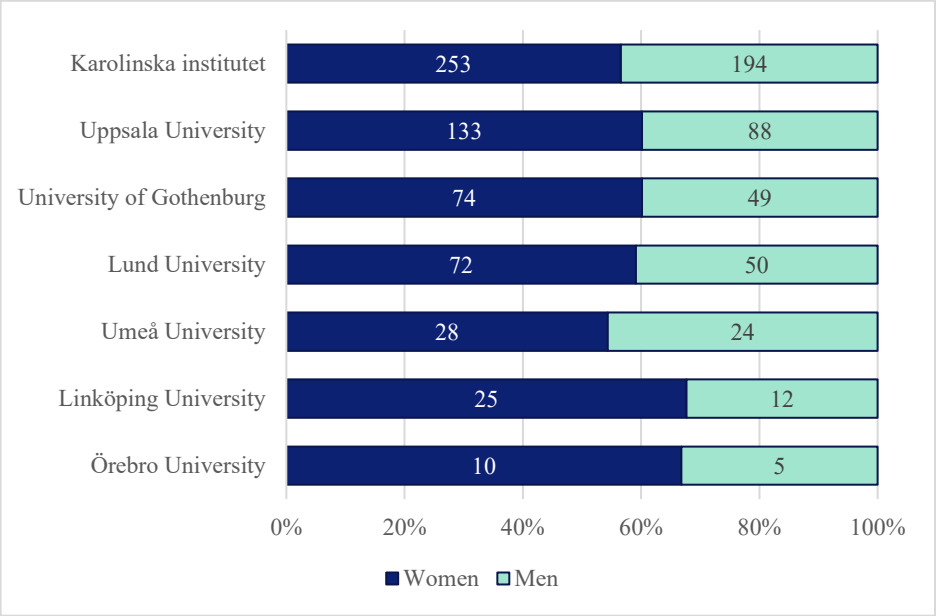


Figure 4 below presents the distribution of FTE professors at the HEIs distributed by gender. The numbers in the figure show the number of professors per gender. All the universities have less than 35 per cent of women among their professors.

Figure 4. Average distribution of professors (FTE) distributed by gender among the HEIs, in per cent and total numbers.

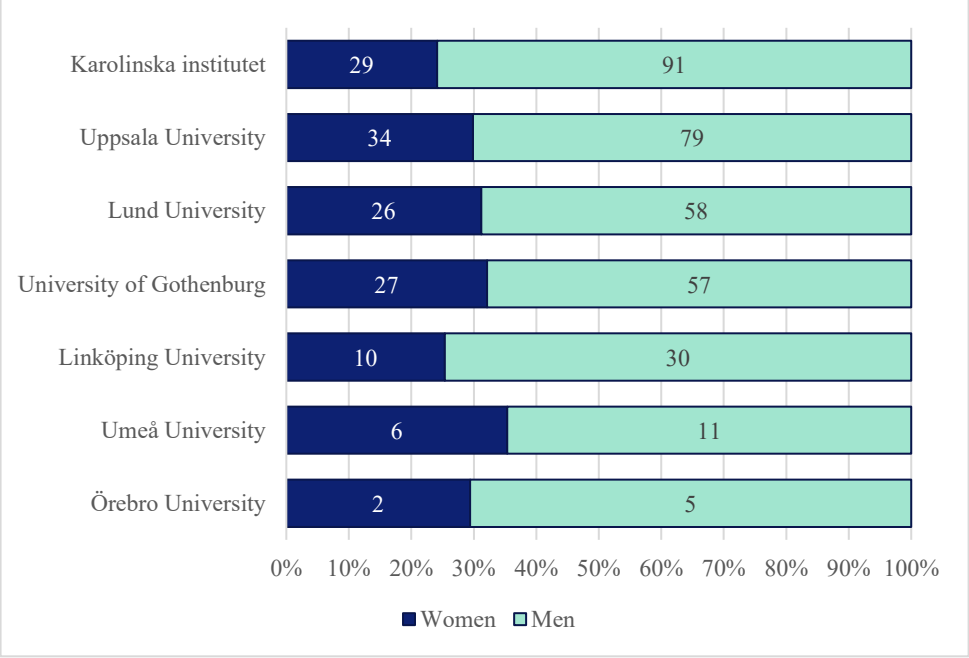
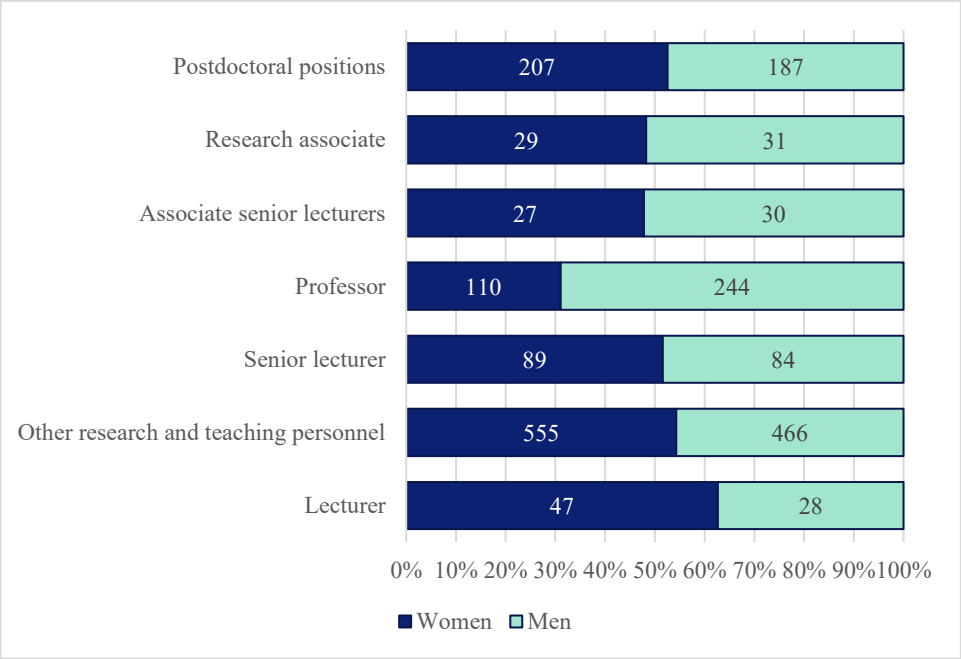


Figure 5 below shows that in all types of positions, except for professors and lecturers, the share of women at national level is around 50 per cent, for professors it is 31 per cent and for lecturer is 63 per cent.

Figure 5. Average distribution of gender in different positions (FTE) in basic medicine at the HEIs in per cent and total numbers.



2.3 Research and development expenditure and funding in Sweden

The seven HEIs included in this evaluation together stands for 99 per cent of the total research and development (R&D) expenditure in basic medicine in Sweden. R&D expenditure refers to all financial resources used for research and development activities at the HEIs.

In this section we present the average R&D-expenditure based on data from the three latest surveys (2017, 2019 and 2021) reported to Statistic Sweden (SCB).[10]

The figures below provide insights into the funding landscape for HEIs by presenting the funding from different financial sources per HEI and their respective per centages. These figures highlight the diversity of funding sources, which helps to identify the financial stability and sustainability of HEIs. A diverse funding portfolio can mitigate risks associated with reliance on a single source. These figures also enable comparisons between different HEIs, fostering a better

[10] Örebro University has reported the average of R&D expenditure directly to the Swedish Research Council, instead of to Statistics Sweden (SCB), for the three years counting in this report, summing up to 49 MSEK in average. Consequently, there is no information presented on distribution on different financial sources for Örebro University in the following figures.

understanding of how institutions manage their funding. Overall, these figures are essential for comprehensively understanding the financial positioning of HEIs in the context of R&D expenditure.

2.3.1 Overview

Table 3 presents the distribution of total R&D expenditure in basic medicine for each HEI, including a specification of the block grants in basic medicine that contribute to this expenditure. Block grants are government funds provided to HEIs to cover a range of operational and strategic needs, including research and development activities. Table 3 shows how much of each type of financial source each HEI spends and compares it to the total funding for all HEIs in Sweden. This allows for a comparison of funding levels across different institutions. Karolinska Institutet has the highest average of R&D expenditure at 2,397 MSEK, which is 50 per cent of the total R&D expenditure in Sweden. Karolinska Institutet also receives the highest block grants per year, 1,087 MSEK in average, accounting for 58 per cent of the total block grants in Sweden for basic medicine. This highlights Karolinska Institute's focus on medical research and its larger size in the research field. Uppsala University follows with 17 per cent of research grants and 14 per cent of block grants. Lund University and University of Gothenburg have similar R&D expenditures of 582 MSEK (12 per cent) and 488 MSEK (10 per cent), respectively, with corresponding block grants of 157 MSEK (8 per cent) and 160 MSEK (9 per cent). Linköping University and Umeå University have lower R&D expenditures of 155 MSEK (3 per cent) and 339 MSEK (7 per cent), with block grants of 42 MSEK (2 per cent) and 128 MSEK (7 per cent). Örebro University has the smallest R&D expenditure listed at 49 MSEK (1 per cent). The data for Örebro University is incomplete, with only the total amount of R&D expenditure information available (see footnote 9).

The block grant that the seven HEIs obtain, constitutes approximately 99 per cent of the total block grant allocated in Sweden for basic medicine. Karolinska Institutet obtains 58 per cent of the total block grant followed by Uppsala University with 14 per cent.

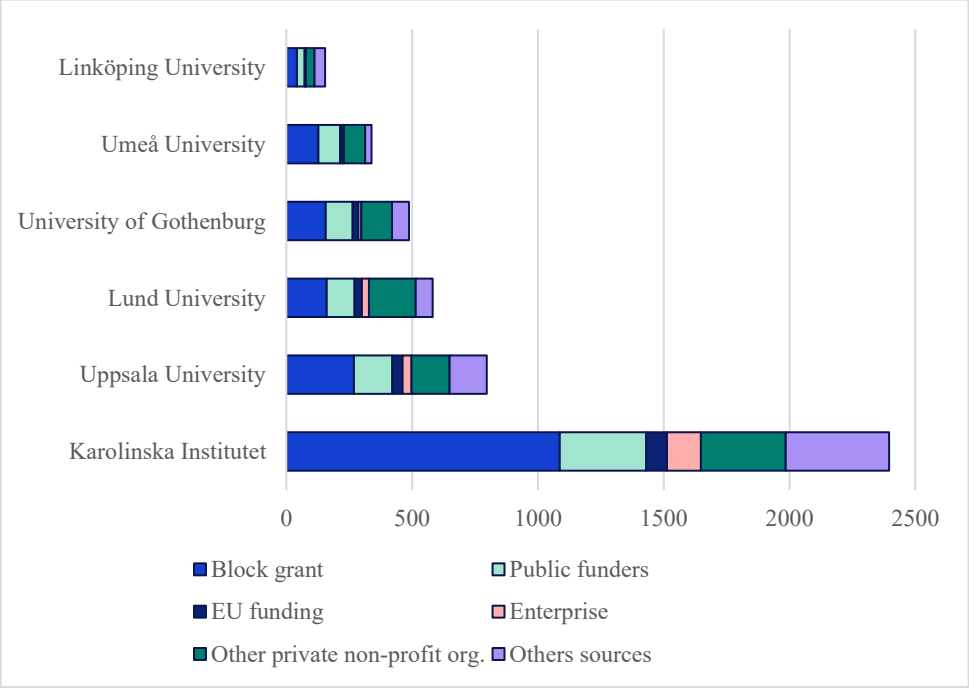
Table 3. Average R&D expenditure and block grants for basic medicine, million SEK, and share of all Swedish HEIs.

HEI	R&D expenditure (MSEK)	Per cent of total R&D expenditure per year	Block grants per year (MSEK)	Per cent of total block grants per year
Karolinska Institutet	2 397	50%	1 087	58%
Uppsala University	797	16%	269	14%
Lund University	582	12%	157	8%

HEI	R&D expenditure (MSEK)	Per cent of total R&D expenditure per year	Block grants per year (MSEK)	Per cent of total block grants per year
University of Gothenburg	488	10%	160	9%
Linköping University	155	3%	42	2%
Umeå University	339	7%	128	7%
Örebro University[11]	(49)	(1%)		
Total for all HEIs in Sweden	**4 818**		**1 870**	

Figure 6 below presents the distribution of different funding sources for the R&D expenditure per HEI. Karolinska Institutet has a larger amount of funding for all the funding sources. Uppsala university is the second largest HEI in obtain funding, followed by Lund University.

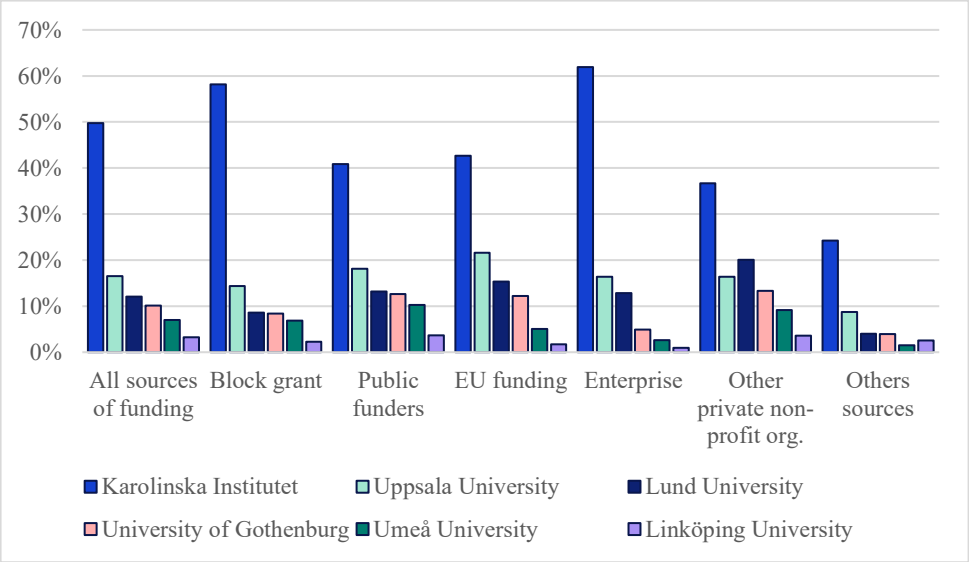
Figure 6. Distribution of different funding sources per HEI, million SEK.



[11] Ibid.

Figure 7 below presents the distribution in per cent of the different funding sources per HEI. Karolinska Institutet has the highest per centage of funding from all sources in basic medicine. A significant portion of external funding is also obtained by Karolinska Institutet, particularly from private sector from both Sweden and other countries (Enterprise).

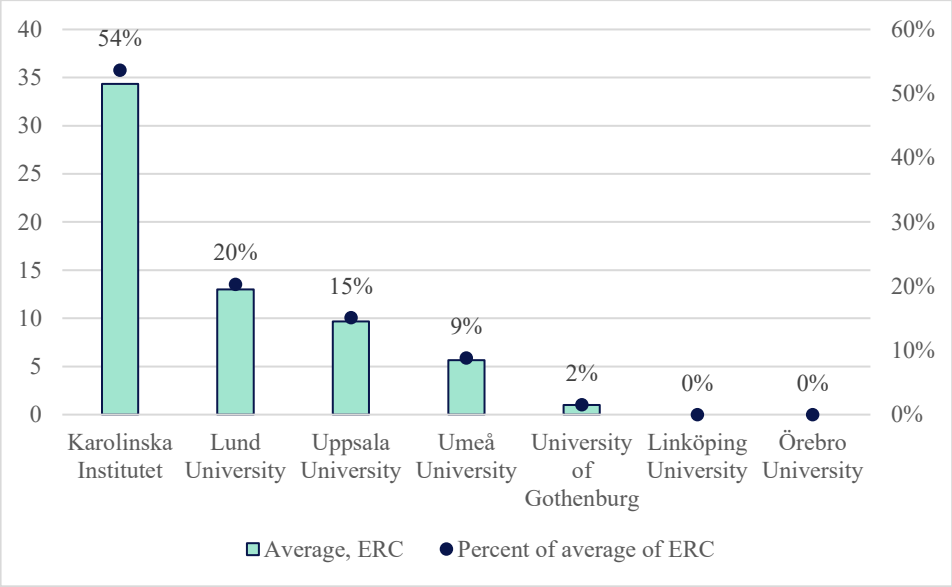
Figure 7. Average distribution of financial sources and HEI.



2.3.2 European Research Council

The HEIs in this evaluation obtain 99 per cent of the European Research Council (ERC) funding in basic medicine in Sweden. Karolinska Institutet obtains more than 50 per cent followed by Lund University with 20 per cent and Uppsala University with 15 per cent. The rest of the universities together have about 10 per cent of the ERC funding in Sweden.

Figure 8. HEIs average of ERC funding, million SEK and per cent of total.



2.4 Bibliometric statistics

In this section, the Swedish Research Council presents bibliometric statistics on publications in basic medicine from 2018-2022. The first section compares Sweden to other countries, followed by detailed statistics based on publications in various subdisciplines and from different Swedish HEIs.

2.4.1 Methods and indicators

The statistics are compiled using data from Web of Science[12]. Publications in Web of Science are categorised into at least one out of 250 subjects. For this evaluation in basic medicine, publications within ten subjects have been selected[13], referred to in this report as subdisciplines. In the figures, biochemistry is short for *biochemistry & molecular biology* and pharmacology is short for *pharmacology & pharmacy*.

For citation statistics, the Swedish Research Council employs a fractional counting method. This approach means that if a publication has two authors from different countries, each country is credited with half a publication and half a citation.

The proportion of highly cited publications indicates how large proportion of a countries or an organisation's publication volume is among the ten per cent most cited publications in the world. It is calculated for a country, for example, by dividing the sum of the country's publications that are among the 10 per cent most cited by the sum of all the country's publications. The global average for this indicator is ten per cent. If a country has a proportion of highly cited publications of 13 per cent, this means that the country has a 30 per cent higher proportion of highly cited publications than the world average.

The number of citations is counted using an open year citation window (i.e. all citations are counted) and self-citations are excluded from the analysis.

2.4.1.1 Text mining and visualisation using VOSviewer

In order to get an overview of the content in the publications within each discipline, term maps have been created using the program VOSviewer. This program provides a text mining functionality and can identify relevant noun phrases, terms, in documents. Noun phrases are sequences of words that function as a single unit, such as "breast cancer". In these maps, the distance between two terms is an indication of the relatedness of the terms. The size of the sphere illustrates how often the term have been used and the lines indicates where two terms have been used in the same publications. The different colours represent

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[12] For detailed description of the publication database and how indicators are calculated, see: *The bibliometric database at the Swedish Research Council- contents, methods and indicators* (2017). Vetenskapsrådets homepage.

[13] biochemistry & molecular biology, cell biology, genetics & heredity, immunology, medicinal chemistry, microbiology, neuroscience, pharmacology & pharmacy, physiology.

clusters of terms that often occurs in the same publications.[14] Individual term maps have been made on Swedish publications within each subject in basic medicine for the years 2018-2022 and are shown in appendix 5.

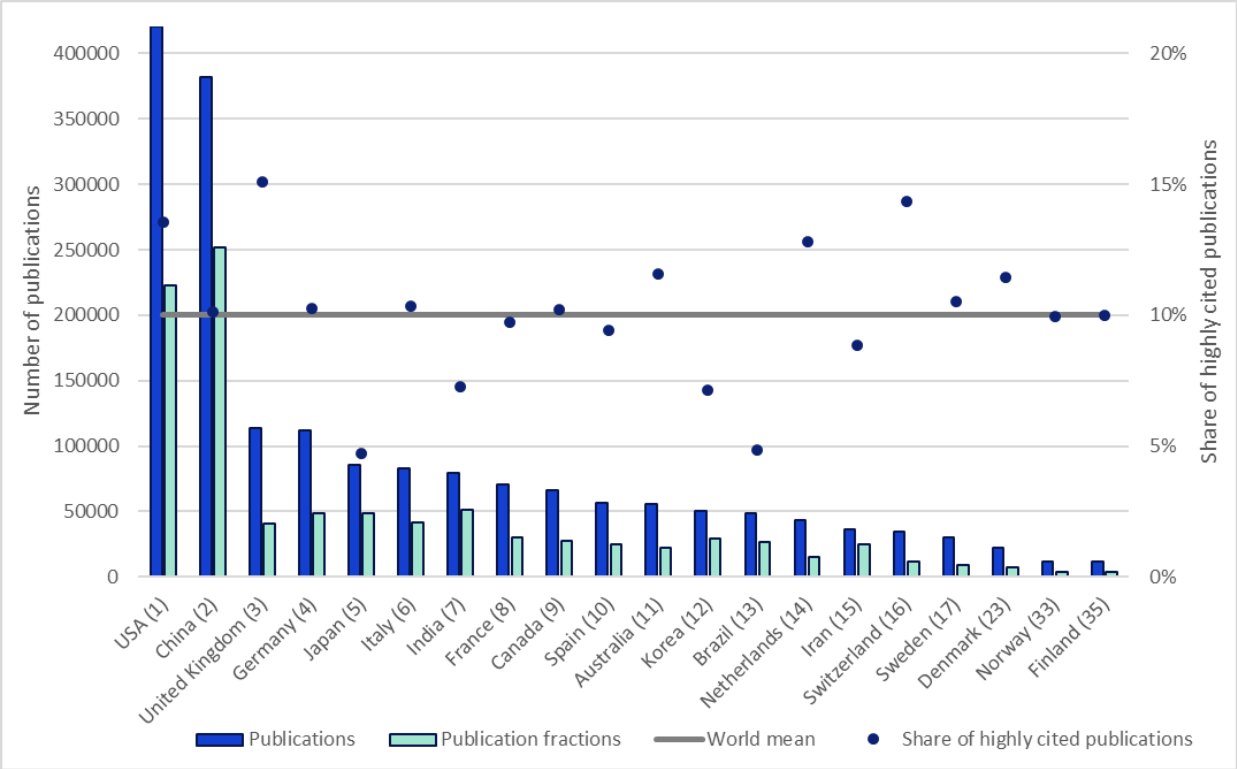
2.4.2 Basic medicine publications in the world

The countries that published the largest number of scientific articles within basic medicine between 2018 and 2022 are shown in figure 9. The actual number of publications is shown in blue bars, left axis, and the number of publication fractions is shown in turquoise bars, left axis. The citation impact is shown in dots, right axis, and the world average of citation impact at 10 per cent is indicated with a line. USA produced the highest number of publications whereas China had the largest number of publication fractions. This is explained by the fact that USA co-publish more with other countries than China does. The larger the gap is between the number of publication and publication fractions, the more co-publications a country has. Sweden is the 17th largest producer when it comes to actual number of publications and had around 30 000 publications from the period.

United Kingdom and Switzerland had the highest citation impact as measured by the share of highly cited publications. Their citation impact was around 15 per cent, which indicates that they had 50 per cent more highly cited publications than the world average. Swedish publications were also cited more than the world average and had a citation impact of 11 per cent. In comparison with our neighbouring countries, Sweden had a lower citation impact than Denmark, but slightly higher than Norway and Finland.

[14] Van Eck, N.J., & Waltman, L. (2011). Text mining and visualization using VOSviewer. *ISSI Newsletter*

Figure 9. Number of publications, number of publication fractions and share of highly cited publications, per country.

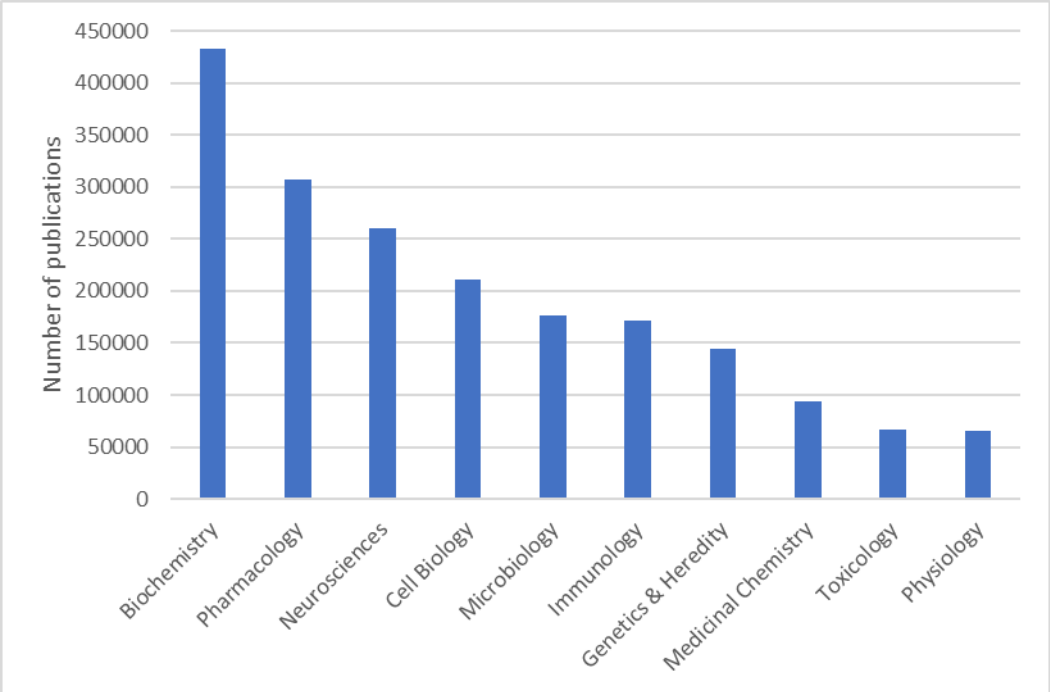


The numbers in the brackets indicate where the country is placed when it comes to number of publications. Source: Clarivate Analytics

2.4.2.1 Number of publications per subdiscipline

The number of publications within different subdiscipline in basic medicine from the world between 2018 and 2022 is shown in figure 10. The number of publications were highest within biochemistry and molecular biology and substantially less within toxicology and physiology.

Figure 10. The total number of publications in the world within different subdisciplines.

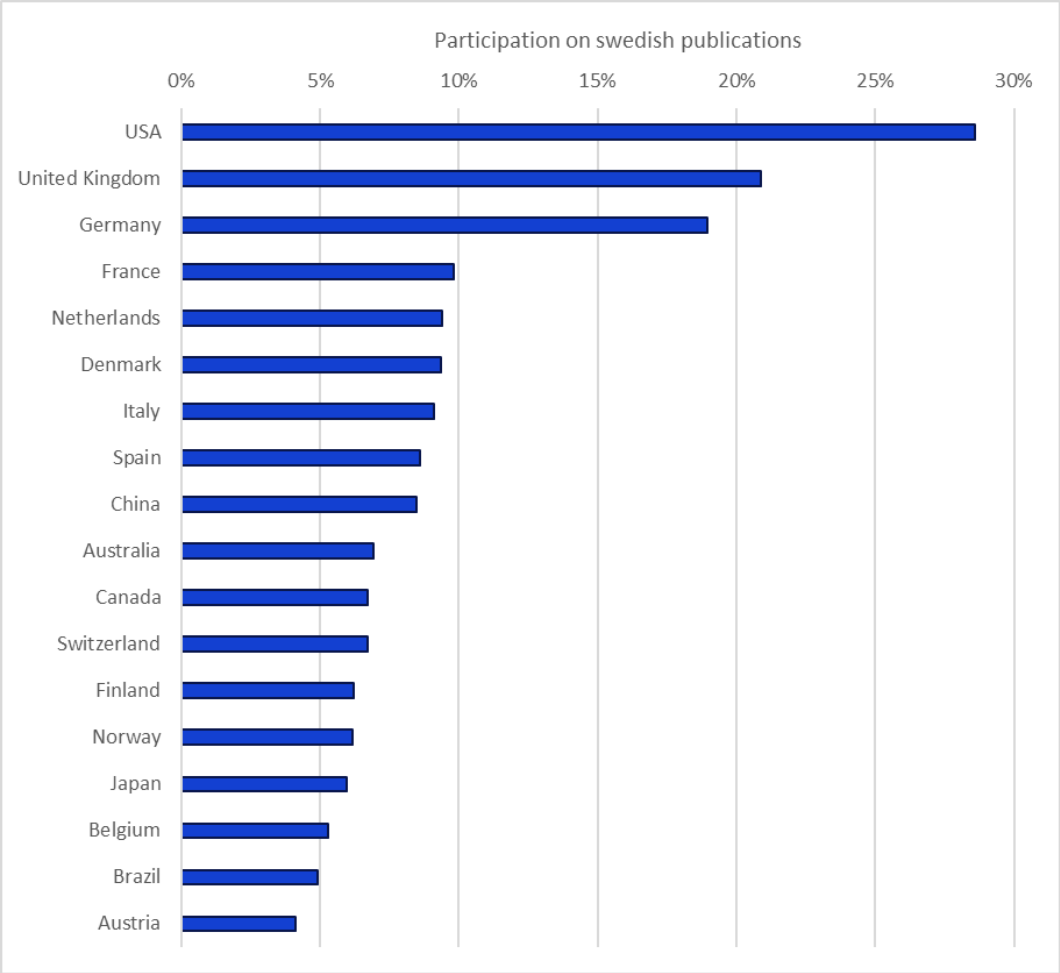


Source: Clarivate Analytics.

2.4.3 International co-publications

Figure 11 shows the countries that Swedish researchers co-publish with most frequently, in the form of proportion of co-publications out of all Swedish publications within basic medicine. Swedish researchers co-publish the most with researchers in USA; there is at least one author from USA on 28 per cent of Swedish publications. Swedish researchers also co-publish much with researchers from United Kingdom and Germany.

Figure 11. The proportion of internationally co-authored publications on Swedish publications, per collaborating country.

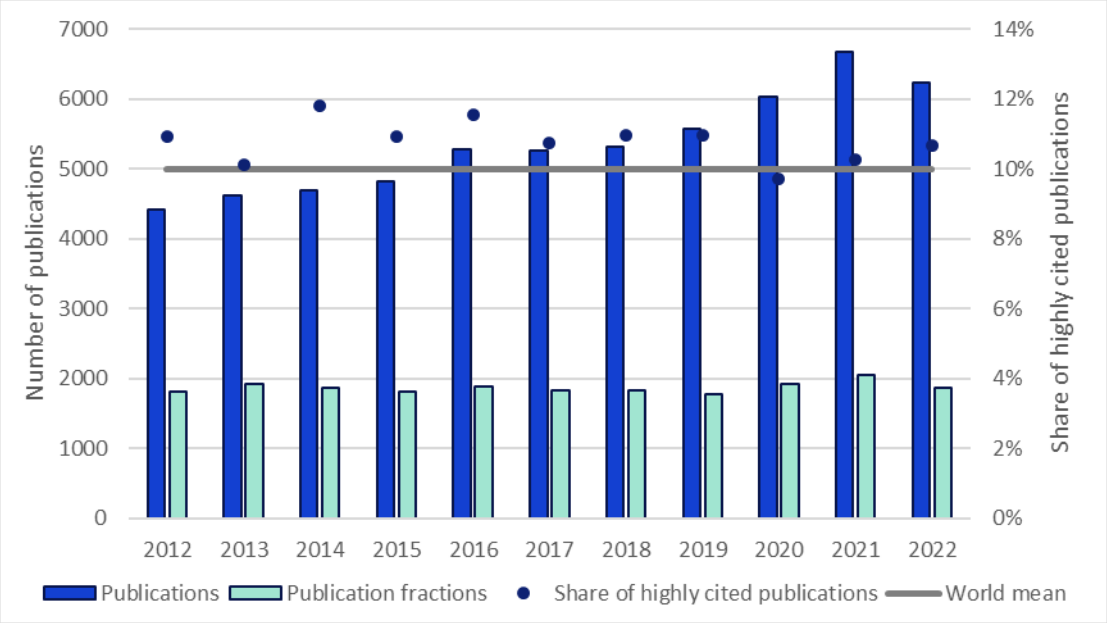


Source: Clarivate Analytics.

2.4.4 Swedish publications in basic medicine

Figure 12 shows the number of publications and share of highly cited publications within basic medicine from Sweden between 2012 and 2022. Whereas the actual number of publications has increased during the period, the publication fractions have been stable. This means that the numbers of international authors on Swedish publications have increased. In 2012 the average numbers of participating countries were 2,5 per publication, whereas from 2019–2022 the average number was 3,3 countries per publication. During the same period the average number of authors has increased from 9 to 13 authors per publication. The share of highly cited publications has been around 10–12 per cent during the period.

Figure 12. Number of publications, number of publication fractions and share of highly cited publications from Sweden, per year.

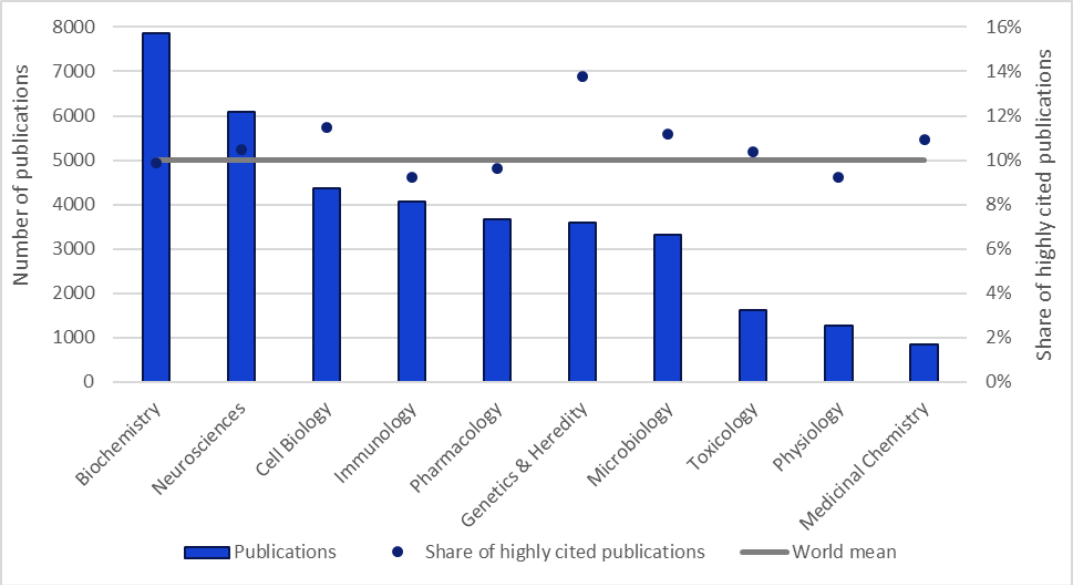


Source: Clarivate Analytics

2.4.4.1 Swedish publications per subdiscipline

Figure 13 shows the number of publications and share of highly cited publications per subject from Sweden between 2018 to 2022. Sweden published most within biochemistry and molecular biology and neuroscience and substantially less within toxicology, physiology and medicinal chemistry. In comparison with the world in total (figure 10), Sweden published a greater proportion within neurosciences, genetics and immunology, and a lesser proportion in pharmacology and medicinal chemistry. Sweden had a citation impact around world average in most subdisciplines. The highest citation impact was in genetics and heredity where the share of highly cited publication was 14 per cent. The lowest citation impact for Sweden is in immunology and physiology (9 per cent).

Figure 13. Number of publications and share of highly cited publications from Sweden, per subdiscipline.

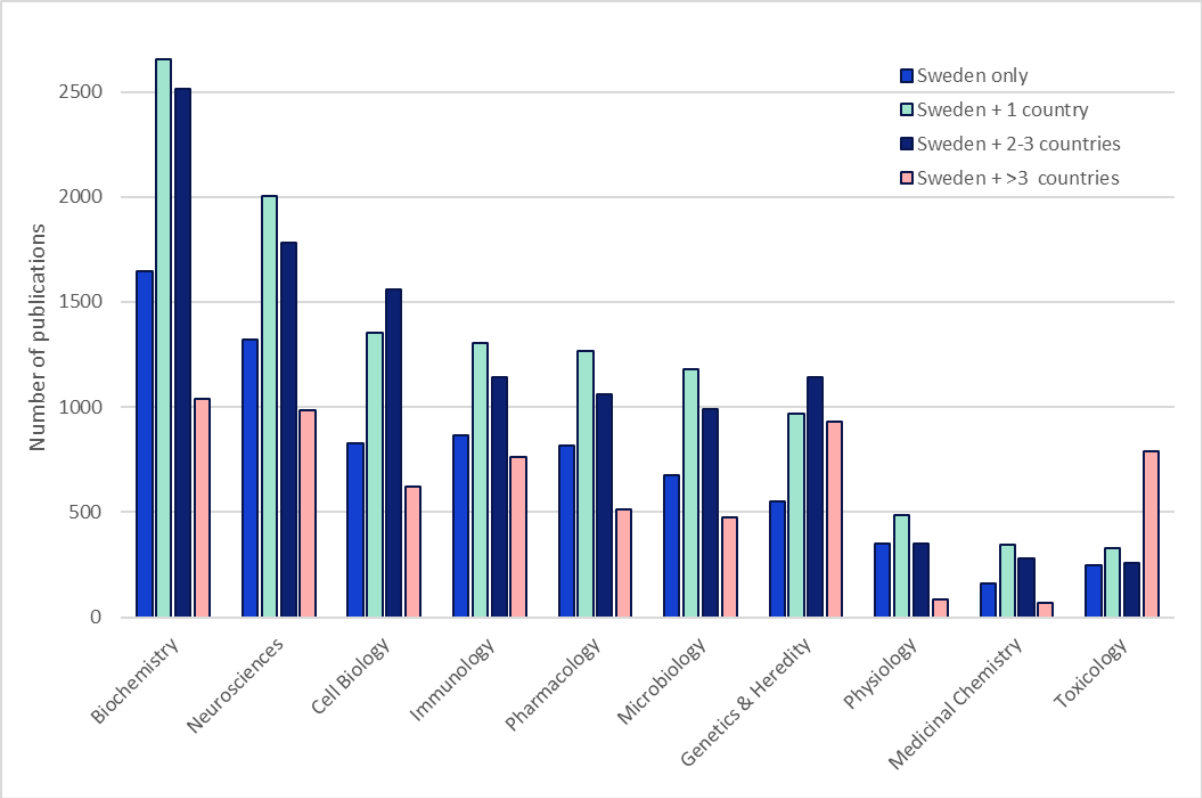


Source: Clarivate Analytics

2.4.5 International collaboration

Figure 14 shows the number of publications with international collaboration in different subdisciplines. More specifically the figure shows the number of publications with no international co-authors; co-authors from one other country; co-authors from two to three countries and finally the number of publications with co-authors from more than three countries. Co-publication with one to three countries was the most common way of publishing within most subdisciplines. One exception was in toxicology where publishing with more than three other countries was most common.

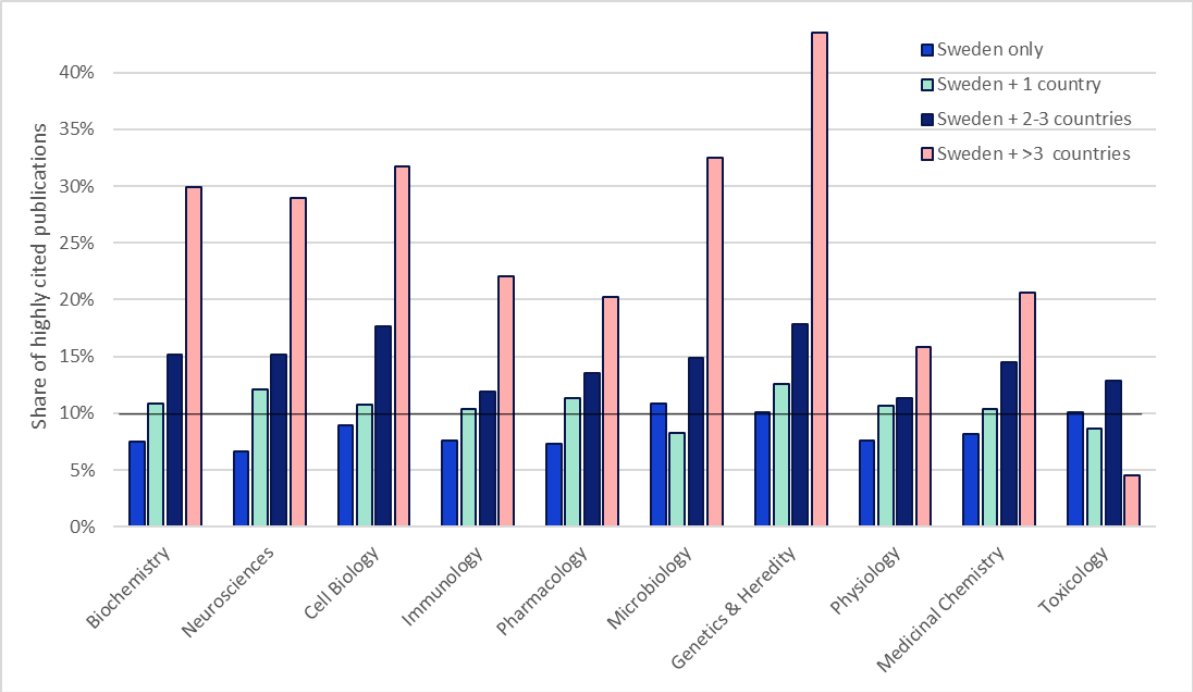
Figure 14. Distribution of publications across subdisciplines, along with the extent of international co-authorship.



Source: Clarivate Analytics

Figure 15 shows the share of highly cited publications of the publications in figure 14. The world average at 10 per cent is indicated with a straight line. International co-publishing has a big effect on the citation impact, the more countries involved in a publication, the more citations. Publications with only Swedish authors had a citation impact below world mean in most subdisciplines, except for microbiology, genetics and heredity, and toxicology. Already by co-publishing with one other country the citations increased noticeably. With co-authors from two to three other countries the citation impact increase further and co-publishing with even more countries had an enormous positive effect on the citation impact. There was only one exception and that was in toxicology. In toxicology there are many risk assessment reports included involving many countries and they are generally not highly cited.

Figure 15. Distribution of share of highly cited publications across subdisciplines, along with the extent of international co-authorship.

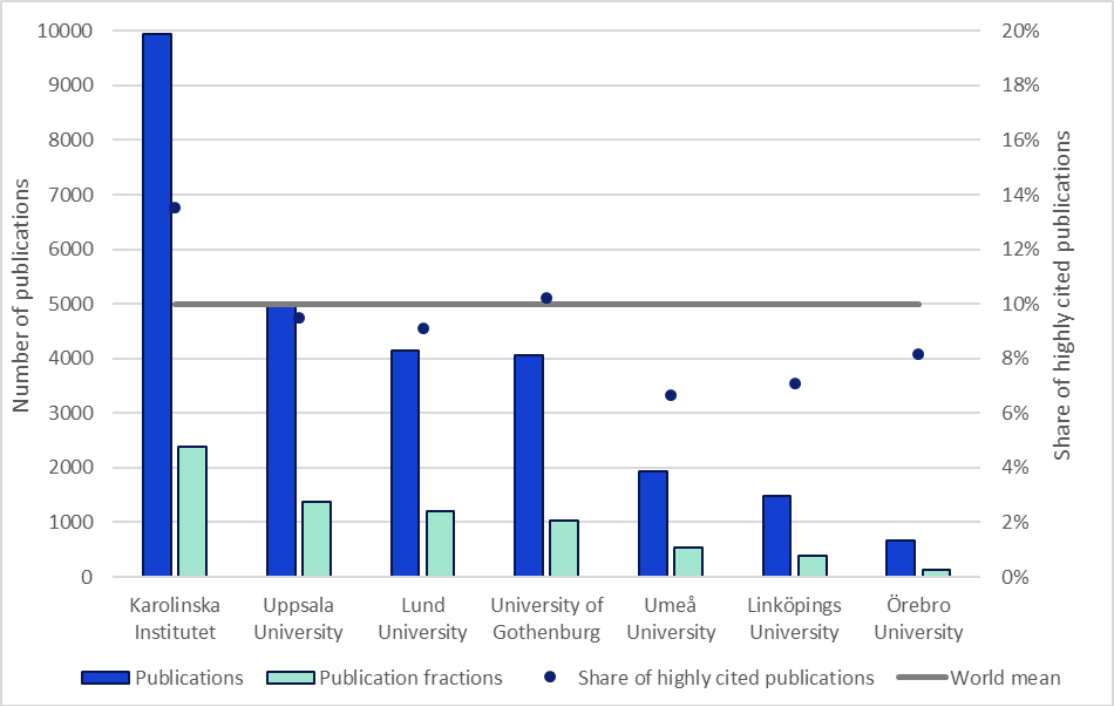


Source: Clarivate Analytics

2.4.6 Publication statistics per HEI

Figure 16 shows the number of publications, publication fractions and share of highly cited publications from the Swedish universities included in the evaluation. The number of publication fractions are about one fourth of the number of publications, which means that in average 25 per cent of the authors on the publications came from the university in question. Karolinska Institutet had the best citation impact, 14 per cent of highly cited publications. Uppsala University, Lund University and University of Gothenburg had citation impact around world average. However, Umeå University, Linköping University and Örebro University had citation impact below world average.

Figure 16. Number of publications, publication fractions and share of highly cited publications per HEI.



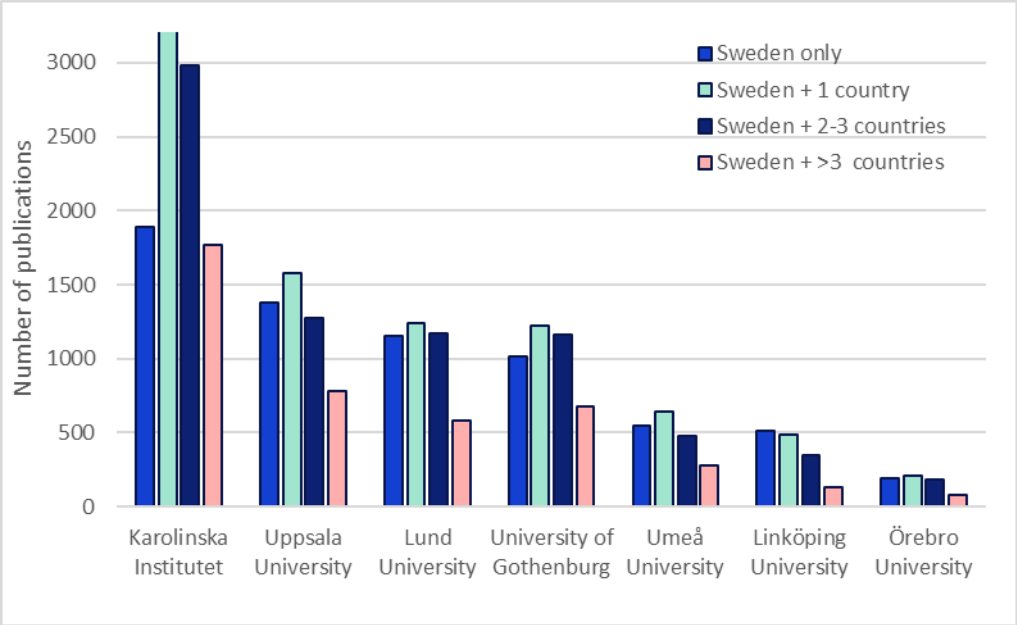
Source: Clarivate Analytics

2.4.6.1 Citation profiles-co-publications

Figure 17 shows the number of publications per HEI with: no international co-authors; co-authors from one other country; co-authors from two to three countries and finally the number of publications with co-authors from more than three countries.

For most universities the numbers of publications with Swedish authors only and with one or two to three other countries are fairly equal, whereas the number of publications with more countries involved are lower. An exception is Karolinska Institutet where the number of publications having only Swedish authors is lower than the number of publications with co-authors from one and two to three other countries.

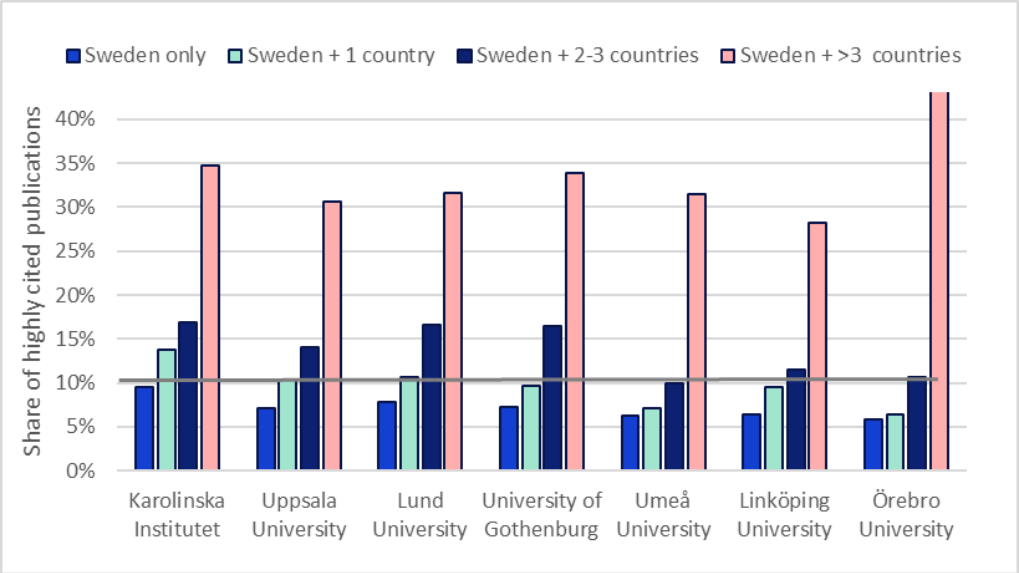
Figure 17. Distribution of publications across HEIs, along with the extent of international co-authorship.



Source: Clarivate Analytics

Figure 17 shows the share of highly cited publications among the publications in figure 16. The world average at 10 per cent is indicated with a straight line. As shown in figure 18, international co-publishing has a big effect on the citation impact, the more countries involved in a publication, the more citations. Whereas the citation impact for most universities was low on publications without any international co-authorship, Karolinska Institutet stands out with a citation impact close to world average even with only Swedish authors. With one other country involved all universities, except Umeå University and Örebro University, reached citation impact of world average. Where there are co-authors from 2–3 other countries, all universities reached world average, and several universities even reached high citation impact. Having co-authors from more than 3 other countries had an enormous positive effect on the citation impact and, in conclusion, the citation impact of the Swedish publications within basic medicine is heavily influenced by the number of international co-authors.

Figure 18. Distribution of share of highly cited publications across HEIs, along with the extent of international co-authorship.



Source: Clarivate Analytics

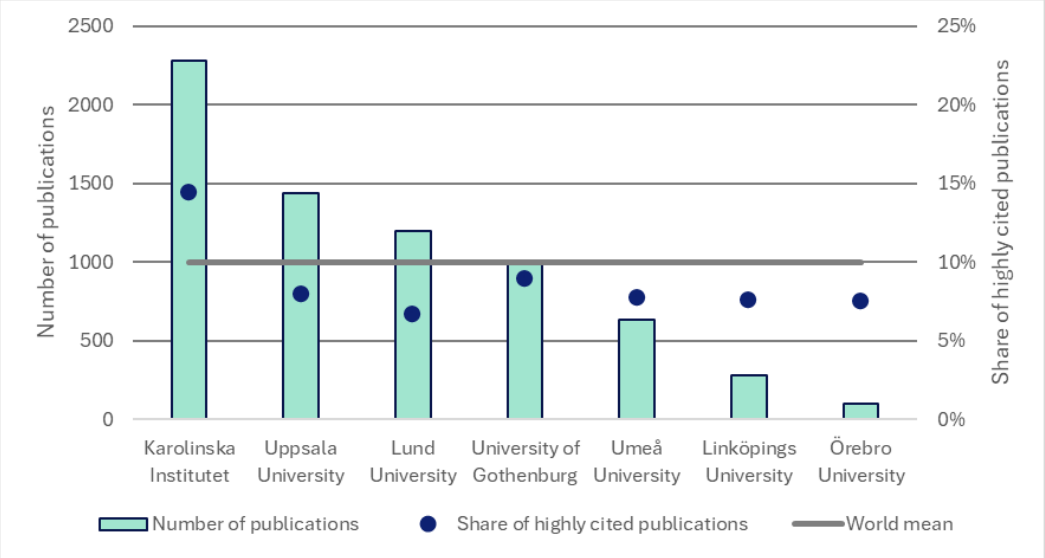
2.4.7 Publications per subject and HEI

In figures 19 to 29, publications (bars, left axis) and share of highly cited publications (dots, right axis) within different subdisciplines are shown for each HEI. It is important to take into consideration that if the number of publications is high, the citation impact is a statistically stable measurement, but the lower the number of publications, the more unstable is the value of citation impact. For some universities the number of publications is very low for some disciplines, and we do not show citations statistics with less than 100 publications. Hence, citation impact is not indicated for some universities in some figures, mainly for Örebro University. The subdisciplines are shown in order by highest number of publications.

2.4.7.1 Biochemistry and molecular biology

In basic medicine the highest number of publications is within biochemistry and molecular biology. Karolinska Institutet has the highest number as well as the highest share of highly cited publications in this. In fact, Karolinska Institutet is the only Swedish university that has a citation impact above world average in this subject. University of Gothenburg has a citation impact close to world average.

Figure 19 Number of publications and share of highly cited publications in biochemistry and molecular biology, per HEI.

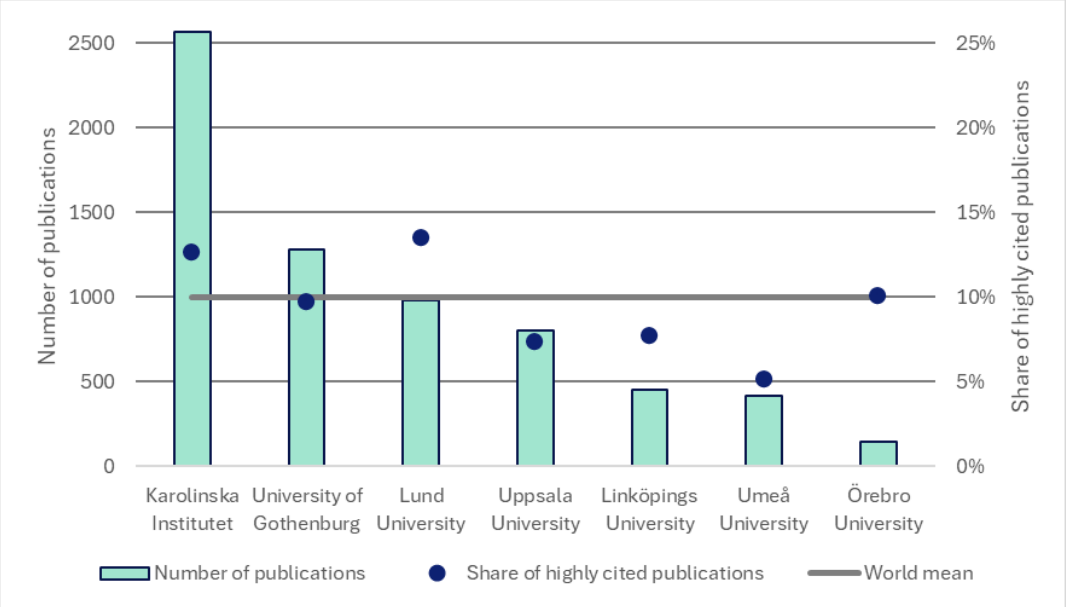


Source: Clarivate Analytics

2.4.7.2 Neurosciences

In neurosciences, Lund University had the highest citation impact followed by Karolinska Institutet which also had a citation impact above world average. University of Gothenburg and Örebro University had a citation impact around world average whereas Linköping University, Uppsala University and Umeå University were below world average.

Figure 20 Number of publications and share of highly cited publications in neurosciences, per HEI.

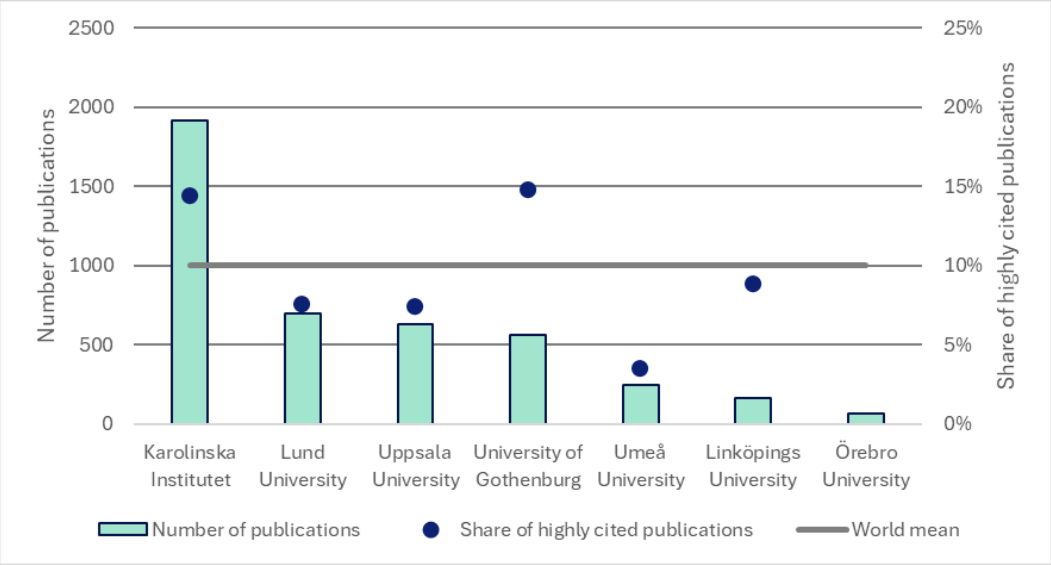


Source: Clarivate Analytics

2.4.7.3 Cell biology

In cell biology, Karolinska Institutet and University of Gothenburg both had high citation impact, around 15 per cent and Linköping University was close to world average. Lund University and Uppsala University had a citation impact around 7 per cent and the citation impact from Umeå University was 3 per cent. Citation impact is not shown for Örebro University since they have too few publications within cell biology.

Figure 21 Number of publications and share of highly cited publications in cell biology, per HEI.

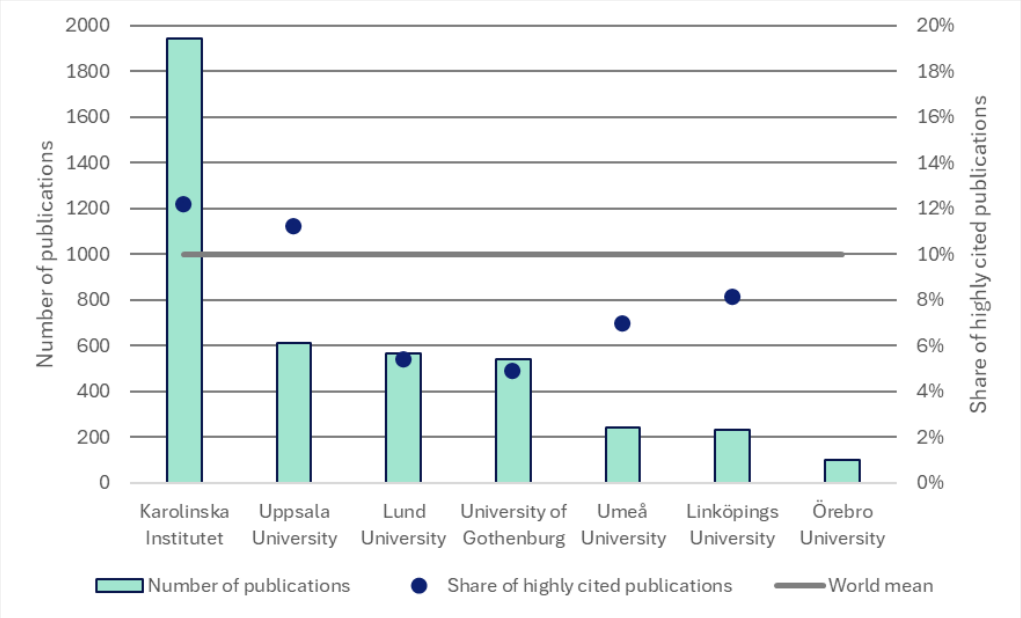


Source: Clarivate Analytics

2.4.7.4 Immunology

In immunology Karolinska Institutet was dominating with three times more publications than Uppsala University who was the second largest. Karolinska Institutet had the highest citation impact, 12 per cent. Uppsala University also had a citation impact above world average, 11 per cent, but Lund University and University of Gothenburg were only around 5 per cent. Umeå University had a citation impact of 7 per cent and Linköping University 8 per cent. Citation impact is not shown for Örebro University since they have too few publications within cell biology.

Figure 22 Number of publications and share of highly cited publications in immunology, per HEI.

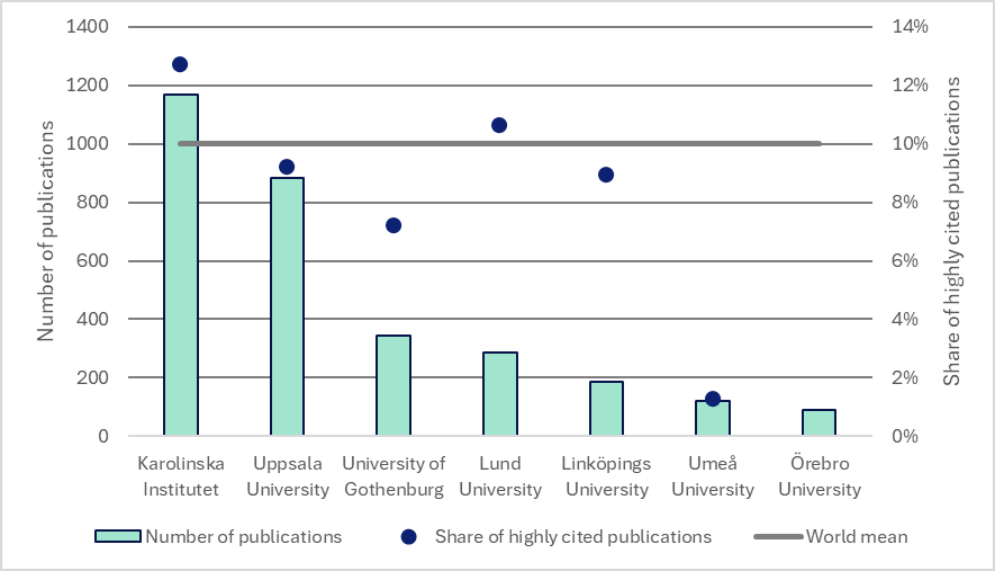


Source: Clarivate Analytics

2.4.7.5 Pharmacology and pharmacy

In pharmacology and pharmacy, Karolinska Institutet and Uppsala University had the highest number of publications, and Karolinska Institutet had the highest citation impact, 13 per cent. Lund University was slightly above world average, 11 per cent, and Uppsala University and Linköping University was slightly below, 9 per cent. Umeå University had a citation impact of 1 per cent but they also had very few publications within this subject. Citation impact is not shown for Örebro University due to low publication volume.

Figure 23 Number of publications and share of highly cited publications in pharmacology and pharmacy, per HEI.

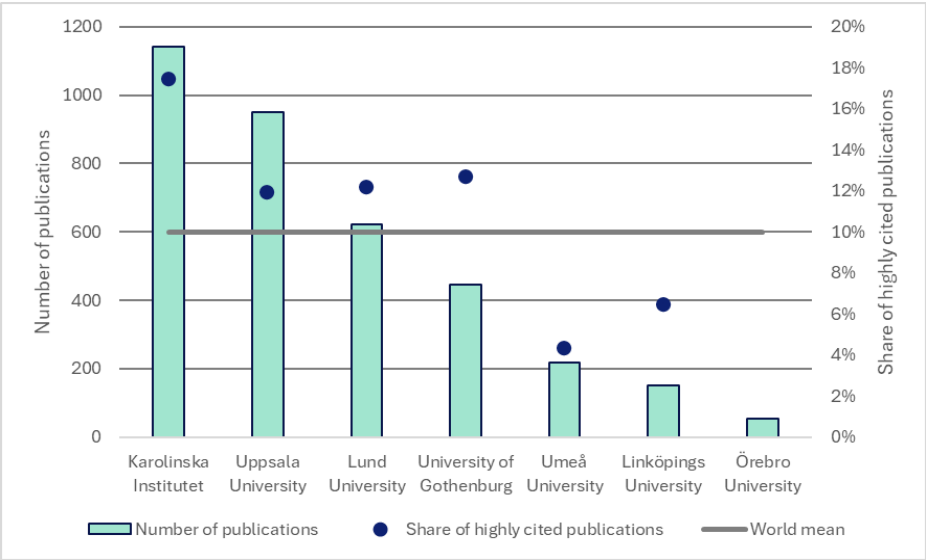


Source: Clarivate Analytics

2.4.7.6 Genetics and heredity

In the subject genetics and heredity, Uppsala University almost had as many publications as Karolinska Institutet, although Karolinska Institutet had higher citation impact, 17 per cent. Uppsala University, Lund University, and University of Gothenburg all had high citation impact, around 12 per cent. Umeå University and Linköping University had lower citation impact, 4 and 6 per cent respectively. Data is not shown for Örebro University due to low number of publications.

Figure 24 Number of publications and share of highly cited publications in genetics and heredity, per HEI.

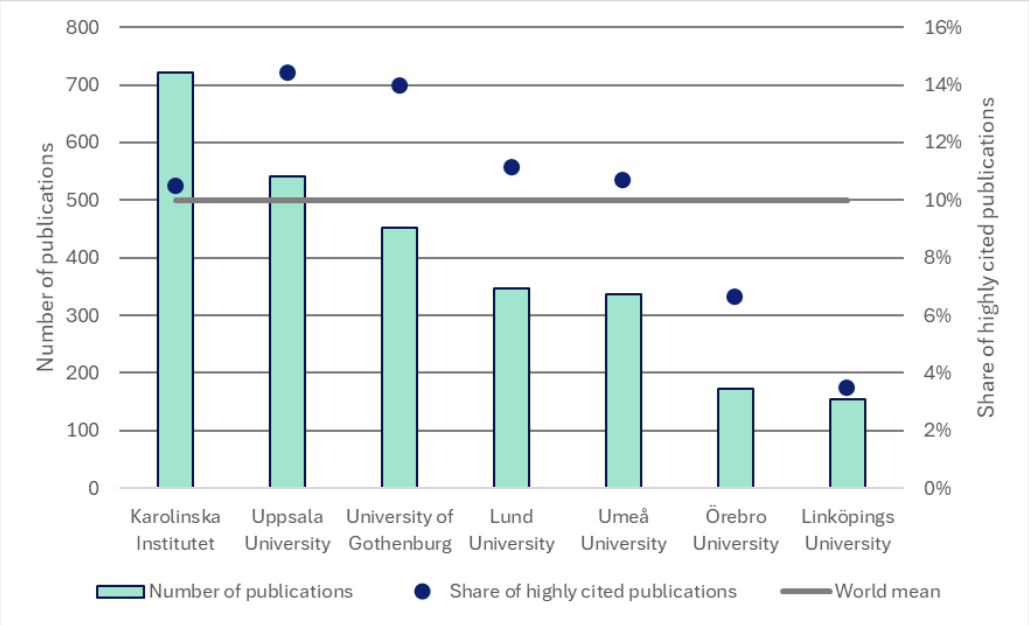


Source: Clarivate Analytics

2.4.7.7 Microbiology

In microbiology, Uppsala University and University of Gothenburg had high citation impact, 14 per cent, and Karolinska Institutet, Lund University and Umeå University were around 11 per cent. Örebro University and Linköping University had lower citation impact, 7 and 3 per cent respectively.

Figure 25 Number of publications and share of highly cited publications in microbiology, per HEI.

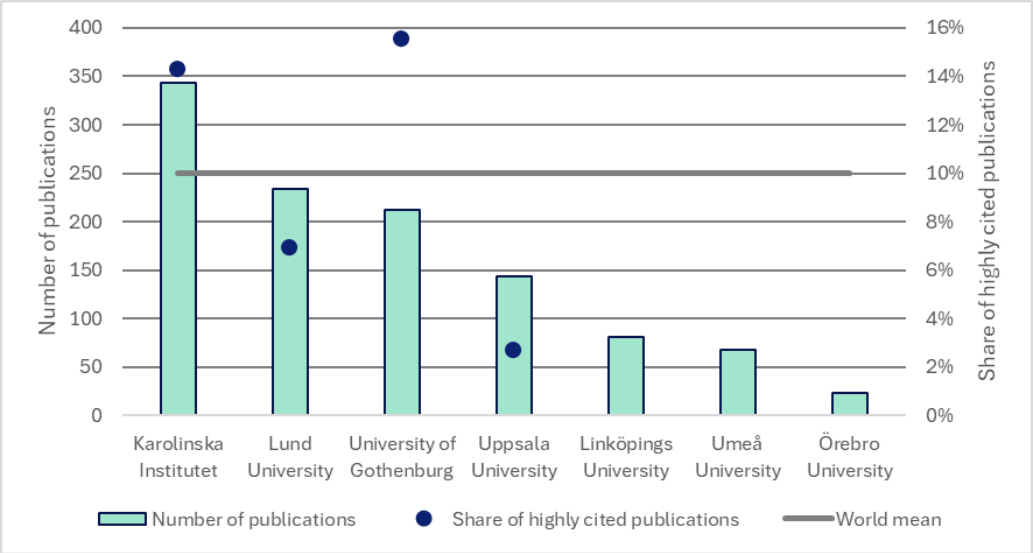


Source: Clarivate Analytics

2.4.7.8 Physiology

The number of publications in physiology was relatively low and citation impact is only shown for four universities. Karolinska Institutet and University of Gothenburg both had high citation impact, 14 and 16 per cent respectively. For Lund University it was 7 per cent and for Uppsala University it was 3 per cent. The percentages should however be interpreted carefully due to the low number of publications.

Figure 26 Number of publications and share of highly cited publications in physiology, per HEI.

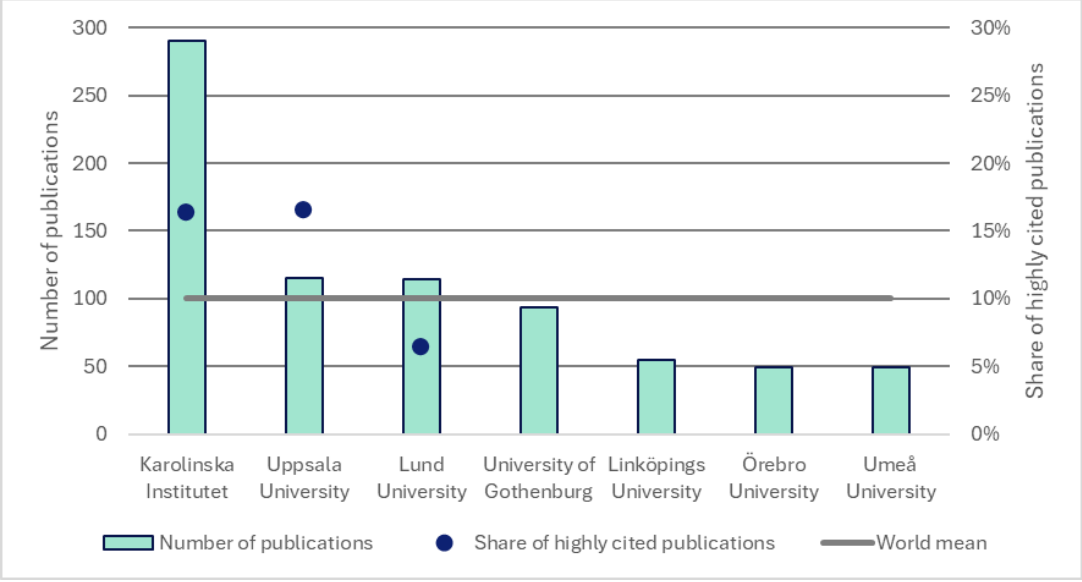


Source: Clarivate Analytics

2.4.7.9 Toxicology

The number of publications in toxicology was also relatively low and citation impact is only shown for three universities, and thus the percentage should be interpreted carefully due to the low number of publications. Karolinska Institutet and Uppsala University both had high citation impact, 16 per cent. For Lund University it was 6 per cent.

Figure 27 Number of publications and share of highly cited publications in toxicology, per HEI.

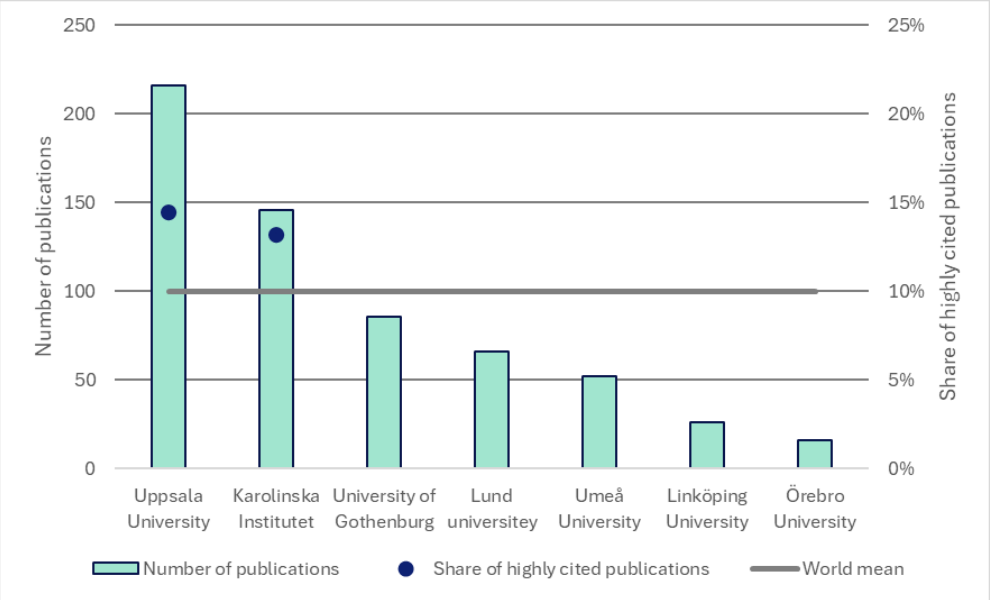


Source: Clarivate Analytics

2.4.7.10 Medicinal chemistry

In the smallest subdiscipline, medicinal chemistry, the number of publications was so low that the citation impacts are excluded for most HEIs in the figure. Interestingly, this is the subdiscipline where Karolinska Institutet did not have the largest number of publications, instead Uppsala University had the largest number of publications.

Figure 28 Number of publications in medicinal chemistry, per HEI.

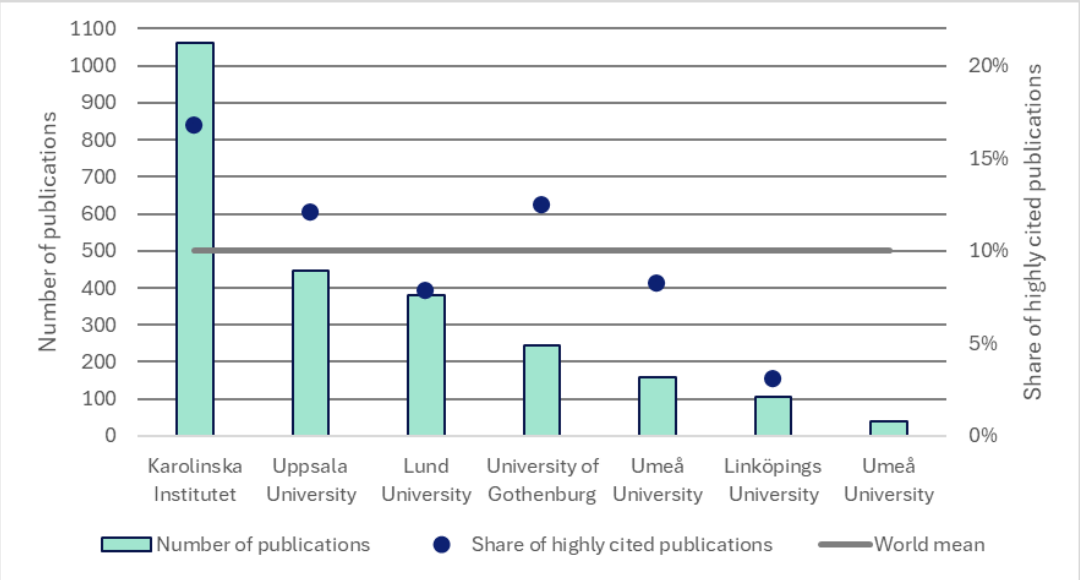


Source: Clarivate Analytics

2.4.7.11 Cancer biology

Cancer biology is not a s of its own in Web of Science. As a result, we have identified publications within this field using cancer related search words in titles and abstracts. In total there were 30 000 publications from Sweden in basic medicine. From these publications, 1955 publications had a cancer related word in the title or abstract and the number of publications and the share of highly cited publications per university in figure 29 are based on these publications. Karolinska Institutet had very high citation impact, 17 per cent, and University of Gothenburg and Uppsala University also had a citation impact above world average, 12 per cent.

Figure 29 Number of publications and share of highly cited publications in cancer biology, per HEI.



Source: Clarivate Analytics

3 The evaluation panel's report

3.1 Executive summary

The panel was assigned by the Swedish Research Council to evaluate scientific quality and societal impact of basic medical research in Sweden from an international perspective. The aim was to provide an overview, and a qualitative assessment of research based on a selection of top publication and case studies provided by the HEIs, and comprehensive bibliometric and statistical analyses compiled by the Swedish Research Council.

The publications submitted by the HEIs constituted 1.5 per cent of their total output in basic medical research. These publications were categorized into the following subdisciplines: biochemistry, cancer biology, cell biology, genetics, immunology, microbiology, molecular biology, and neuroscience. Correspondingly, panel members and external reviewers were organized into subpanels, wherein each publication underwent evaluation by a minimum of three reviewers. Assessments were conducted in accordance with the criteria established by the Swedish Research Council. Prior to the assignment of consensus grades, the publications were subjected to rigorous discussion within the subpanels. Each subpanel was presided over by a member of the main evaluation panel, as detailed in Table 5 of Appendix 1.

The overall view from the peer review was that the Swedish has excellent basic medical science across all subdisciplines. The vast majority of the research in the submitted publications is hypothesis-driven, although high quality method development papers were also submitted to several subdisciplines and highly ranked. Between 70 to 80 per cent of the submitted publications in each subdisciplines obtained the highest scores (4* and 3*), which impressively underlines the advanced standing of basic medical science in Sweden. However, given the selection of only the top 1.5 per cent of publications for assessment, a high overall publication score was anticipated.

The reported impact cases were diverse, spanning several key areas, particularly technological and innovative advancements, economic benefits, health improvements, and policy influence. However, some case studies presented potential or academic/scientific impacts rather than concrete socio-economic benefits. In several instances, descriptions of the pathway from research to impact was vague. Some studies also lacked sufficient evidence, making it difficult to verify the reported impacts. These gaps in clarity and evidence weakened the overall assessment to some extent.

According to national statistics on personnel in basic medicine, the gender distribution was roughly even, except for professors, with 70 to 80 per cent male bias. Karolinska Institute employs 35 per cent of all the quantified personal, with the largest proportion in the post doc category. It is also noted based on the

bibliometrics, that basic medical research enormously profits from international collaborations and recruitment of international scholars.

The panel unanimously identified the originality of the science, the high degree of inter- and multi-disciplinarity, funding, and access to excellent technology platforms as underlying reasons for the high quality of basic medical science in Sweden. The size of HEIs, the extent of funding and their integration into larger research campuses (with neighbouring HEIs) were also recognized as a quality-promoting factors.

3.2 International overview of basic medicine

The following section presents an overview of the pressing challenges facing society and explores the evolving trends within basic medicine. Understanding these interconnected domains is crucial for addressing contemporary health issues and shaping the future of medical research.

3.2.1 Challenges in society

The society faces significant health challenges, which underscores the enormous importance of basic medical research and clinical science. There is no question that basic medical science has made ground-breaking discoveries in recent decades, which have been transformed by industry and other actors into treatments of various types of diseases that were either poorly treatable or untreatable in the past. Although the developments are breathtaking and promising, basic curiosity-driven science must continue deepening our understanding of fundamental biological processes to provide knowledge and innovation in health care and societal well-being.

Artificial intelligence (AI), machine learning and big data have revolutionized basic as well as applied research in the last few years and found their way into 3D structure predictions of proteins, interpretation of biomedical images and molecular data, drug design and much more. The demand for professionals with this skill set combined with expertise in life science exceeds the supply leading to a fierce competition for these professionals nationally and internationally among the HEIs. It will become a Herculean task to attract people with these multidisciplinary skills into basic science and health science institutions both in Sweden and globally, and a priority for HEIs and health system to attract and train them as a matter of urgency. In health science also needs a similar search for personnel to develop precision medicine. This development, which precisely tailors treatments with patient-specific data, further highlights the importance of training aa new generation with combined research skills in HEIs. This process is already ongoing and has opened new avenues for personalized care.

There are numerous challenges that science must meet in the future. With the rising life expectancy, research of aging processes is needed to extend the “healthspan” of humans. Antimicrobial resistance has become a global health threat and mental illness has already become a major cause of illness. These complex health challenges require interdisciplinary insights and hence, it is

necessary to traverse traditional disciplinary boundaries to achieve the needed breakthroughs. Novel immunotherapies and CRISPR/-based gene therapies are now used to treat previously untreatable diseases. However, the high expectations of these novel therapies face restricted effectiveness, complex interdisciplinary pharmacology and high costs[15]. Only the inter- and multi-disciplinary nature of research combined with a refined research funding strategy can deliver the much-needed progress.

Creative and forward looking basic as well as clinical research requires financial support. The pressure to secure funding pushes scientists towards safer, more predictable studies and away from long-term, riskier studies that tend to produce truly novel and important findings. Funding must be competitive. However, short-term funding associated with the tremendous pressure to publish frequently and in high profile journals often rewards those who overhype findings and chase statistical significance. The consequence is that many published studies cannot be replicated. It is an urgent and important task for science funders to improve the current science funding system and create incentives to undertake longer, less predictable studies that provide opportunities for significant discoveries.

3.2.2 Trends

In the nineties and noughties, skills in molecular biology, cell biology and proteomics were key in the basic life sciences. Although knowhow in these subdisciplines is still essential, future successful laboratory work will be required in addition to these “traditional science skills”, different skill sets based on emerging trends in research and technology, which include AI and machine learning, open source, single-cell technologies, subcellular proteomics, CRISPR-mediated gene editing, and most importantly collaborations and to traverse disciplinary boundaries.

3.3 Overview of scientific quality

The review of the scientific quality was based on three main criteria: originality, significance, and rigour. High scores required excellence in all three areas, with originality reflecting important and innovative contributions to field knowledge, significance addressing potential impact within and beyond the field, and rigour strongly influencing the overall assessment through appropriate analysis, experimental design, and provision of interdisciplinary evidence. The evaluation revealed an extremely positive impression of top publications in basic medicine conducted by Swedish HEIs. Most of the submitted publications were highly ranked by the sub panels. The publications reported cutting edge research and were published in top journals.

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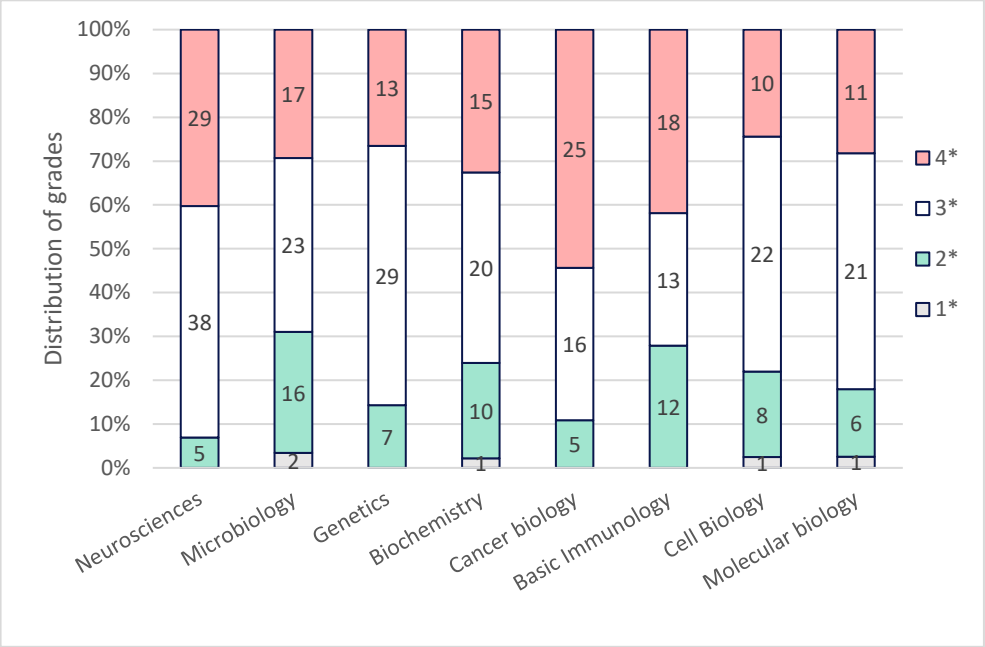
[15] Rueda, Beriain and Montoliu (2024), *Affordable Pricing of CRISPR Treatments is a Pressing Ethical Imperative*. The CRISPR Journal, Vol. 7, No. 5. DOI number: 10.1089/crispr.2024.0042

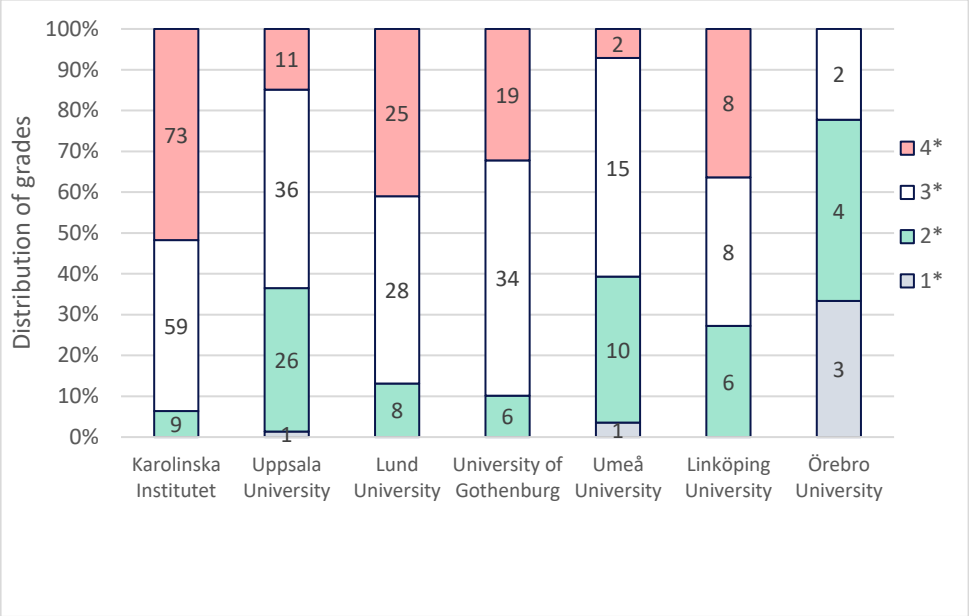
The results from the peer review per sub panel are shown in figure 30. The proportion of the grades are shown on the left axis and the number of publications receiving each grade are indicated in the bars.

Figure 30. Distribution of peer review grades, per subdiscipline.



In figure 31, the grades are shown per HEI. Karolinska Institutet hade the largest proportion of 4*, followed by Lund University, Linköping University and University of Gothenburg. Karolinska Institutet, University of Gothenburg and Lund University had the largest proportion of the top grades 3* and 4* and very small proportion of 2* and no 1*. A detailed table of the results from the peer review, per HEI and subdiscipline, can be found in Appendix 3.

Figure 31 distribution of peer review grades, per HEI.



The genetics research in Sweden was viewed as extremely strong and productive. It was noted that a proportion of the publications reported impressive datasets of global value but that more emphasis could have been placed on connecting the data to original research questions. there would be benefit in taking advantage of the large volumes of genetic data to execute fundamental mechanistic studies in biological systems. The publications dealing with cancer biology were from different disciplines (research subject in the basic medicine). The Swedish cancer biology is generally strong and provided several outstanding and excellent papers that impressed with quality and breadth, many of which delt with traditional oncogenic and tumour suppressor signalling and only few delt with molecular oncology. The biochemistry panel concluded in their review exercise that almost 80 per cent of the submitted output scored outstanding or excellent. In addition, it was noted that a substantial number of publications, most of them highly ranked, deal with metabolite-directed and drug discovery-directed research, while cryoEM- and cryoET-based structural studies were rare. The evaluation of the cell biology discipline also revealed a striking number of outstanding and excellent papers that impressed with originality, interdisciplinarity and the use of cutting-edge technologies. The Swedish cell biology community has clearly a strong international standing. Research in microbiology has always been strong and is still strong in Sweden. More than two thirds of the submitted publications reached an outstanding or excellent ranking. Highly rated publications dealt with the COVID-19 pandemic and microbiota-host interactions. It was noted that collaborations between microbiology and immunology sometimes resulted in particularly fruitful outcomes. The publications submitted to the molecular biology panel impressed with rigorous scientific performance. After reviewing the publications, the panel concluded that 80 per cent of the papers belong to the outstanding and excellent ranks. The papers reported hypothesis-driven work,

metadata and development of technologies. In the neuroscience panel almost 80 per cent of the submitted publications scored outstanding or excellent reflecting the traditionally strong standing of Swedish neuroscience research at the international level. The panel members noted that neuroscience greatly benefits from local and national facilities that provide high quality service in genomics, transcriptomics, proteomics, bioinformatics and neuroimaging.

It was also observed that publications with scores of 2* were of varying quality across the different subdisciplines. A considerable number reported competitive work with novel interesting findings, while the majority, however, scored low due to lack of mechanistic investigations.

The panel agreed that smaller universities in terms of staff and R&D expenditures also produced remarkably high-quality papers. One should also take into consideration that fewer students and staff (lecturers and researchers) make it more difficult for small universities to produce the same publication output, to arrange seminars, attend conferences and build networks with researchers locally. Smaller universities in Sweden also face challenges due to their 'regional' location, where they are not embedded in environments with multiple HEIs that facilitate scientific participation and exchange.

3.4 Subdiscipline basic immunology

Basic immunology identifies the complex network of cells, tissues, and organs that work together to protect us from pathogens like bacteria, viruses, and fungi. This research field is investigating how the body recognizes "self" from "non-self" and how it launches an attack against foreign substances. This includes the study of innate immunity as well as adaptive immunity. Basic immunology provides the foundation for understanding how our bodies stay healthy and how we can develop treatments for immune-related diseases.

3.4.1 Overall view of basic immunology subdiscipline basic immunology

A total of 43 publications were reviewed and discussed in detail by the international sub-panel members. The discussion was very transparent, open and scientific. The subdiscipline panel rated immunological research in Sweden as excellent overall. The research is internationally competitive, and the researchers are innovative and apply state-of-the-art technologies, including single cell work, sequencing, flow cytometry etc.

Immunology has developed into a very wide-ranging topic, interdigitating with many other disciplines and touching on virtually all disease areas. Dysregulation of the immune system is nowadays considered as one of the major pillars of many disease concepts and the pathogenesis of infectious and non-infectious diseases (NCDs). In the field of cardiovascular research, this regulation of the immune system is regarded as a major contributor to the development of diseases including arteriosclerosis. It is therefore not surprising that immunological research in Sweden covers a wide range of topics, including chronic

inflammation, autoimmunity, allergology, neuroimmunology and cancer research. However, cancer research was not part of the remit of this panel, as this was dealt with in a separate panel. Some of the published work was indeed paradigm-shifting. Many publications were more on the technical side. Overall, the data quality was high without any doubts and objections.

From the bibliometric report it was concluded that the proportion of high-cited publications in the field of immunology from Sweden is just below the global mean. Most immunology papers are published jointly with authors from another country, followed by publications with two to three other countries. This is a clear indication of international collaborative efforts in immunological research in Sweden. The share of highly cited publications is highest among publications published by Swedish authors together with collaborators from more than three countries. In contrast, the publications published by Swedish authors only are just below the 10 per cent threshold (world average). Overall, immunological research is therefore very much comparable with other fields of basic medicine.

Breaking this down by individual universities, it is evident that only Karolinska Institutet and Uppsala University have a share of highly cited publications above the world mean value. All other universities rank below the world means.

3.4.2 Scientific quality of subdiscipline of top publications basic immunology

The participating universities ranked in this subdiscipline, are slightly different. Karolinska Institutet and Lund University have traditionally been very strong in the past, and this is also the case in this evaluation. Of the 43 publications, 21 came from Karolinska Institutet, ten from Lund University, four each from University of Gothenburg and Uppsala University, followed by Linköping University with three and Örebro University with only one publication.

In terms of scoring, Karolinska Institutes has the highest proportion of high ranked publications, twelve 4* and six 3* publications. Lund University had four 4*, two 3* and four 2*. Uppsala University had three 3* and one 2*. University of Gothenburg had two publications with 3* and 2*. Linköping University had two 4* and one 2* and finally Örebro University's only publication was a 2*.

The subdiscipline panel would like to highlight nine publications from Karolinska Institutet, six of them covering the development of the immune system in newborn infants, and three of them determining spatial transcriptomics and lymphocyte clonal dynamics. Equally, highlight one publication from Lund University, which reports intestinal cross-tolerance. These publications were considered flagship studies.

For the future, the subdiscipline panel recommends leveraging more patient samples and materials. Increased collaborations with university hospitals and further international collaborations are also advised. Additionally, greater translation of research into clinical applications for diagnostics and treatments is recommended. There is significant potential for this in basic immunological

research in Sweden. The scope of the evaluated publications was however limited to basic medical science, which likely accounts for the lack of detailed clinical applications.

3.5 Subdiscipline biochemistry

Biochemistry broadly explores the chemical and physicochemical processes and substances that occur in living organisms. It integrates principles from biology, physics, and chemistry to understand the molecular mechanisms that govern cellular and organismal life. Biochemistry studies the interactions of macromolecules (nucleic acids, proteins, lipids, and carbohydrates) with each other and with metabolites, small-molecule effectors or gases, thereby defining how the resulting flow of molecule information generates order within the chemical universe to sustain life.

Biochemistry plays a pivotal role in driving biomedical discoveries and applications and integrates numerous, interconnected fields. Consistently, the Swedish biochemical research evaluated as part of basic medicine comprises several fields, such as molecular biology, cellular biology, biochemical method development and analytics, and small-molecule discovery, and material science.

3.5.1 Overall view of subdiscipline biochemistry

The biochemistry expert subdiscipline panel was extremely impressed with the very high quality of the 46 submitted publications.

Based on the bibliometric analysis, biochemical and molecular biology research world-wide has contributed most publications (well over 400.000 publications) within the field of basic medicine. In Sweden, Karolinska Institutet produced the highest publication number in biochemistry and molecular biology (around 2200 and approximately 30 per cent more than Uppsala University that ranks second in this metric). Karolinska Institutet holds the highest share of highly cited publications (14 per cent), followed by the University of Gothenburg which generated a citation impact close to the world average.

Overall, biochemistry in Sweden has excellent scientific output on the international level and ranks among the best in the world. Our conclusion is based on 46 publications. with a particular strength in metabolism related research and method development for innovative ‘omics’ or systems biology methods. The strength of biochemical research in Sweden is also reflected by case studies that have translated discoveries in metabolism and method development into impressive societal impact (please see chapter 3.6).

3.5.2 Scientific quality of cutting-edge publications of subdiscipline biochemistry

The biochemistry expert subdiscipline panel evaluated the 46 submitted publications and found them to be of very high quality in terms of interdisciplinarity, novelty, scientific reliability, and stringency, which is reflected

by an average rating of 3* over all papers, corresponding to “internationally excellent” in terms of originality, significance and rigour. Hence biochemistry in Sweden is important for the research field on an international level.

A total of 15 publications received the highest possible rating “world-leading” (4*) including nine publications from the Karolinska Institutet, five publications from the University of Gothenburg and one publication from Linköping University. An additional 20 publications were rated “internationally excellent” (3*), while a number of those received 4* from individual reviewers. Over 75% of the total publications were thus rated at least as excellent.

Below is the average score from the different HEIs:

- 16 publications from Karolinska Institutet were evaluated, with an average rating of 3,5
- 17 from the University of Gothenburg, with an average rating of 3,2
- five from Uppsala University, with an average rating of 2,6
- three from Linköping University, with an average rating of 2,7
- three from Umeå University, with an average rating of 2,3; and
- two from Örebro University, with an average rating of 1,5.

Karolinska Institutet and University of Gothenburg score overall above average. To a certain level larger and/or more highly funded HEIs produce higher-quality publications than smaller, less funded HEIs. The findings presented herein are based upon a restricted selection of publications from these institutions, and this constraint should be considered in their interpretation.

This range of topics is also reflected across all publications evaluated by the biochemistry subdiscipline panel. However, a few interesting trends can be observed: Over 20 per cent of the publications deal, in the widest sense, with the effects of metabolites or other small biomolecules and frequently employ global mass spectrometric approaches (“metabolomics”). A second noticeable group of publications focuses on the development of drug-like molecules by screening approaches or the analyses of the cellular targets and effects of drugs. Both topics – metabolite-directed and drug discovery-directed work – are slightly overrepresented among the most highly ranked publications, suggesting that biochemical research in Sweden is particularly strong in these disciplines, which are supported by significant core infrastructures. The same applies to studies that may be classified as “methods development”. While not particularly strongly represented overall (around 10 per cent), 2 such studies scored as” world-leading” (4*). Interestingly, both papers introduce new “omics”-approaches, underlining the trend described above. The strength of biochemical research in Sweden is also reflected by case studies that have translated discoveries in metabolism and method development into societal impact (please see below, section on societal impact).

Cryo-EM studies are not particularly highly represented among the papers in the biochemistry subdiscipline panel. However, the subdiscipline panel concluded that this is likely because some leading structural biology laboratories in Sweden belong to natural sciences departments, not included in the evaluation.

The few publications that were assigned lower scores (1* or 2*) do not show any particular commonalities; some are of a rather descriptive nature and others are rather brief communications.

In summary, the subdiscipline panel concluded that there is biochemical work in Sweden of extremely high quality and the investment in basic medicine and core infrastructures has enabled advanced technologies, such as metabolomics and small-molecule screening. This has paid off and will continue to be crucial for Sweden to be at the forefront of biochemical research.

3.6 Subdiscipline cancer biology

Cancer biology is a constructed subdiscipline in great part because cancer deals with failures in self-organization of biological programs and, accordingly, cuts across most of biomedicine.

3.6.1 Overall view of subdiscipline cancer biology

Cancer biology deals with a broad range of subjects and questions: cell cycle and cell growth, plasticity and differentiation, cell structure, genetics (molecular and population), tissue architecture and function, tissue wounding and repair, inflammation, pharmacology, medicinal chemistry, toxicology, clinical trials, screening, early detection of disease, care and treatment of patients, evolutionary biology, infectious disease, psychology, etc. Among the submitted publications surprisingly few were in molecular oncology (oncogenes, tumour suppressors, tumour microenvironment, targets and targeted therapy, immune-oncology).

The top ranked outputs (4*) included several novel screening methodologies (especially breast cancer), immuno-oncology studies shedding light on such as lymphoid structures, senescence and metabolomics. Of the 25 highest scoring submission, 12 were from Karolinska Institutet, 5 from University of Gothenburg, and 5 from Lund University. The overall quality of reviewed publications was very good indeed although none acquired “flagship” status.

In terms of comparative weight between the various institutions, the Karolinska Institutet is in a class of its own in terms of top quality as well as in funding. It also has a massive block grant and is a selectively biomedical university rather than a university having multiple scientific disciplines. This needs to be borne in mind when comparing the Karolinska Institutet with all other HEIs. Nonetheless, the traditional universities (especially Uppsala University, Lund University and University of Gothenburg) all also clearly has excellent research.

3.6.2 Scientific quality of cutting-edge publications of subdiscipline cancer biology

Within the cancer biology papers that we assessed, there was a fairly equal distribution of (arbitrary) fields: 7 in detection and screening, 7 in tumour profiling with proteomics and other ‘omics, 5 in classical molecular biology (e.g. cell cycle, oncogenes, tumour suppressors), 5 in signalling and signal

transduction, 3 tissues and stem cells, 2 on technological advances in detection and therapy, 6 on novel molecular therapeutic targets, 6 on classical tumour biology and 6 on immune-oncology. Of the total submissions in the cancer biology remit, 54 per cent were rated 4*, 34 per cent scored 3*, and 10 per cent were rated 2.0*.

Overall, the quality of the 4* publications is outstanding, not only in quality but also in breadth. Swedish research is also marked by extensive collaborations, both within Sweden and internationally. On occasions (e.g. AI Cancer diagnosis, CAR T cell development) Sweden has been first in Europe to import several innovative technologies. This demonstrates not only the excellence of the quality of research but also self-confidence and openness of the Swedish scientific community. Also, the level of infrastructural support available to Swedish investigators within their own and other institutions is impressive. The overall sense is that Swedish research system strongly support scientific research and the higher education institutions.

Internationally, Sweden punches above its weight across the board of cancer subdisciplines in terms of innovation, quality and overall publications.

3.7 Subdiscipline cell biology

The fields covered by cell biology can be broadly described as studies focusing on stem cells, tissue regeneration, metabolism and disease mechanisms. The evaluated research spanned multiple biological processes, including haematopoiesis, bone development, blood type conversion, neurodegenerative diseases, vision restoration, embryonic development, pancreatic function, atherosclerosis and metabolism. The studies use various techniques to investigate fundamental biological processes and potential therapeutic interventions for multiple diseases and conditions.

3.7.1 Overall view of subdiscipline cell biology

The evaluation of basic medicine in Sweden for 2024 involved a comprehensive review process of 43 publications by a subdiscipline panel of five experts.

The quality of the scientific output of the publications and case studies in cell biology was of high international quality and impressive. The highest-scoring publications were highly interdisciplinary, collaborative, and/or based on modern cutting-edge methods. Others contributed to the establishment of technologies supporting research worldwide. It was also noted that many publications, even within an institution, benefited from cross-departmental works, including clinicians, which appeared beneficial in relating mechanisms explored in cells to their effect in disease-relevant scenarios and tissues. This excellent “cross-fertilisation” of basic biology and clinics may have supported the outcome that virtually all studies, except for one, was reaching international standards (2*- 4*). Very strong papers shed light into mechanisms that are related to an important physiological function or medical problem.

The overall view of the subdiscipline panel was that the top publications in cell biology is excellent. Whilst more detailed comparisons with other countries are difficult to analyze, the general opinion was that the field was producing internationally competitive publications.

3.7.2 Scientific quality of cutting-edge publications of subdiscipline cell biology

The sub panel agreed that the submitted publications in cell biology showed that Swedish research in this field is of high international quality. A significant 76 per cent of the papers evaluated were rated as world-leading (4*) or internationally excellent (3*), demonstrating an exceptionally high standard of research. Publications are discovery-based and cover a wide range of biological and medical disciplines, from basic cell and molecular biology to applied clinical research and evolutionary studies. Whilst research spanned a variety of important fields including, vascular biology in relation to neurodegeneration, microbiology and transfusion medicine, microbiology in relation to evolution, ophthalmology, some of the key areas were metabolism in relation to diabetes and stem cell biology (including hematopoietic cell lineage and differentiation into different tissues).

During the evaluation, challenges arose with a few studies where the authors' contributions were unclear, particularly in cases where most of the research appeared to have been conducted at foreign institutions. In response, this led to eliminating two publications from the cell biology subdiscipline panel due to insignificant contributions from the submitting institution.

Of the total of 41 publications evaluated, ten received a 4* score, 22 were rated as 3* papers, eight achieved 2* status, and only one paper was rated as 1*. The institutional break-down of submissions showed that Uppsala University (11), Karolinska Institutet (10), and Lund University (9) contributed the most publications for evaluation. Karolinska Institutet demonstrated the strongest performance, with six of the ten 4* papers. Lund University followed with two 4* papers, while Uppsala University and Linköping University each had one 4* manuscript. The distribution of 3* publications was more diverse, with Uppsala University leading with six, then University of Gothenburg with five, and Karolinska Institutet and Lund University contributing four each. Umeå University had two 3* publications, and Linköping University had one. Uppsala University contributed four of the eight 2* publications, Lund University three, and Umeå University one.

There was ample evidence of ground-breaking discoveries reflected in the 4* publications. They spanned a wide range of medical fields involving cell biology. Many involved the use of modern or cutting-edge technologies that shed light on molecular mechanisms and cellular contributions to disease. For example, one study elucidated the role of perivascular fibroblast activity in the pathogenesis of ALS. The research was based on an innovative idea, supported by a comprehensive set of experiments and techniques, leading to an integrated molecular, cell biological and pathophysiological view of ALS that was clinically

relevant. Others uncovered a previously unknown stem cell niche in the epiphyseal growth plate, which is highly relevant to understanding growth and development. The rigorous use of genetic lineage tracing and novel insights into the regulation of this niche made this an outstanding publication. All the 4* manuscripts demonstrated exceptional originality of approach, with outstanding impact in their respective fields, supported by rigorous experimental execution.

The sub panel was also impressed by the publications rated 3*. Publications scoring 2* or 1* were in general slightly less rigorous in their analysis or more focused on developing methodologies. The main reasons for the lower scoring publications were a narrower focus on specific technical aspects and method development, or readouts for specific drug screening purposes without elucidating broader biological concepts. Despite this, they were considered to generate impact and provide valuable insights, particularly for drug-related research.

International collaboration was a significant factor in the scored publications where 65 per cent (27 out of 41) demonstrated involvement with at least one foreign institution. The prevalence of international collaboration increased with publication score. Specifically, 90 per cent of 4* publications (nine out of ten) and 63 per cent (14 out of 22) of 3* publications were a result of intensive international collaboration. In contrast, only 33 per cent of publications scoring 2* or below involved such collaborations.

International interactivity correlated with the institutional performance of Swedish universities in cell biology. Eight out of ten studies from Karolinska Institutet and all nine studies from Lund University involved international collaboration. All six of Karolinska Institutet publications rated as world leading (4*) involved international collaborations. In four of them, the senior corresponding author had an affiliation with an institution abroad. The two 4* publications from Lund University and the one from Uppsala University also had senior authors with affiliations in at least two countries.

The countries that were most frequently involved in collaboration with Swedish institutions were the UK and the USA (20 per cent), Finland (15 per cent), followed by Denmark and Germany (each 12 per cent). The participation of numerous countries in Swedish publications underscores the global reach and impact of Swedish research in this domain.

In conclusion, research in cell biology in Sweden is of high quality, internationally competitive and highly collaborative. This excellent performance contributes significantly to the advancement of the field worldwide and establishes Sweden as a key player in cell biology research.

3.8 Subdiscipline genetics and heredity

The subdiscipline of genetics and heredity covers human and model organism genetic studies in health including genome wide association studies, rare disease studies and large omics studies, especially transcriptomics. The genetics sub-discipline also includes epigenetics, epigenomics (non-Mendelian modes of

inheritance). It also includes non-constitutional genetic studies such as those in cancer. This subdiscipline overlaps peripherally with some other subdisciplines such as molecular biology and cancer biology, but the major areas reviewed had a strong genetics core.

3.8.1 Overall view of subdiscipline genetics and heredity

The sub-panel for the genetics subdiscipline were in good agreement in the assessment across most of the publications.

The bibliometric analysis concludes that Karolinska Institutet has the best citation impact across Swedish universities in basic medicine. Uppsala University, Lund University and University of Gothenburg have citation impact around world average. Umeå University, Linköping University and Örebro University have citation impact below world average. These data map to the size of the universities and their numbers of research active staff (PhD students to professors).

In genetics and heredity however, Uppsala University has almost as many publications as Karolinska Institutet, although Karolinska Institutet has a higher citation impact of 17 per cent. Uppsala University, Lund University, and University of Gothenburg all have high citation impacts, around 12 per cent. Umeå University and Linköping University had lower citation impact, 4 and 6 per cent respectively. Data is not shown for Örebro University due to low number of publications.

The overall view of the panel was extremely positive for the subdiscipline of genetics and heredity. There was evidence of a very high level of technical skills (e.g. as evidenced by large single cell transcriptomic studies), real-world applications to problems in Sweden (specific pathogenic variants and rare diseases) and a clear global integration illustrated through collaborations with countries such as the USA, UK and Germany among others. There are likely to be excellent omics core facilities supporting some of these impressive omics-based outputs which had a very cutting edge fell to them. The genetics outputs are largely focused on health with some very good quality fundamental research which plinths the understanding of mechanisms that are important as the building blocks of biomedical research. The sub panel wanted to note that technology-based research, while very important, may not sustain the high-quality research outputs without research based on original thinking and fundamental principles. It therefore applauds the ambition of the funder to promote basic science, and this subdiscipline panel further encourages follow on hypothesis-based genetic research from these high-quality research active Swedish universities.

3.8.2 Scientific quality of cutting-edge publications of subdiscipline genetics and heredity

The subdiscipline of genetics and heredity ranked 49 publications from the Swedish institutions where 13 was ranked as 4*; 29 as 3*; 7 as 2* and none as 1*. The top-ranking publications were derived from Karolinska Institutet, University of Gothenburg, Uppsala University and Lund University. The journal spread for

top scorers included broad and specialist journals, (Nature, Nature Communications, Nature Medicine, Nature Genetics, Science, Cell Stem Cell, The Lancet Diabetes and Endocrinology and Science Translational Medicine). The topic areas included transcriptomics, genetic variation in human disease, epigenetic variation in human disease, using omics to study genome evolution, diabetes, cancer and antibiotic resistance. This is a fairly broad disciplinary mix representing a good spread of expertise across the research community in Sweden. The level of scientific quality is therefore very high in the genetics subdiscipline and is contributing novel research outputs in several important contemporary areas of research with global visibility. The genetics studies focus on global health problems, with some studies tracking and understanding the mechanisms behind variants and disease sub-types afflicting Swedish populations. All these types of research were considered competitive and world leading in their contributions by the sub panel members. Novelty and originality were frequently attributed throughout the discussions, and the topic areas are important whether in health or in more fundamental research areas. No questions were raised or doubts cast over scientific reliability or stringency of any outputs.

There were seven submitted papers that ranked as 2* in both broad and specialist journals. The data collection quality was not of concern, but in one or two of the publications for example, studies associated phenotypes with molecular genetic findings that the panel thought could have had a stronger mechanistic link which rendered the research sound but perhaps still in early days in terms of cause and effect. Other studies were quite technically based and while sound in execution, did not push forward discovery research in the output, although they thought it might support another research later and so attracted a lower overall score.

Across many publications in the genetics subdiscipline, the panel observed that Swedish scientists have produced a lot of outputs where single cell transcriptomics or other genetic data has ‘catalogued’ a lot of information in several tissue or cell types. The major feedback from the sub-panel, despite the high impact and high quality of the work and of the journals in which the work has been published, was to ask what do these data contribute to our understanding of the system or to a disease scenario? The sub-panel suggested that future studies might benefit from focusing on how to use these large data resources and apply them to hypothesis driven research strategies rather than to generate more of them with additional closely related cell types or dis-ease conditions. Nevertheless, these outputs are timely, high quality and will contribute as useful open-source research resources globally.

In summary, the subdiscipline of genetics panel found that Swedish researchers are competing extremely strongly and making significant contributions to genetics.

3.9 Subdiscipline microbiology

Microbiology encompasses virology, bacteriology and parasitology and the science of the microorganisms and its host. The impact of microbiology on human

and animal health and medicine can be achieved through drugs, modulators and vaccines to prevent and cure infectious diseases but also through policy implementations.

3.9.1 Overall view of subdiscipline microbiology

Microbiology in Sweden is excellent and has maintained its long tradition of excellence in research in this field. A total of 58 publications were evaluated, of which 29 per cent achieved 4* and 40 per cent were rated 3* by the sub panel, supporting the conclusion that this field is at the forefront of biomedical sciences worldwide. From the bibliometric report it is concluded that microbiology has a proportion of highly cited publications above world average.

The highest quality publications are characterised by excellence in strategic research planning, state-of-the-art technologies used, validation processes of results and downstream mechanistic insights generated. This is reflected by publications in highly respected journals such as Cell, Cell Host & Microbe, Nature Communications, Science Immunol, Nature, PNAS, Nature Microbiology, EMBO J, which are not only general journals but also high-impact journals in the field.

Specific areas that can be mentioned are the pioneering role in the COVID-19 pandemic related research areas and the discoveries in microbiota-host interactions that are world leading due to the ability of the universities to use the national technology platforms as well as large scale clinical cohorts. In addition, the panel recognises continued excellence in the deep basic science of the biology of microorganisms and their interactions with the host. In some universities, particularly Karolinska Institutet, but also University of Gothenburg, the tradition of close collaboration between immunologists and microbiologists is evident and extremely successful considering the rapid response to the COVID-19 pandemic.

Microorganisms do not respect borders, and this is also reflected in the importance of international collaborations that Swedish basic researchers in microbiology have established. The publications submitted met the criteria of authors from Swedish universities (co-)leading the work, but it was also clear that international co-authorships led to highly cited papers.

In terms of funding of different universities, Karolinska Institutet is by far the best funded entity, bringing in a considerable amount of external funding, which enables the recruitment of post-doctoral fellows, which comprise a large proportion of the academic workforce. However, given the standing of Karolinska Institutet, the proportion of EU-funded income could be improved. In fact, this applies more generally to all HEIs, they should encourage researchers to apply from the European Research Council (ERC) and the European Innovation Council (EIC).

The gender aspect, overall, shows the same trend where the proportion of male/female is reasonable until the level of professorship, where the trends are strongly in favour of men. Hopefully, this is a point of concern that can be addressed now and in the future.

3.9.2 Scientific quality of cutting-edge publications of subdiscipline microbiology

A total of 58 publications were assessed. Karolinska Institutet achieved primarily 3* and 4* ratings. Uppsala University saw a range, with mostly 2* and 3*. Umeå University received a mix of 2*, 3*, and 4* ratings. The University of Gothenburg earned mostly 3* and 4*. Lund University's results were primarily 4*. Örebro University received one publication in each of the 1*, 2*, and 3* categories.

An important issue must be considered regarding the panel evaluation process. The pandemic situation in the COVID-19 period favored several papers to be published in high-ranked Journals following a scientific COVID-19 fashion and the urgency to publish preliminary data. Some of these papers, as they were evaluated by this panel, were not judged as cutting-edge publications because they include premature results.

For the sake of brevity, we highlight one 4* publication in each of the three categories highly represented as outstanding, original and novel: COVID-19, Microbiome, Basic Pathogen Biology:

Robust T cell immunity in convalescent individuals with asymptomatic or mild COVID-19, from the Karolinska Institutet, is a comprehensive and robust study on the polyfunctionality of spike-T cells. The study reveals functional memory T cells that can protect against recurrent infections. This early pre-vaccine publication on SARSCOV-2 highlights robust T-cell immunity in convalescent individuals with asymptomatic or mild Covid-19. What is remarkable is the rapid response to the COVID-19 pandemic and the organisation of the analysis of fresh samples, which shows a very well organised but also highly collaborative network working under very difficult circumstances. It is also an example of how basic virology and deep cellular immunology have been brought together with all the tools and expertise to provide the scientific community with much needed information.

A study from University of Gothenburg demonstrates the major role of TFH cells in gut IgA responses but also shows that we no longer need to focus on TH17 cells, as they were dispensable for gut IgA responses to oral immunisation with cholera toxin and ovalbumin. This has fundamental implications for the design of mucosal vaccines and adjuvants. The group is a world leader in IgA responses and uses a variety of technical approaches as well as advanced animal models to gain insight into the mechanistic aspects of the interaction between the microbiome, in particular segmented filamentous bacteria, and the gut immune system. Not only were flow cytometry, microscopy and single cell analysis combined, but specific mouse genetics was also used. This paper highlights the critical importance of animal models in basic medicine.

A publication from Lund University elucidated the mechanism of action of two TAC systems leading to the creation of a broad-spectrum, evolvable phage defence system. This outstanding work provides a mechanistic explanation of

antiphage defence using a toxin-antitoxin system. The study shows how direct recognition of a phage protein by a bacterial toxin-antitoxin-associated chaperone unleashes toxin activity to prevent infection. The work is a good example of interdisciplinary work where biochemistry, bacteriology, structural biology and phage genetics play complementary roles in unravelling the mechanisms of bacterial interaction with phages. This work may have implications for the development of new tools using phage technology to control bacterial burden. International collaborations are common to all the three flagship papers.

It is also encouraging to see young scientists flourishing, who seems to be conducting important basic medical research with high quality publications.

It is also noted that there is room for diversity within Swedish microbiology, where research in areas such as mosquito immunity is supported and carried out at a very high scientific level. In addition, the outstanding level of research is linked to the ability of research teams to collaborate within Sweden and as mentioned above, internationally.

Weaknesses were associated with the low ratings found in some of the COVID-19 related papers, which may have been rushed to publication before they were ready. Some show weaknesses in design, interpretation and experimental work. When considering areas outside of COVID-19, some of the papers were considered weak because they were only observational and lacked mechanistic investigations.

To ensure a sustainable lead in microbiology research, it is important that the research culture encourages early and mid-career researchers to apply for research grants. We also recommend that universities try to optimise the interactions between the hospital and basic researchers in order to fully capitalise on providing mechanistic insights into clinical problems.

3.10 Subdiscipline molecular biology

Molecular biology seeks to understand the fundamental building blocks and mechanisms that make life possible. It is a field that bridges biology and chemistry, and it plays a crucial role in advancements in medicine, biotechnology, and many other areas.

3.10.1 Overall view of subdiscipline molecular biology

The landscape of publications and case studies from the Swedish HEIs that participated in this evaluation shows a high level of quality in molecular biology. The submitted material reflects significant development and a high degree of innovation. The selection criteria and strategy used by the HEIs for the submitted material were somewhat similar to each other, relying on indexed sources followed by a manual selection process based on specific criteria. This approach generally provided a comprehensive overview of the research landscape. Karolinska Institutet stands out with regards to both the total number and the quality of its publications and case studies in this field. This is likely due to

Karolinska Institutet's focus on dedicated basic medicine research, while other HEIs adopt a broader scope.

Overall, the publications submitted to this panel demonstrated rigorous scientific performance across all HEIs, with the Karolinska Institutet standing out. Nevertheless, the other HEIs also showed excellent output despite having significantly lower R&D expenditures.

From the bibliometric report it was concluded that Karolinska Institutet has the highest number as well as the highest share of highly cited publications in this subject. In fact, Karolinska Institutet is the only Swedish university that has a citation impact above world average in this subject. University of Gothenburg has a citation impact close to world average. This correlates with the fact that Karolinska Institutet obtain 50 per cent followed by Uppsala University and Lund University with 17 respective 12 percent of all sources of R&D expenditure in Sweden.

3.10.2 Scientific quality of cutting-edge publications of subdiscipline molecular biology

A total of 39 publications, approximately 10 per cent of all submitted publications for this evaluation, were submitted for molecular biology. Most of these publications came from Karolinska Institutet (15), followed by Uppsala University (9), the University of Gothenburg (7), Lund University (6), and Linköping University (2). The average scores for the publications in molecular biology were fairly consistent across the HEIs. Karolinska Institute, the University of Gothenburg, and Lund University received similar average scores of 3.3*, while Uppsala and Linköping universities achieved average scores of 2.5*. Notably, no papers were submitted from Umeå University or Örebro University in the field of molecular biology.

The sub panel was generally impressed by the level of scientific input coming from all the HEIs. In particular the contributions from smaller universities in terms of staff and R&D expenditure. The strong representation of fundamental research was highly appreciated. The discussion at the consensus meeting focused strictly on the quality of the research, the way how findings were validated, and the models used for those validations. A distinction was made between work that was more innovative and that which was more incremental, such as metadata analysis. Scores were not determined by citations or journal impact factors, although HEI initially based their decision on paper submissions on citation scores, which the panel agreed do not accurately represent scientific quality.

The overall quality of the publications in molecular biology was exceptionally high, setting a benchmark for other countries regarding technological advancements and representing ground-breaking research on a global scale. Even smaller universities were able to produce remarkably high-quality papers, of which many focus on technology development, further enhancing the scope of innovation. The research covers topics such as fundamental biological studies in transcriptomics, bioinformatics, mitochondrial biology, and metabolism,

reflecting the advanced platforms and unique technological resources available to life scientists in Sweden. Additionally, this may indicate the transcriptomic developments that have been pioneered in Sweden.

We would like to highlight two exemplary publications that received a unanimous score of 4*, reflecting their quality and impact. The first was submitted by the University of Gothenburg, and the second by Karolinska Institutet. These works serve as excellent examples of research excellence in the field of molecular biology. The paper from Gothenburg University showed that efficient RNA turnover by REXO2 (RNA Exonuclease 2) is required to maintain promoter specificity and proper regulation of transcription in mammalian mitochondria. This offers a very important and broad link between dinucleotide metabolism and transcriptional choices in mammalian mitochondria in vivo and in vitro, providing novel and relevant insights on mitochondrial transcription initiation. This work is technically and conceptually of very high quality and likely challenging to set up.

The second example revealed functions of Smc5/6 at the molecular level and establish DNA loop extrusion as a conserved mechanism among eukaryotic structural maintenance of chromosomes (SMC) protein complexes, which is essential for the spatial organization of chromosomes in eukaryotic. This paper presented an excellent combination of in vitro biochemistry/biophysics and in-cell studies to show, for the first time, the loop-extruding capacity of this cohesion subcomplex, a novel insight on the mechanisms and molecules involved in the structural maintenance of chromosome structure. This is a significant contribution to the field of molecular biology.

These two examples reflect the fundamental nature of the science conducted in these HEIs, which has a broad impact on basic biology. Publications with scores below 2* also demonstrated high quality, featuring less innovative and more incremental knowledge along with few limitations such as lack of validation experiments.

In summary, a considerable number of published papers showcase pioneering work in the field of molecular biology at the HEIs that provided the publications, characterized by innovative approaches and significant findings. While some exceptional publications present ground-breaking contributions, others are indeed high-quality yet more incremental in nature, reflecting a diverse landscape of research excellence.

3.11 Subdiscipline neuroscience

“How does the brain work?” is arguable one of the greatest scientific questions of our time, but it also represents a formidable research challenge with many layers of complexity, some of which might have not been fully recognized yet. Complex questions often require elaborate, innovative and “out of the box” approaches, whereas one kind of knowledge or any amount of this particular knowledge does not suffice. To tackle how the brain works, the subject matter of the neurosciences field, it will most likely require an interdisciplinary approach to harmonise

information of many different disciplines in a coordinated and coherent whole. Departing from a traditional neuron-centric view, nowadays the formation and functioning of the nervous system in health and disease is seen as the collective and emergent outcome of dynamic and intricate interactions between different glia cell types and neurons.

3.11.1 Overall view for subdiscipline neuroscience

The members of the Neuroscience sub-panel found that the overall quality of the evaluated publications was in general very good or excellent. Although some of the publications submitted dated as far back as 2018 the panel was careful in evaluating these papers in the context of the research done at the time and their impact since then. In some publications the affiliation included, in addition to foreign institutions, two or more Swedish universities and shared senior co-authorships. The panel considered internationalisation and collaborative work between institutions important to foster excellent research and was happy to see that this was the case in a large number of the publications evaluated.

The neurosciences sub-panel evaluated 72 scientific publications and of those 29 were marked as 4* (40 per cent), 38 as 3* (53 per cent) and 5 as 2* (7 per cent). No scores of 1* were given. Main key criteria for evaluation included originality and innovation (i.e. novel ideas or insights that are disruptive or advance our knowledge and are not only incremental) and the contribution(s) to the field (i.e. addressing an important research gap, challenging established knowledge and offering new insights). In general, publications considered of outstanding or high quality were published in high impact factor journals and also amassed the highest number of citations, some in a relatively short period of time. The excellent quality of the neuroscience publications reflects also the high level of funding of the neurosciences in Sweden of which Karolinska Institutet has by far the biggest share. Nevertheless, the subdiscipline panel found commendable the quality of publications coming from other universities (e.g. Gothenburg and Lund) in which the R&D funding is a fraction (1/4 to 1/5) of the one available to Karolinska Institutet. Overall, the subdiscipline panel was unanimous in highlighting the importance of continued funding of excellent fundamental research deemed critical to the high quality of translational research and reflected in the high socio-economic impact reported in some of the case studies. These case studies were evaluated on the merits of economic (e.g. IPs, start-ups, companies, financial returns) and on social impacts (e.g. better medical diagnostics, treatments, etc.).

3.11.2 Scientific quality of cutting-edge publications of subdiscipline neuroscience

The subdiscipline panel considered the quality of the scientific publications to be in general outstanding, in their majority achieving 4* or 3*. This reflects the importance of the neuroscience research in Sweden and also its overall internationally high standing and reputation. Although most of the institutions selected their papers on the basis of bibliometrics, the panel did not base its evaluation on these metrics but rather focused on novelty, originality and contribution to the field, and on the excellence of hypothesis driven research.

Members of the subdiscipline panel commented that at least some of this quality comes from the cutting-edge technology facilities and centres available at Swedish universities essential to enable the high-quality genomics, transcriptomics, proteomics, bioinformatics, and neuroimaging (MRI and PET) studies reported in many neuroscience publications marked with 4* or 3*. These research facilities were deemed to be a great and essential asset to maintain and advance the excellent quality of Swedish Neuroscience. There was also consensus on the high quality and comprehensiveness of the clinical cohorts supporting outstanding and impactful translational neuroscience (e.g. blood biomarker discovery for neurodegenerative disorders, MRI and PET) reported in some of the publications. Good examples include publications from Örebro University. The neuroscience panel noted that this outstanding research from Örebro University was the result of many years of excellent basic research, highlighting the key and vital importance of continued financial support of fundamental research to reap the benefits later.

The few scientific publications marked with 2* were in general of very good quality, showing methodological rigor and robust experimental evidence for the conclusions reached but deemed less disruptive and mainly incremental (which is also important) and, consequently, of lesser impact. No issues on scientific reliability or stringency were found in any of the papers assessed.

The neuroscience panel members pointed out that some areas of neuroscience were underrepresented in the publications available for evaluation. These included areas such as human iPS and 3D organoid cultures, which are increasingly thought to be valuable pre-clinical research models important to reduce the species gap of studies traditionally relying in animal models; functional studies (e.g., based on or including electrophysiology, behaviour testing, etc.) and cognitive neurosciences. The subdiscipline panel observed that some studies were solely based on state-of-the art transcriptomics and although providing important insights (e.g. about heterogeneity of cell populations) they were a bit unidimensional and descriptive and could have benefited of complementary approaches with advanced data analytics, computational biology and modelling, functional proteomics to gain more mechanistic insight. Neuroinflammation was also underrepresented. This was a bit surprising considering the outstanding quality of Swedish immunology and inflammation research. Supporting interdisciplinary disciplines may constitute a good opportunity to promote further disruptive and impactful research in the future.

3.12 Overview of societal impact

The reported impacts were diverse, spanning several key areas, particularly technological and innovative advancements, economic benefits, health improvements, and policy influence. Many case studies effectively outlined the background, context, and significance of their research and its impact, providing a clear explanation of the problem they aimed to address. In numerous cases, the sections describing the enabling conditions for achieving impact were particularly

well-crafted, offering valuable insights into the broader environment that facilitates research-driven outcomes.

However, some case studies presented potential or academic/scientific impacts rather than concrete socio-economic benefits, which fall outside the intended scope of the evaluation. Additionally, some studies lacked sufficient evidence to substantiate their claims, making it difficult to verify the reported impacts. In several instances, the narrative describing the pathway from research to impact was vague, failing to clearly demonstrate how the reported outcomes were directly linked to the underlying research. These gaps in clarity and evidence weakened the overall assessment to some extent.

Overall, based on the demonstrated societal impact of basic medicine, the panel considers Swedish basic medicine to be highly successful. It concludes that without foundational discoveries in basic medicine, achieving significant societal and economic benefits would be unlikely. Therefore, the panel strongly recommends maintaining substantial support for basic medical research to ensure continued progress and impact.

3.13 Societal impact in basic medicine

The subsequent sections detail the assessment of societal impact (outside academy). Societal impact was reviewed through case studies conducted primarily by the societal impact experts in the panel, with support from appropriate scientific panel members. In the review of societal impact, the panel members made individual pre-assessments before the panel meeting. At the panel meeting consensus grades on each case study were established.

The panel review of the societal impact based their overall view on ‘reach and significance’. Reach was understood as the extent and/or diversity of the beneficiaries of the impact, as relevant to the nature of the impact. Significance was understood as the degree to which the impact has enabled, enriched, influenced, informed or changed the performance, policies, practices, products, services, understanding, awareness or wellbeing of the beneficiaries.

The panel reviewed altogether 57 cases from Karolinska Institutet, Lund, Uppsala, Umeå, Linköping, and Örebro universities showcasing societal impacts stemming from research in basic medicine. To qualify, the described impact must have occurred within the past five years, and the contributing research must have been published within the last 20 years by researchers affiliated with the submitting university at the time of publication. Claimed impacts were diverse including changes particularly in the following impact ‘domains’: technological/ innovation; economic; health and policy. The beneficiaries included in the case studies are:

- Companies and Industry: This category encompasses startups, SMEs, and large pharmaceutical companies. Reported benefits include financial investment, innovation, enhanced knowledge, service and product development, commercialisation, business growth and diversification, as well

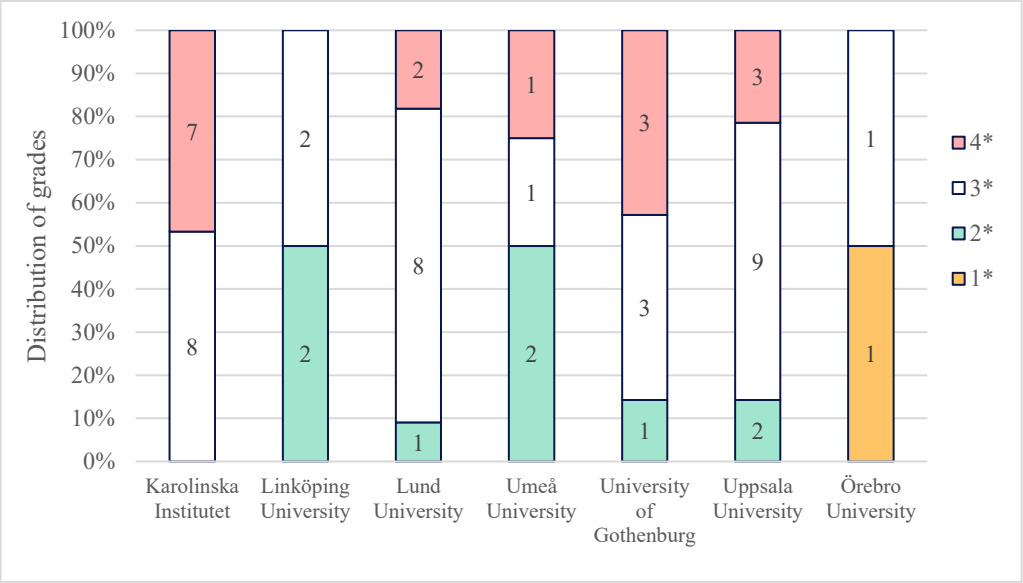
as new methodologies, tools, and diagnostics. Job creation was also noted as a benefit, indirectly supporting employees.

- Clinical Studies, Practice, Practitioners, and Healthcare: Benefits include increased knowledge, advancements in clinical trials, adoption of new tools, technologies, and methodologies, improved clinical trial effectiveness and efficiency, and refined disease classification.
- Policymakers: Impact was observed in the development, shaping, and modification of policies, guidelines, and regulations—including drug approval and licensing processes—through organisations such as the United States Food and Drug Administration (FDA), European Medicines Agency (EMA), United Nations (UN), European Union (EU), World Health Organisation (WHO), and Swedish regulatory bodies.
- Patients: Some cases demonstrate improvements in diagnosis and prognosis, with a few showing enhancements in patient health and quality of life. However, the extent of benefits for patients was lower than expected. This was partly due to some case studies being in early drug development stages, while in other cases, relevant patient outcome data may have existed but was not included.
- Law Enforcement & Judiciary: Reported benefits included enhanced knowledge, shifts in judicial practices, improved drug categorisation, and adjustments in sentencing guidelines.
- Environment: One study addressed environmental benefits, specifically focusing on the reduction of antimicrobial resistance.

The cases fell into the following main subdisciplines: cell biology, molecular biology, biochemistry, genetics, microbiology, immunology, neuroscience and cancer, while several of them were interdisciplinary.

A 4* rating was awarded to cases demonstrating outstanding reach and significance. Many submissions showed strong potential, though their impact was not yet fully realised. Depending on their level of reach and significance, these cases received 3* or 2*. Cases with only minor demonstrated impact at the current stage were given 1*. The distribution of the scores between the universities is presented in Figure 30. Many case studies did not provide sufficient evidence to verify or corroborate their impact and the narrative describing the pathway from research to impact was vague, lacking clarity on how the reported impacts directly stemmed from the underlying research. These uncertainties compromised the evaluation to certain extent. Examples of cases with outstanding impact are provided in the following paragraphs.

Figure 32. Scores of case studies in different HEIs.



Examples of outstanding case studies

The standout case studies, presented below, are optimally structured and supported by robust evidence. These cases strongly demonstrate societal benefits of high-quality research.

'Pharmacometric approaches used in the discovery, development, and usage of new medicines' from Uppsala University has had a transformative impact on global drug development, establishing industry-standard methodologies and influencing regulatory guidelines. The widespread adoption of these approaches by pharmaceutical companies, regulatory agencies, and academic institutions, alongside the creation of a successful global consultancy, demonstrates exceptional reach and significance. These contributions have not only advanced scientific knowledge but also directly improved patient outcomes through more efficient drug development.

'**The discovery of the CRISPR-Cas mechanism for genome editing**' from Umeå University has revolutionised genetic engineering, enabling precise gene editing with profound implications for medicine, agriculture, and biotechnology. It has facilitated the treatment of genetic disorders, accelerated drug discovery, and enhanced agricultural productivity. CRISPR diagnostics provide rapid nucleic acid detection, and in 2023, Casgevy became the first FDA-approved CRISPR therapy for severe sickle cell disease and beta thalassemia. With over 100 CRISPR-based therapies in clinical trials, the field is expanding rapidly, backed by more than 80,000 patents and a market value exceeding $3 billion in 2024. CRISPR Therapeutics, a publicly traded company, is important in this expansion.

'Transforming prostate cancer diagnostics and screening' from Karolinska Institutet has developed Stockholm3, an AI-assisted, blood-based diagnostic test that integrates multiple biomarkers for prostate cancer detection. This non-invasive test has been successfully implemented in Sweden, Germany, and

Switzerland, improving early detection of prostate cancer and reducing healthcare costs. It is also being used alongside MRI advancements for enhanced imaging.

'Improving legal security and increasing the number of solved crimes using advanced forensic DNA analyses' from Uppsala University is focused on forensic applications, improving the sensitivity of forensic tests in collaboration with Swedish police.

'Rapid RNA-Extraction-Free COVID-19 Testing: Expanding Diagnostic Capacity for Global Health Impact' from Karolinska Institutet. This case shows a driven innovation in clinical methods, demonstrated by its adoption both in Sweden and internationally. This is a key example of pioneering work in rapid, RNA-extraction-free COVID-19 testing, which significantly enhanced testing capacity and reduced turnaround times during the pandemic. While similar assay methods were developed elsewhere, this innovation overcame critical RNA extraction bottlenecks, leading to faster, more scalable, and cost-effective testing worldwide.

'Neuroblastoma: preclinical breakthroughs with clinical impact' from University of Gothenburg. The case demonstrates significant impact in cancer diagnosis and treatment, improving patient outcomes and clinical practices. Preclinical neuroblastoma breakthroughs, such as drug repurposing, show promising clinical results. Integrated genomic analysis is personalising treatments, impacting standard care and developing new targeted inhibitors.

'Antibiotic pollution and resistance' from University of Gothenburg. This case study had a significant impact on international and national policy, demonstrating how environmental antibiotics contribute to antibiotic resistance in pathogens. The research influenced key organisations, including the United Nations, and inspired new groups to contribute to this growing field. The case study effectively provided corroborating sources of impact.

'Revolutionising cervical cancer prevention: from HPV screening and vaccination to cancer elimination strategies' from Karolinska Institutet. This case spearheaded a coordinated effort to improve cervical cancer prevention through advanced screening methods, HPV vaccination (including for boys), and enhanced state-of-the-art diagnostics.

The remaining 4* case studies show significant contributions to critical health challenges. However, these cases still exhibit deficiencies in presenting concrete evidence to substantiate the claims made in their narratives, particularly regarding demonstrating patient efficacy and outlining clear impact pathways.

'Large-scale solution-phase proteomic analysis using proximity-based assays' from Uppsala University has developed proximity ligation and extension assays, leading to the commercial success of Olink Proteomics. In 2024, Olink Proteomics was acquired by Thermo Fisher Scientific for $3 billion, further highlighting the impact of this research.

'The single-cell transcriptome-sequencing revolution' from Karolinska Institutet has pioneered single-cell transcriptome sequencing, significantly advancing biomedical research. This technology has enabled precise cell-type identification in humans and model organisms and has been instrumental in cancer characterisation, neurodegenerative disease research (Alzheimer's, Parkinson's), and COVID-19 studies. Stockholm's biotech sector has been transformed by innovations such as spatial transcriptomics and in-situ RNA sequencing, now commercialised by 10x Genomics. These breakthroughs have established Stockholm as a hub for single-cell and spatial technologies, inspiring new biotech startups and contributing to large-scale brain mapping within the NIH BRAIN Initiative.

'Biomarker discovery for neurodegenerative disorders' from University of Gothenburg is based on the development of ultrasensitive tests for neurodegenerative biomarkers in cerebrospinal fluid and blood, enabling early Alzheimer's disease (AD) diagnosis. Biomarkers such as Aß42/Aß40 ratios, phosphorylated tau, and neurofilament light (NfL) are now widely used in clinical practice. A commercial NfL test by Quanterix is available globally.

'Development of p-tau biomarkers' from Lund University has played a key role in the diagnosis of Alzheimer's disease (AD) by developing p-tau217, a biomarker that can detect AD up to 20 years before symptoms appear. This research has gained international attention, including a New York Times front-page feature, raising public awareness. Lund University has also contributed to global recommendations for blood biomarker use in clinical practice and trials. p-tau217 is now in use in the U.S. and will soon be available in Sweden.

3.13.1 Summary of societal impact

3.13.1.1 Strengths

- Many case studies effectively presented the background, context, and significance of their research and its impact, clearly outlining the problem they aimed to solve.
- In many studies, the sections describing the conditions that enabled impact were particularly well-written and provided valuable insights into the broader environment that facilitates research impact.

3.13.1.2 Weaknesses

- Some case studies included potential impact or academic/scientific impact, which falls outside the scope of societal impact.
- Many case studies lacked sufficient evidence to verify or corroborate their impact.
- In several cases, the narrative describing the pathway from research to impact was vague, lacking clarity on how the reported impacts directly stemmed from the underlying research.

Overall, based on the demonstrated impact of basic medicine, the panel considers Swedish basic medicine to be successful. It concludes that without discoveries in

basic medicine, significant societal and economic impact cannot be achieved. Therefore, the panel strongly recommends maintaining substantial support for basic medicine.

3.14 Final Remarks

Based on all the material received in this evaluation, the basic medical science in Sweden is highly successful and research groups across all subdisciplines consistently publish high impact work in top-tier journals. Competitive funding is essential to maintain and further develop the high scientific standards. The statistical analysis shows that Swedish researchers in basic medicine are also successful in obtaining highly competitive external funding, which accounts for the majority of their research funding (Table 3, chapter 2.3.1 Overview of Research and development expenditure in Sweden). According to a report by the Swedish Research Council[16], less than 50 per cent of the Swedish R&D expenditures support the basic and applied research of HEIs. The report also highlights that basic and applied research obtain a similar share of financial support. This is not self-evident when looking at global science funding, which currently favors applied, outcomes-based research over curiosity-driven basic research in many countries. It is important to keep in mind that basic science always proceeds applied science. Consequently, without basic science there is nothing that can be translated into application. In this context it is fascinating to read what Vannevar Bush wrote on page 17 of his 1945 report to President Harry S. Truman[17]: “Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science”. This appeal is timeless!

The panels unanimously agreed that basic medical science in Sweden is remarkably strong in establishing collaborative networks, both nationally and internationally. The collaborations foster the scientific progress by enabling access to novel methods and technologies. The consequence of this successful networking is multidisciplinarity, which pays off by raising the research quality, output and citations. Statistics show that the overall scientific quality increases with the number of collaborating partners. In addition to increasing scientific quality, it was noted by the panel members that collaborations also enabled Swedish scientist to be among the first in Europe to pioneer several innovative technologies (CAR-T cells, AI-based cancer diagnostics, transcriptomics technologies, etc.).

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[16]The Swedish Research Barometer 2023. Swedish research in international comparison, VR2326.

[17] Science - the endless frontier. A report to the president. Vannevar Bush, 1945. National Science Foundation, 75th anniversary edition.

The advancement of science depends on a tight interplay between scientific research and technology development, which includes inventing new instruments as well as methods. Technology development was well represented among the publications which were evaluated as being of outstanding quality. It is very likely that more of technology and method development is carried out in life science institutes of Swedish universities than have been seen by the evaluation panels. Access to outstanding local and national technology platforms has an enormous impact for basic science. The easy access to technology represents an important contributing factor to the high quality of Swedish research. The danger of access to such fabulous technical platforms can be that researchers produce large omics data sets whose meaning and understanding of a biological process and/or specific disease is far from clear. This concern was discussed during the evaluation process and shared by panel members.

The strengths of basic medical science in Sweden

- Multi and interdisciplinarity: Swedish basic medical science successfully traverses disciplinary boundaries and seeks collaborations nationally and internationally with academia and industry.
- Cutting-edge technology: local facilities and national platforms centre provide easy access to novel, complex and costly technical expertise. Particularly the establishment of the national platforms centre SciLifeLab, is unique and contributes to interdisciplinarity and enables research at the forefront of science.
- Strong tradition of basic medical science: increase of knowledge and impact on human health.
- High public reputation of basic medical research.
- Recognition of the strong basic medical research by government funding and charities.
- Sweden is strong in IT and AI, which is capitalised by basic medical science researchers.

The weaknesses of basic medical science in Sweden

- Disciplines are advised to place more value on hypothesis-driven research as opposed to data-driven research.
- The size of some HEIs is subcritical.
- Swedish basic medical research is under immense pressure in terms of recruiting young academics.
- Like elsewhere, Swedish basic medical science is driven by high citation impact, which does not necessarily correlate with quality.

It is important to realize that one cannot predict which line of research leads to application. It is also important to remember that basic, hypothesis-driven research usually has a long way to go until the scientific and societal impact becomes evident. It also does not seldomly happen that during this long journey, fundamental observations only interest a few experts and are therefore not published in flashy journals and not highly cited. Hence, papers must be read and evaluated and not judged by citations or by the journal, in which they are published.

3.15 Recommendations to HEI

The evaluation revealed that basic medical science thrives in Sweden, although with measurable differences in performances among the HEIs. The differences of HEIs size and R&D expenditures correlate to certain degree with number and citation rates of publications, and in general, with the rankings of the research output that was evaluated during the peer review process. On the very large sized scale, the Karolinska Institutet does better than smaller HEIs. On the very small sized scale, Örebro University, with the smallest size and lowest R&D expenditures produced received a lower proportion of high score publications by the international peer review panels. The conclusion that size of HEIs and overall funding correlates with number, quality and citations of research outputs is not unique to Sweden but is generally observed throughout the world.

It was, however, noted in the final discussion of the neuroscience panel that Örebro University, despite the issues discussed above, provided ‘excellent and impactful translational neuroscience’ as a result of many years of excellent basic research. Based on the neuroscience scoring, Örebro University may consider whether it is advantageous to favour focused research area(s) by promoting local talents.

Karolinska Institutet showed outstanding research outputs in all disciplines. This outcome highlights that size, funding and international collaborations are key assets for the scientific output and higher scoring. A further benefit is also the ‘greater’ scientific environment with universities and research institutions nearby the Karolinska Institutet. This benefit allows scientific networking at all disciplinary levels and is shared with Universities of Gothenburg and Lund University but is unfortunately not available to the Universities of Uppsala, Umeå, Linköping and Örebro.

University of Gothenburg, Lund University and Uppsala University scored excellent in most of the evaluated disciplines and showed overall a world average citation impact. A question that should be addressed in these HEIs is whether to remain world average across disciplines, or focus and become outstanding, above world-average in specific discipline(s).

Umeå University, Linköping University and Örebro University scored on average less in the peer review and showed an overall citation impact below world average. One should, however, keep in mind that number of personal and funding is much lower in these HEIs. and was very successful in obtaining ERC funding. Still, Umeå University and Linköping University should reflect on the question whether the breadth of scientific disciplines should be favoured over selecting those, in which they already lead the field.

The HEIs have like most Universities in Europe a gender bias at the professor level. The number of female professors is in all Swedish HEIs around 30%. This number does not fit our time anymore and demands from the HEIs to swiftly even the imbalance. The forthcoming retirement wave is an opportunity to realize this at long last.

The evaluation also revealed that HEIs, without exception, greatly benefit from national and particularly international collaborations. The statistical analysis and the peer reviewing revealed that international co-authorships increased citations and quality of papers. The panel applauded the tradition of international networking in Swedish science and strongly encourages the HEIs to carry on this tradition.

4 Appendix 1

All the appendices are compiled and written by the evaluation team at the Swedish Research Council and have been used as a basis for the evaluation panel.

4.1 Evaluation panel

Table 5. The evaluation panel in basic medicine.

Name	Affiliation	Country	Focus
Reinhard Fässler	Max Planck Institute	Germany	Chair
Sirpa Jalkanen	University of Turku	Finland	Co-chair, Societal impact
Lesley Paterson	Mesh Associates (freelancer)	United Kingdom	Societal impact
Anna Sandström	AstraZeneca	Sweden	Societal impact
Christoph Ballestrem	University of Manchester	United Kingdom	Scientific quality (Cell Biology)
David Teis	Medical University of Innsbruck	Austria	Scientific quality (Biochemistry)
Gerard Evan	The Francis Crick Institute	United Kingdom	Scientific quality (Cancer Biology)
Harald Renz	University of Marburg	Germany	Scientific quality (Basic Immunology)
Jean-Pierre Gorvel	Centre d'Immunologie de Marseille-Luminy	France	Scientific quality (Microbiology)
João Relvas	University of Porto	Portugal	Scientific quality (Neuroscience)

Name	Affiliation	Country	Focus
Laura Zelarayan-Behrend	The University of Göttingen	Germany	Scientific quality (Molecular Biology)
Maria Yazdanbakhsh	University of Leiden	Netherlands	Scientific quality (Microbiology)
Mikael Knip	University of Helsinki	Finland	Scientific quality (Basic Immunology)
Rebecca Oakey	King's College London	United Kingdom	Scientific quality (Genetics)
Sonja Lorenz	Max Planck Institute	Germany	Scientific quality (Biochemistry)

4.2 Methods

Assessments of the research carried out at individual HEIs (evaluation units) form the basis for the national overview. The focus is on the results of the research, and more precisely on two components: the quality of scientific production (cutting-edge publications and bibliometrics) and the societal impact of research (impact case studies). The scientific quality and the societal impact are assessed as two separate components. The panel was provided with material including publications, case studies as well as a bibliometric analysis and statistics supplied by the Swedish Research Council (see below).

4.2.1 Scientific quality

The evaluation of scientific quality was based on the review of 403 cutting-edge scientific publications. The publications were reviewed by scientific experts in the evaluation panel and external reviewers. The bibliometric analysis, covering the period from 2018 to 2022, was assessed by the panel. Generally, the bibliometric data (see Section 2.3) indicates the overall quality of publications generated through basic medicine research in Sweden.

4.2.1.1 Peer review of cutting-edge publications

The HEIs submitted a predefined number of cutting-edge publications to be assessed in the evaluation. The selected publications must relate to research conducted primarily by researchers active at the respective HEI. This means that a researcher from the HEI need to be either the lead or corresponding author. Additionally, the publications must have been published between 2018 and 2024.

The number of publications that each HEI submitted was calculated based on the total number of publications that each HEI published between 2018 and 2022. For details, see Table 3, chapter 2.1.

For the review of cutting-edge publications 48 external reviewers were recruited internationally. The external reviewers and the scientific experts in the evaluation panel were divided into eight sub panels. The cutting-edge publications were distributed among the sub panels according to their specific scientific field and each publication was reviewed by three reviewers in the sub panel according to the assessment criteria. The aspects that the peer review was based on are:

- Novelty and originality
- Importance for the research field as a whole
- Scientific reliability and stringency.

For grading of publications, the grading scale and assessment criteria on five levels, used in the Research Excellence Framework (REF) in UK[18], was adopted. Each reviewer gave each publication one overall grade according to the grading scale, see table 6. Subsequently, each sub-panel convened an online meeting to engage in a consensus discussion. During these discussions the grades were thoroughly reviewed and deliberated with the aim to reach a consensus grade for each publication.

Table 6. Definitions of starred levels for the assessment of scientific publications.

Level	Definition
Four stars	Quality that is world-leading in terms of originality, significance and rigour.
Three stars	Quality that is internationally excellent in terms of originality, significance and rigour but which falls short of the highest standards of excellence.
Two stars	Quality that is recognised internationally in terms of originality, significance and rigour.
One star	Quality that is recognised nationally in terms of originality, significance and rigour.
Unclassified	Quality that falls below the standard of nationally recognised work.

Along with the list of their most prominent publications, each HEI submitted a text of maximum two pages explaining the selection, to give the evaluation panel an understanding of the selection process. This allowed the HEIs to explain

[18] Index of revisions to the 'Guidance on submissions' (2019/01). October 2020. Research Excellence Framework (REF).

whether their selection of publications was related to any existing strategy for scientific focus or profile, or to national or international collaborations for example. Table 7 present the distribution of the 403 publications submitted by the HEI among the different research areas in basic medicine.

Table 7. Distribution of articles on subdisciplines.

Research area	Number of publications	Share of total
Basic Immunology	43	11%
Biochemistry	48	12%
Cancer Biology	47	12%
Cell Biology	43	11%
Genetics	50	12%
Microbiology	58	14%
Molecular Biology	39	10%
Neuroscience	75	19%

4.2.2 Societal impact

The evaluation of societal impact was based on in total 57 case studies compiled and submitted by the HEIs for the evaluation panel's assessment. The case studies describe concrete examples where research within basic medicine has had significant impact on society beyond the research community.

The number of case studies submitted by each HEI was based on the average number of research and teaching staff (in full-time equivalents) in the years 2017, 2019 and 2021 according to available data from the Swedish Higher Education Authority.

In each case study, three different components were described by the HEI: (a) Reach and significance – the referred impact on society; (b) Key processes and factors – approaches and conditions that have been crucial to the impact and (c) Contributing research – the main content of the research that contributed to the impact.

The assessment is made by the evaluation panel reading the case studies. The following aspects are applied:

- Reach – the extent and/or diversity of the beneficiaries of the impact.

- Significance – the degree to which the impact has enabled, enriched, influenced, informed or changed the performance, policies, practices, products, services, understanding, awareness or wellbeing of the beneficiaries.

The HEIs submitted also a brief descriptive text of maximum two pages to describe the purpose of their selection of case studies linked to the HEIs strategy in the research field.

The case studies were graded by the panel according to a five-level scale (see table 8) and assessment criteria derived from the Research Excellence Framework (REF)[19]. Each case study was reviewed by the three panel members specifically assigned to assess societal impact, as well as by other panel members possessing expertise in the relevant research field. Each reviewer assigned an overall grade to each case study based on this scale. Subsequently, the evaluation panel convened an online meeting to discuss and reach consensus on the evaluation of the case studies. This was followed by a meeting in Stockholm where further discussion took place. During these deliberations, the assigned grades were thoroughly reviewed and debated, with the objective of establishing a consensus grade and corresponding comments for each case study.

Table 8. Definitions of starred levels for the assessment of case studies.

Level	Definition
Four stars	Outstanding impacts in terms of their reach and significance.
Three stars	Very considerable impacts in terms of their reach and significance.
Two stars	Considerable impacts in terms of their reach and significance.
One star	Recognised but modest impacts in terms of their reach and significance.
Unclassified	The impact is of little or no reach and significance; or the impact was not eligible; or the impact was not underpinned by excellent research produced by the submitted unit.

[19] Index of revisions to the 'Guidance on submissions' (2019/01). October 2020. Research Excellence Framework (REF).

5 Appendix 2 Background material per HEI in the evaluation

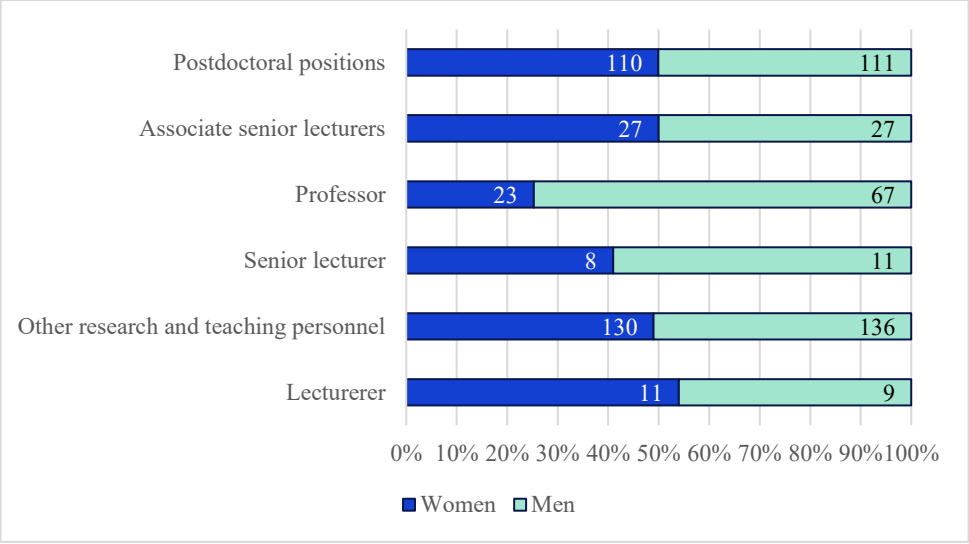
5.1 Research and teaching staff in basic medicine per HEI

In the figures below the statistics were compiled with data reported to Statistic Sweden (SCB) and to the Swedish Higher Education Authority and presents the average of the different statistics material for the years 2018–2022 for research and teaching staff (FTE) and for the years 2017, 2019 and 2021 for research and development expenditure.

5.1.1 Karolinska Institutet

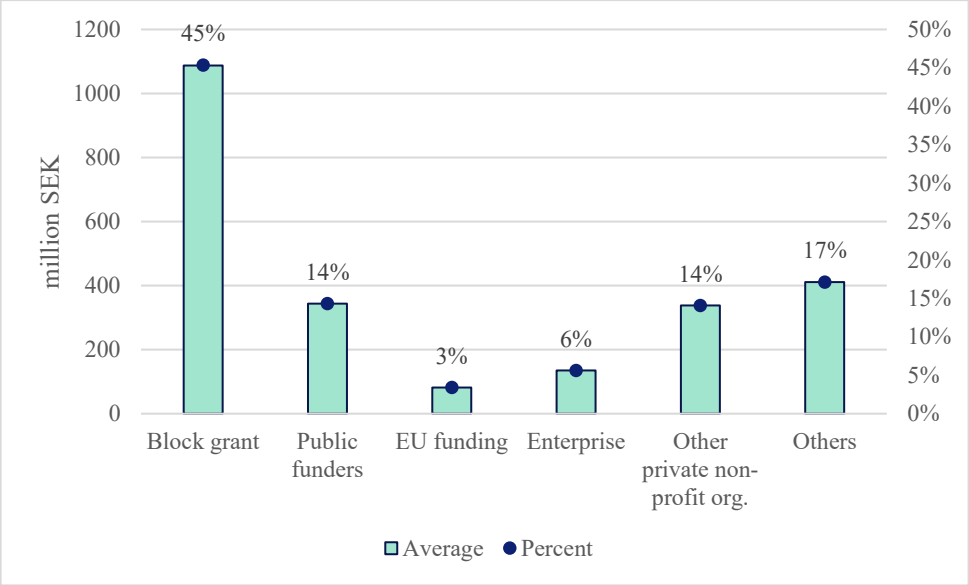
Karolinska Institutet has 35 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The distribution between gender in the staff is even except for the professor position where men constitute more than 70 per cent.

Figure 33. Distribution of different positions among staff (FTE) at Karolinska Institutet.



The figure below presents the distribution of different R&D funding sources for Karolinska Institutet. More than 40 per cent of their funding are block grants. Karolinska Institutet gets 14 per cent of the funding from public funding agencies and 14 per cent from private non-profit organisation, such as the Knut and Alice Wallenberg Foundation, and 3 per cent from EU. The average of the total R&D expenditure per year for Karolinska Institutet is 1 087 million SEK (approximately 94 million EUR).

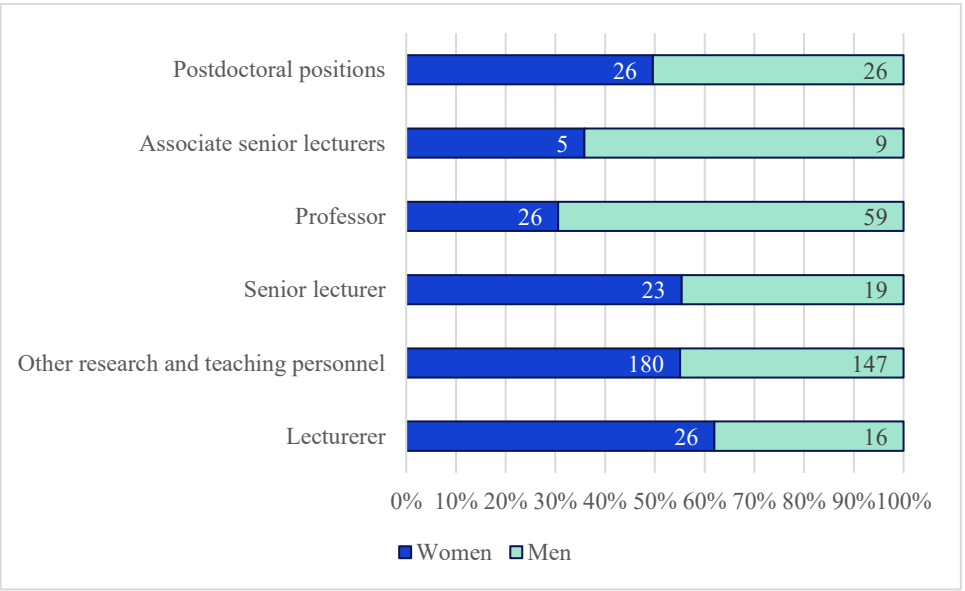
Figure 34. Distribution of different funding sources for Karolinska Institutet.



5.1.2 Uppsala University

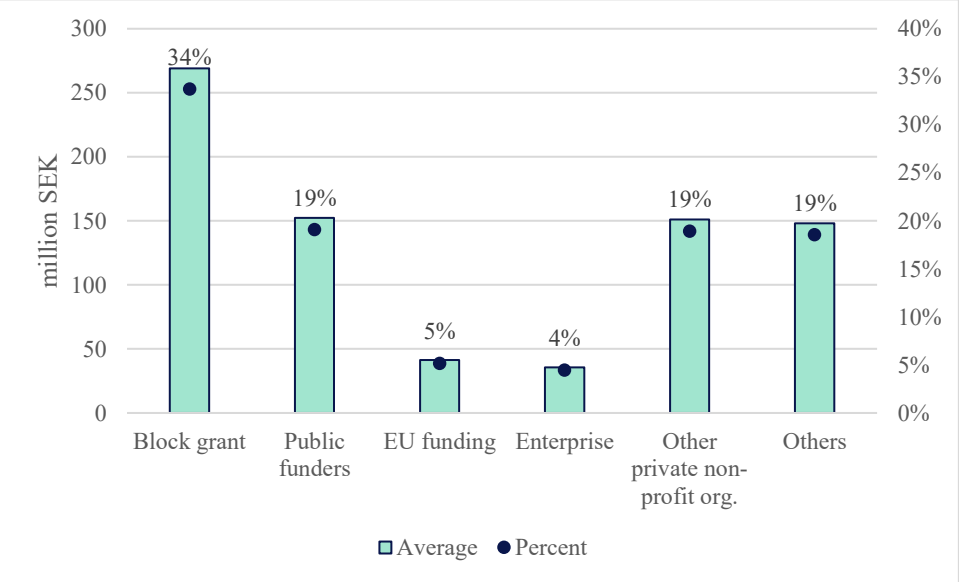
Uppsala University has 26 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The distribution between gender in the staff is approximately even for three of the six different positions. Associate senior lecture and the professor position have more than 60 per cent men. In the lecturer position women represent just about 60 per cent.

Figure 35. Distribution of different positions among staff (FTE) at Uppsala University.



The figure below presents the average distribution of different R&D funding sources for Uppsala University. Of the total funding that Uppsala University has in basic medicine, 34 per cent are block grants. Uppsala University gets 19 per cent from public funding agencies and 19 per cent from private non-profit organisation, such as the Knut and Alice Wallenberg Foundation. The support from the private sector (Enterprises) is 5 per cent and 4 per cent, respectively. The average of the total R&D expenditure in basic medicine per year for Uppsala University is 797 million SEK (approximately 69 million EUR).

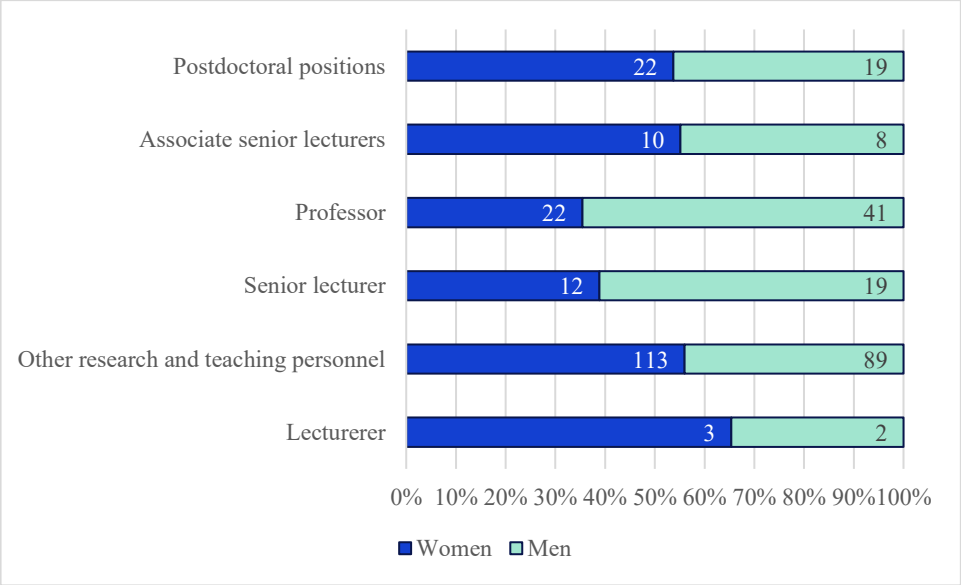
Figure 36. Distribution of different funding sources for Uppsala University.



5.1.3 Lund University

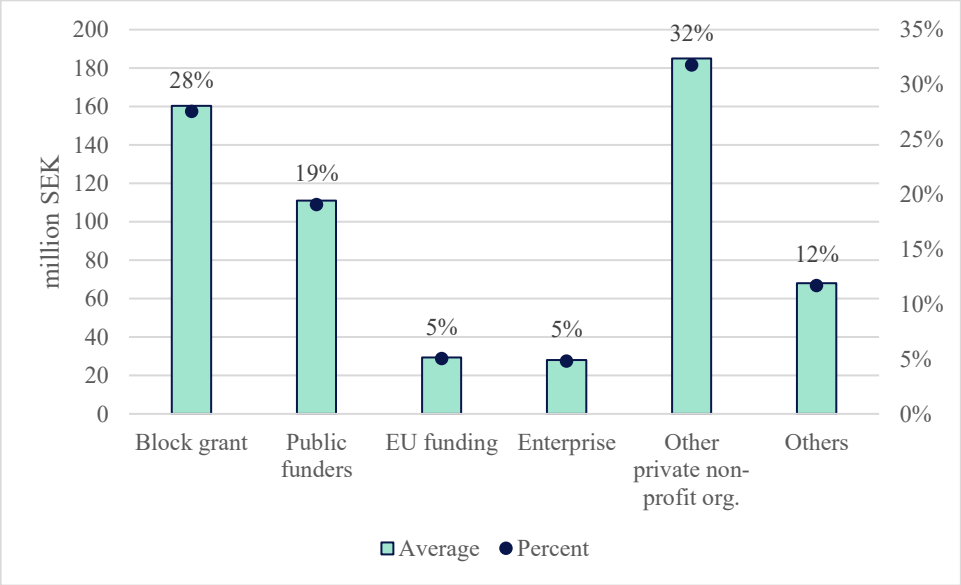
Lund University has 17 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The gender distribution among the staff is approximately even for three of the six different positions. The positions of associate senior lecturer and professor have more than 60 per cent men. In the lecturer position women represent more than 60 per cent.

Figure 37. Distribution of different positions among staff (FTE) at Lund University.



The figure below illustrates the distribution of various R&D funding sources for Lund University. Over 30 per cent of their R&D funding in basic medicine comes from private non-profit organisation such as the Knut and Alice Wallenberg Foundation. Additionally, 28 per cent is funded through block grants, and approximately 20 per cent is provided by public funding agencies. The support from EU and the private sector is 5 per cent each. The average of the total R&D expenditure in basic medicine per year for Lunds University is 582 million SEK (approximately 50 million EUR).

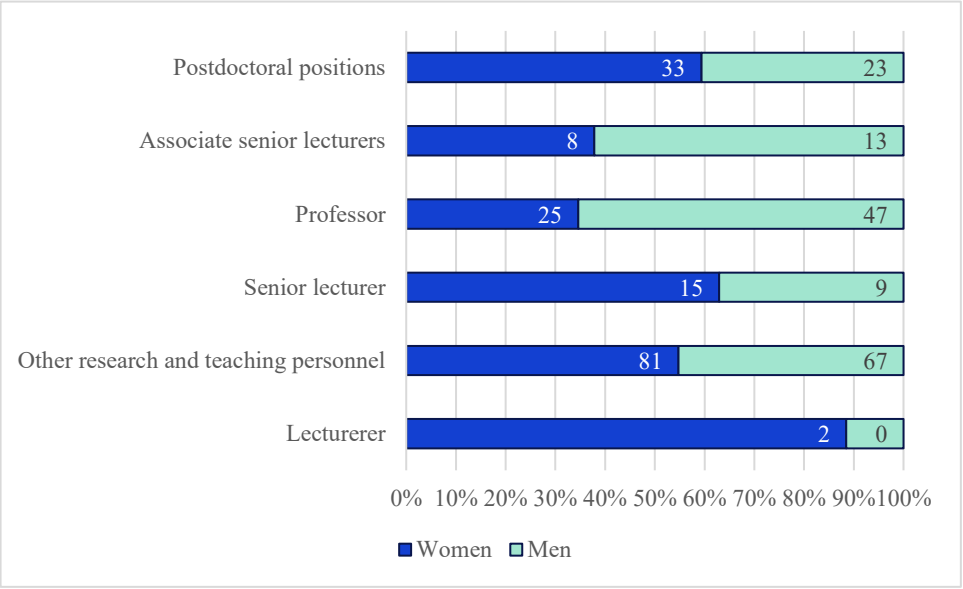
Figure 38. Distribution of different funding sources for Lund University.



5.1.4 University of Gothenburg

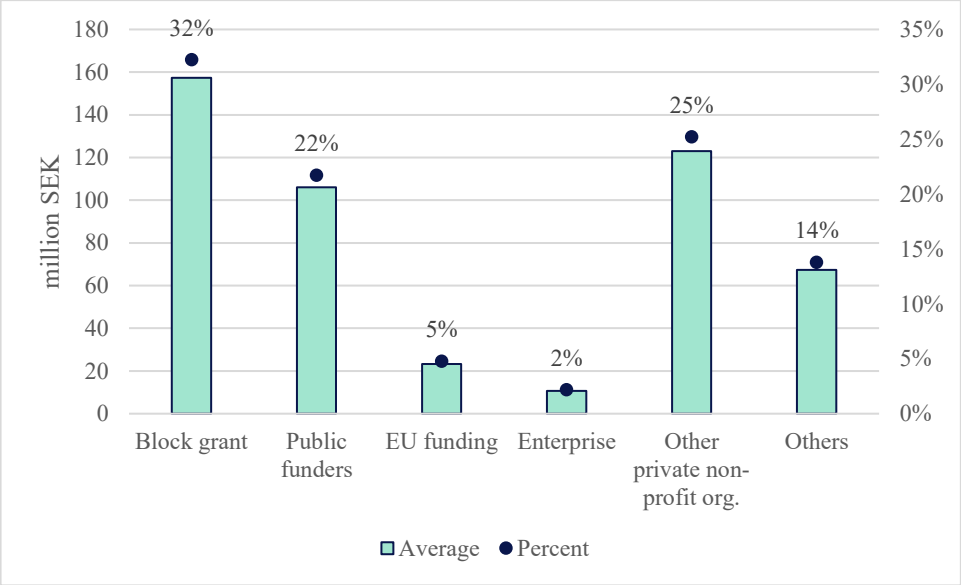
University of Gothenburg has 15 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The positions of associate senior lecturer and the professor have more than 60 per cent men. In contrast, women represent 60 per cent or more in postdoctoral position, senior lecture and lecture. Within the lecturer position, there are two FTE women and 0,2 FTE men.

Figure 39. Distribution of different positions among staff (FTE) at University of Gothenburg.



The figure below illustrates the distribution of various R&D funding sources for University of Gothenburg. Block grants constitute most of their R&D funding, with 32 per cent. Additionally, 25 per cent comes from non-profit private organisations, such as the Knut and Alice Wallenberg Foundation, and 22 per cent is provided by public funding agencies. The support from EU and the private sector is 5 per cent and 2 per cent, respectively. The average of the total R&D expenditure in basic medicine per year for University of Gothenburg is 488 million SEK (approximately 42 million EUR).

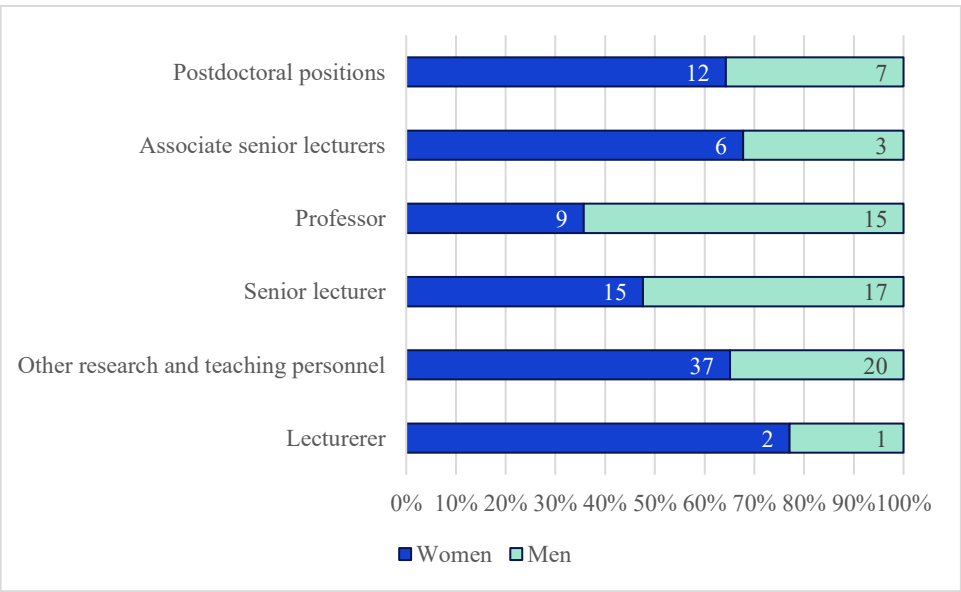
Figure 40. Distribution of different funding sources for University of Gothenburg.



5.1.5 Linköping University

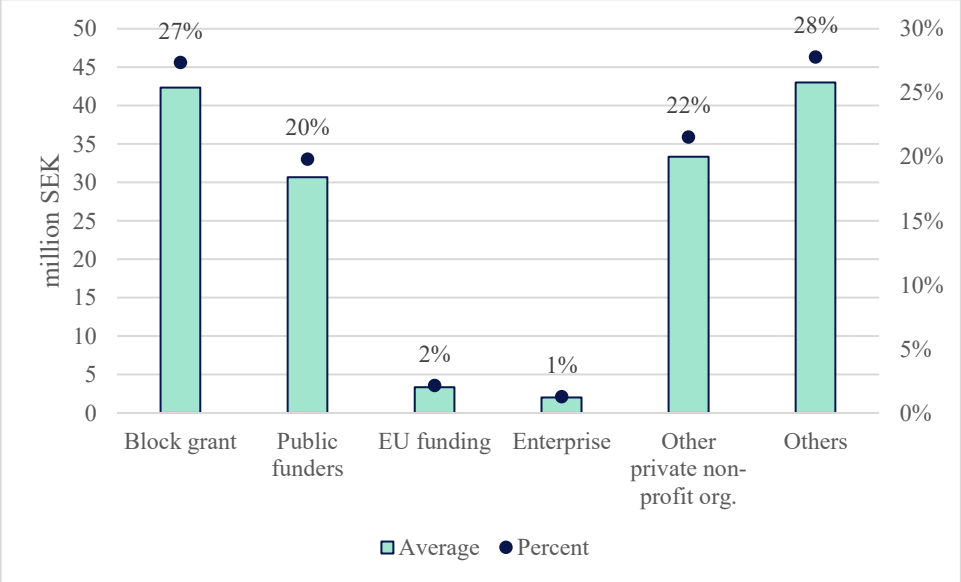
Linköping University has 7 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The distribution between gender in the staff indicates that women represent more than 60 per cent in almost all the positions except for the professor position and senior lecturer position where men constitute more than 60 per cent. Only three FTE individuals hold the lecturer position: two women and one man.

Figure 41. Distribution of different positions among staff (FTE)at Linköping University.



The figure below presents an analysis of the R&D funding sources for Linköping University. Unlike the other HEIs most of their funding comes from the category other fundings sources which are 28 per cent, followed by block grants with 27 per cent. Public funding agencies and private non-profit organisations stand for around 20 per cent each. The support from EU and the private sector is 2 per cent and 1 per cent, respectively. The average of the total R&D expenditure in basic medicine per year for Linköping University is 155 MSEK (approximately 13 million EUR).

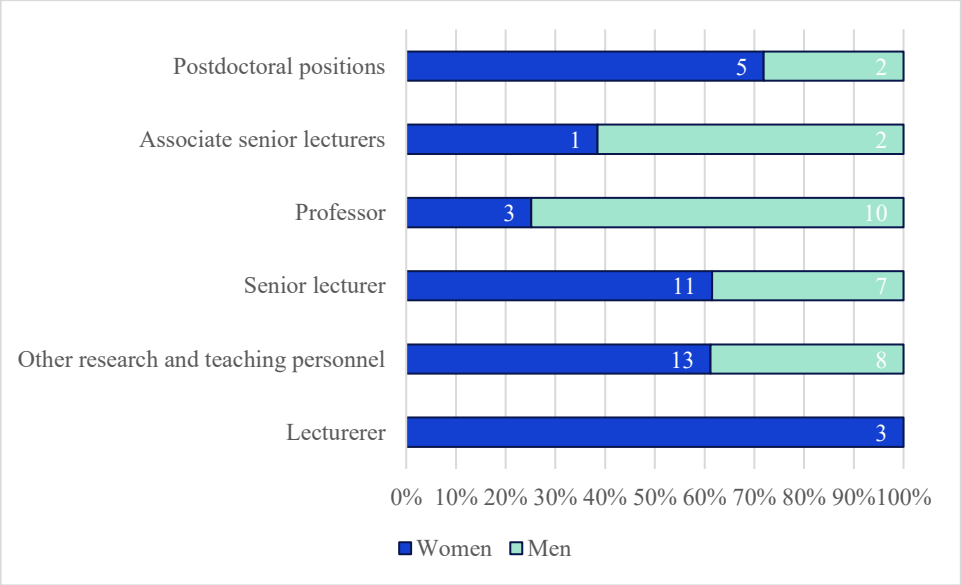
Figure 42. Distribution of different funding sources for Linköping University.



5.1.6 Umeå University

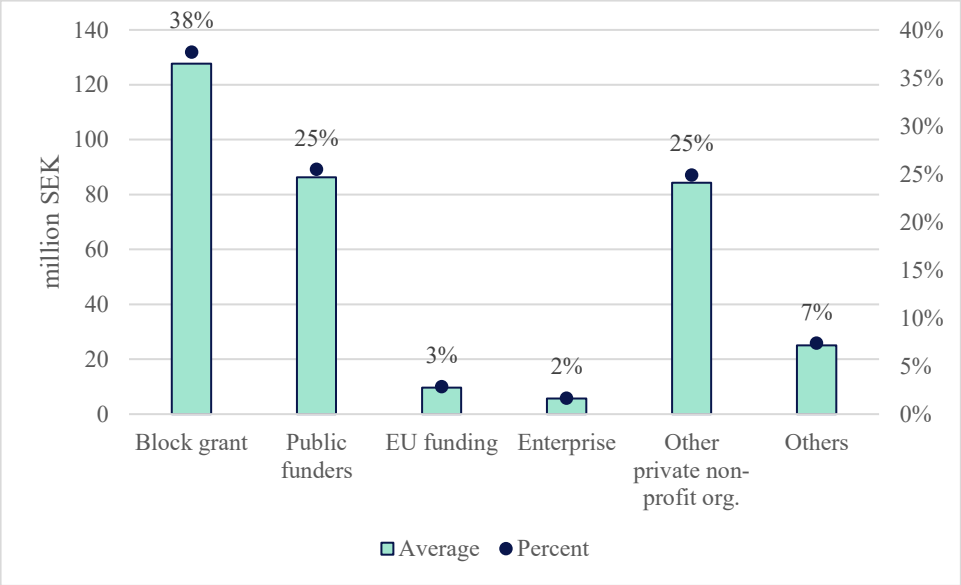
Umeå University has 3 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The distribution between gender in the staff indicates that women represent the majority except for the professor position where men constitute more than 70 per cent. The lecturer position comprises three FTE women, whereas the associate senior lecturer position consists of one FTE woman and two FTE men.

Figure 43. Distribution of different positions among staff (FTE) at Umeå University.



The figure below illustrates the distribution of R&D funding sources for Umeå University. Block grants are the most significant funding source, constituting 38 per cent of their total R&D funding in basic medicine. This is followed by public funding and private non-profit organisations, which account for 25 per cent each. The average of the total R&D expenditure in basic medicine per year for Umeå University is 339 million SEK (approximately 29 million EUR).

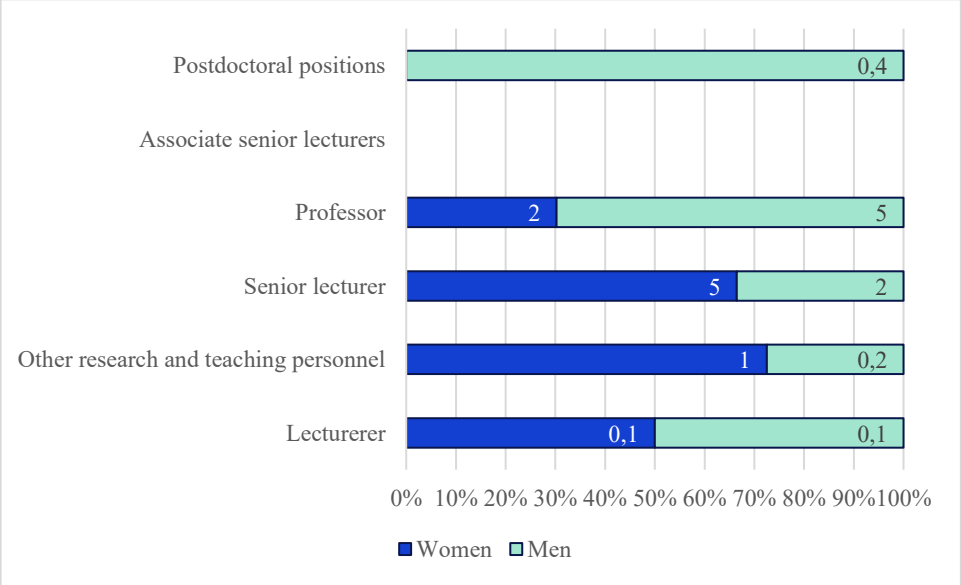
Figure 44. Distribution of different funding sources for Umeå University.



5.1.7 Örebro University

Örebro University has almost 3 per cent of all research and teaching staff (FTE) in basic medicine in Sweden. The distribution between gender in the staff indicates that women represent most of the senior lecturers and other research and teaching personnel. In the lecturer position men and women are equally represented. Men constitute more than 70 per cent of the professor positions and 100 per cent of the postdoctoral positions.

Figure 45. Distribution of different positions among staff (FTE) at Örebro University.



5.2 Explanation of the statistics

In the statistical data for personal at the HEIs, we have merged the positions “Associate senior lecturers” and “Research associate” to “Associate senior lecturers”.

In the R&D-expenditure, “Public funders” include Swedish Research Council, Swedish Research Council for Health, Working Life and Welfare (Forte), Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) and Swedish Innovation Agency (VINNOVA) and Swedish Energy Agency.

The financial source “Others” includes other grants, funding from HEIs and funds managed by the higher education institutions, other government agencies, The Legal, Financial and Administrative Services Agency, municipalities and regions, public research foundations, foundations and private non-profit organisations abroad and other funds.

Enterprises includes business enterprises both in Sweden and abroad.

6 Appendix 3 Top publications grades

Table 9. Results from peer review, per subdiscipline and HEI.

	1*	2*	3*	4*	Total
Neurosciences		**5**	**38**	**29**	**72**
Karolinska Institutet			14	18	32
Lund University			8	6	14
Umeå University		3	5		8
Linköping University		1	3	3	7
Uppsala University		1	5	1	7
University of Gothenburg			2	1	3
Örebro University			1		1
Microbiology	**2**	**16**	**23**	**17**	**58**
Karolinska Institutet		3	9	8	20
Uppsala University		8	3	1	12
Umeå University	1	3	5	2	11
University of Gothenburg			4	3	7
Lund University		1	1	3	5
Örebro University	1	1	1		3
Genetics		**7**	**29**	**13**	**49**
Uppsala University		6	7	6	19
Karolinska Institutet			7	2	9
Lund University			6	3	9

	1*	2*	3*	4*	Total
University of Gothenburg			6	2	8
Linköping University		1	2		3
Umeå University			1		1
Biochemistry	**1**	**10**	**20**	**15**	**46**
University of Gothenburg		2	10	5	17
Karolinska Institutet		1	6	9	16
Uppsala University		2	3		5
Linköping University		2		1	3
Umeå University		2	1		3
Örebro University	1	1			2
Cancer biology		**5**	**16**	**25**	**46**
Karolinska Institutet		1	5	12	18
University of Gothenburg		1	2	5	8
Lund University			3	5	8
Uppsala University		1	4	2	7
Linköping University			1	1	2
Umeå University		1	1		2
Örebro University		1			1
Basic Immunology		**12**	**13**	**18**	**43**
Karolinska Institutet		3	6	12	21
Lund University		4	2	4	10
Uppsala University		1	3		4

	1*	2*	3*	4*	Total
University of Gothenburg		2	2		4
Linköping University		1		2	3
Örebro University		1			1
Cell Biology	**1**	**8**	**22**	**10**	**41**
Uppsala University		4	6	1	11
Karolinska Institutet			4	6	10
Lund University		3	4	2	9
University of Gothenburg			5		5
Umeå University		1	2		3
Linköping University			1	1	2
Örebro University	1				1
Molecular biology	**1**	**6**	**21**	**11**	**39**
Karolinska Institutet		1	8	6	15
Uppsala University	1	3	5		9
University of Gothenburg		1	3	3	7
Lund University			4	2	6
Linköping University		1	1		2

7 Appendix 4 Case studies grades and comments

Case studies grades in comment present from those that get 4* to 1*. The case studies whit a "4+" demonstrate impactful research within a well-defined context and are further characterized by their comprehensive presentation and adherence to the established guidelines.

Evaluation unit	Title	Final grades	Final comments
Karolinska Institutet	Transforming prostate cancer diagnostics and screening	4+	Novel biomarker algorithm. Substantially reduces false negatives and positives. MRI is good but less noteworthy; Prostate cancer screening method A combination of protein biomarkers, genetic biomarkers and clinical information - reimbursed in CH and DE. Expensive and not yet used for population based screening; Innovation and new services plus implementation. Spin-out and commercialisation. Improved detection and screening. Economic and health impacts. Influenced guidelines.
Karolinska Institutet	Rapid RNA-Extraction-Free COVID-19 Testing: Expanding Diagnostic Capacity for Global Health Impact	4+	Innovation and new clinical methods. Adopted in Sweden (data provided) and internationally. Spinout, partnership and investment. Some corroborating evidence sources; Pioneer work in rapid RNA-extraction-free COVID-19 testing. Crucial in expanding testing capacity and improving turnaround times during the pandemic; COVID-19 diagnostics overcoming RNA extraction bottlenecks. Faster and more scalable testing, reducing cost worldwide and supporting rapid response; Different assay methods also developed in other countries.

Evaluation unit	Title	Final grades	Final comments
Karolinska Institutet	Revolutionizing cervical cancer prevention: from HPV screening and vaccination to cancer elimination strategies	4+	Influenced national health programme regarding screening & vaccination. Influenced policy, guidelines, recommendations and strategy including WHO. God corroborating evidence; HPV screening and vaccination strategies enhancing population-wide immunity. Molecular testing instead of microscopy and clinical studies; Impressive role introducing practices to eradicate cervical cancer. But not so much innovation - more a Swedish public health implementation issue than international. Also, many other players.
Umeå University	The discovery of the CRISPR-Cas mechanism for genome editing	4+	A huge impact, many other players involved later in this development; Innovation. Instrumental tool has led to many other innovations and impacts in a broad range of sectors including drug discovery. Health and economic impacts. Good evidenced; Amazing discovery that revolutionized science in all its areas, from basic research to food and clinical applications. Becoming an essential molecular tool; The discovery of the CRISPR-Cas mechanism for genome editing.
University of Gothenburg	Neuroblastoma: preclinical breakthroughs with clinical impact	4+	Works only for a small subset of neuroblastoma patients; Innovation, cancer diagnosis, clinical practice and treatment, patient outcomes (including high significance), changing practice (network) and services. Some evidence; Neuroblastoma: preclinical breakthroughs with limited but important clinical impact - i.e. compassionate use repurposing lung-cancer drug helped; Integrating genomic/proteomic analysis for improved and personalised treatment, impacting standard of care for neuroblastoma patients, inhibitor for treatment.
University of Gothenburg	Antibiotic pollution and resistance	4+	Outstanding impact in the field of environmental antibiotics and their impact on the transfer of antibiotic resistance to pathogens; A very important area of work that has spearheaded policy actions. It is a moving process to show impact; Antibiotic pollution and resistance underpinning UN and industry commitments to limit antibiotic pollution drug manufacturers (AMR industry alliance). Has something really concrete happened or only recommendations? This was not clear from the case study report. However, there is excellent reach and significance - international & national policy, influenced key organisations (including UN), corroborating sources of impact provided, convincing.

Evaluation unit	Title	Final grades	Final comments
Uppsala University	Improving legal security and increasing the number of solved crimes using advanced forensic DNA analyses	4+	Very influential innovation, varied impacts with reach and significance including solved crime cases, changed practice - police & judiciary. Contacts for corroboration; Improvement of forensic DNA analysis assays including sensitivity with the Stockholm Police. Some new method development; Improving legal security and increasing the number of solved crimes using advanced forensic DNA analyses. Impact outside Sweden?
Uppsala University	Pharmacometric approaches used in the discovery, development and usage of new medicines	4+	Widely adopted drug development model and service company (100 employees), FDA and EMA guidelines, international reach, capacity building. Good impact evidence; Set gold standard for pharmacometric analysis, set new guidelines, improves drug development and efficiency, founders of Pharmetheus, open-source tools, global; Pharmacometrics approaches used in the discovery, development and usage of new medicines, gold standard in FDA/EMA guidelines plus successful consultancy; Also other players in this case report, frequent changes in rules/regulations - impact may be short-lived.
Karolinska Institutet	Uncovering cellular interactions and complexity in tissue biology	4	A great technique, the highest impact still within scientific community; Technique developed before Nov 2019; Pioneer work on ST offering unprecedented insights into gene expression within the spatial context of tissues. Impact in research and clinic; Method of the year -20. Early commercialization facilitated global access to the technology accelerating biomedical research and advanced personalized medicine. Product available on market through US company that acquired start-up but lacks details and evidence on sales, take-up etc.
Karolinska Institutet	Starting the single-cell transcriptome-sequencing revolution	4	Pioneering work with high impact; Techniques/protocols for single-cell transcriptomes (single-cell RNA sequences) enabling systematic identification of cell types across tissues in humans/model organisms. Smart-seq is a widely adopted method for SCSeq, enabling profiling individual cells with unprecedented depth revealing cellular heterogeneity and mutations. High impact in commercialisation (Smart-seq2 and STRT-seq were patented and licensed to Takara Bio USA and commercialized as well as sold to Illumina Inc, respectively) and therapeutic development (the Human Cell AtlasIX and NIH BRAIN initiative). Some commercialisation etc but vague in describing the impacts (to whom/what, how, in what way?) - talks in very general terms. Pathway to impact also unclear.

Evaluation unit	Title	Final grades	Final comments
Karolinska Institutet	Transforming perceptions of nitrate: from suspected toxin to athletic enhancer and cardiovascular protector	4	From the discovery of the nitrate-nitrite-nitric oxide pathway all the way to transforming perceptions of nitrate from suspected toxin to vascular protection; Great example of a fundamental discovery having major impact. Nitrate-nitrite-NO pathway - dietary guidelines plus product development for endurance athletes and clinical trials as intervention for cardiovascular disease. Very well written study report. Highly interesting, still more needs to be done to change the public opinion. Claims a no. of diverse impacts with reach & significance but would have been strengthened by 3rd party endorsement that this research was the catalyst.
Karolinska Institutet	Measuring drug-protein interactions with the cellular thermal shift assay (CETSA)	4	Great tool in drug development; Company growth plus 60 employees. Used by 200 companies including routine drug development in big pharma. Unique innovation in its capacity to detect ligand-protein interactions in cells. Part of drug discovery pipelines around the globe; Spin out company Pelago Bioscience AB with 60 employees. CETSA routinely used in their drug development programs, by companies as AstraZeneca, Pfizer and Glaxo. But lacks other impact details (including timings) and evidence.
Lund University	High-performing blood biomarkers for Alzheimer's disease	4	As there are no really effective treatments, the impact is somewhat limited; Innovation (biomarkers), influenced development of guidelines, benefitted clinical trials and drug development. Beneficiary including WHO. Prof Hansson is world leader in blood biomarker research in AD (e.g. P-tau217). Clinical impact. Excellent competitive funding and publications; Using plasma P-tau217 to stratify among pre-symptomatic AD and identify those with greatest risk of cognitive decline if left untreated. Lacks corroborating evidence.
Lund University	Introduction of antibody modifying bacterial enzymes as drugs against autoimmune conditions and as biotechnological tools for research and therapeutic antibody development	4	The discovery is the treatment of IgG driven autoimmune disease and transplant rejection with bacterial enzymes leading to the drug Imlifidase; Novel approach to the treatment of autoimmune conditions and providing biotechnological tools for research. Two companies involved with about 170 employees; IdeS - Idefirix® approved for kidney transplant rejection and expand to additional autoimmune conditions. Genovis AB has capitalized as well. Somewhat difficult to figure out the real role of the LU scientists in clinical development; Impressive (new drug, biopharma benefits, economic impact) but no specific impact data (including patient outcomes) or evidence sources. Two key publications in 20 years.

Evaluation unit	Title	Final grades	Final comments
University of Gothenburg	Blood-based biomarkers for brain injury and neurodegenerative dementias	4	High impact work, clinical outcomes, biomarkers identified by Zetterberg and Blenow for neurodegenerative dementias used worldwide. Colaboration with CMRU; Blood-based biomarkers reflecting brain injury and neurodegenerative dementias used in clinical trials thus far. Better diagnosis, but effective treatments lag behind. Clinical practice and commercialization have changed, yet focus is heavily on research impact. Vague impact details and no impact evidence sources.
Uppsala University	Large scale solution phase proteomic analysis using proximity-based assays	4	Great work, financial success and outstanding impact worldwide; Significant economic impact (including jobs) through company (Olink Proteomics) set-up, growth and acquisition, benefits to pharma (drug development etc). Large scale solution phase proteomic analysis using proximity-based assays (Olink Proteomics); SciLifeLab of UU. Proximity-based protein assays are used worldwide by both academic, industrial as well as health care users - Olink Proteomics buyout. Lack of impact evidence.
Karolinska Institutet	Preventing skin sensitization and allergic contact dermatitis through stronger regulations and public health recommendations	3	Reduction in negative health impacts. Provided links to EU regulations and corroborating evidence; Professor Liden has written many expert reports for the EU and the OECD on risk assessment and risk management of sensitising metals; This work has strengthened EU regulations by advancing knowledge on skin sensitizers facilitating improved health for sensitized persons; EU regulations regarding skin sensitizers and fragrance allergens by exposure and classification limits and ensuring allergen labelling and shaped safety guidelines. Also, many other players.
Karolinska Institutet	Rapid results to guide public health strategies against SARS-CoV-2 and its emerging variants	3	Major work on the neutralising antibodies against SARS-CoV-2 variants. Impressive impact! SARS-CoV-2 "neutralization assays" that measure the extent to which antibodies can block from entering cells to assess threat from new variants; Further developments have been somewhat dampened by RNA vaccination; Truly significant contribution to the COVID epidemic but its current impact compared to other case studies scores less; SARS-CoV-2 "neutralization assays" that measure the extent to which antibodies can block from entering cells to assess threat from new variants. Contributed research findings to key policy organisations (and media), but difficult to assess the impact that resulted. Good to see attempts to provide impact evidence; Also, many other players globally.

Evaluation unit	Title	Final grades	Final comments
Karolinska Institutet	New synthetic lethal combination therapy for metastatic castration-resistant prostate cancer	3	Excellent impact after long development; Innovative cancer treatment. EMA, FDA & Swedish approval. PARP inhibitor license. Economic & health impacts. This work contributed to collective efforts from research groups and clinical trials for PARP inhibitors in treatment for prostate cancer and its mechanism. Lacked PTI/ impact details and unclear in places.
Karolinska Institutet	Developing the world's first Chikungunya virus vaccine	3	First licensed vaccine. Product approved (on sale soon). Important widespread disease. Range of beneficiaries (including company). Corroborating evidence provided; To see a vaccine developed and then approved for use in humans following phase I-III trials with full participation of the discovery group is very impressive; The scientists developed the first and only live attenuated vaccine against Chikungunya. However, a large-scale human trial to assess side effects is lacking; Vaccine for chikungunya virus, mosquito-borne illness spreading globally. Approval US, CA, and EU, expanding into low- and middle-income countries. Only 10 months protection with the vaccine - not very impressive.
Karolinska Institutet	Pioneering veterinary vaccine development and expanding animal health solutions	3	Strangles vaccine available on market. Uptake by some. Company growth including employees and partnerships. Economic impact and horse health impacts, other impacts small; A great effort that sees a vaccine being developed that goes from bench to bedside. Simply in comparison with other application from KI scores a bit lower; Very significant impact in the field of safe and effective vaccines against equine viral strangles. However, this 15-year-old strategy seems rather conventional; Instrumental in developing Strangvac - the world's first effective vaccine against strangles in horses with limited uptake yet. The company value quite low, impact may not be that great as described.
Karolinska Institutet	Unravelling pathogenetic mechanisms in metabolic diseases identified by whole genome sequencing	3	Innovation and development of tools and methods. Improved diagnostics (1000s of specific diagnoses). Building capacity and networks; Development of bioinformatics tools and cross-disciplinary methods. WGS in inborn errors of metabolism. New monogenic disorders understood in brain and mitochondria; Primarily rare diseases WGS uplift in ability to diagnose rare genetic disorders implemented in Sweden - referrals across Sweden plus a few new mechanisms. Genome wide analyses also done in many other places. Lacks impact evidence sources.

Evaluation unit	Title	Final grades	Final comments
Karolinska Institutet	AI-driven precision diagnostics for enhanced cancer treatment and patient outcomes	3	Innovation/new tech used in 3 regions. Diagnostics & treatment, economic savings and spinout plus partnerships; AI-based diagnostic tool for breast cancers. Spun out to company. Based on a decade of research at KI. Competitive area but impressive work; Analyses microscopic pathology images to assess risk of recurrence for chemotherapy decisions in healthcare in a few Swedish regions saving time and cost. Impact not yet fully seen; Some corroborating evidence. Lacks details in places.
Karolinska Institutet	Dopamine transporter PET Imaging for the diagnosing Parkinson´s disease	3	Highly relevant work with clinical impact. Fluordat better than DaTSCAN for clear and specific visualisation of DAT improving diagnosis in PET/CT or PET/MRI; Not yet markedly outside KI; Innovation and product development. Changed practice in hospitals and used on 4000 patients. Impact evidence sources. Lacked details on what this means for patients.
Linköping University	The fight against emerging internet drugs	3	Largely routine type of activity; Range of beneficiaries. Data for classification, risk assessment, legislative & judicial use etc. Built relationship with agencies. Limited impact data/ evidence; Toxicology, Pharmacology, Neurosciences. Weaker on research, but high societal impact. Pharmacological profiles of new psychoactive drugs; Activities mostly in Sweden, some EU level. Important, timely topic. Easy to have a (political) impact compared to experimental research; New methodology and processes to become contracted by the EUDA to deliver pharmacological data on emerging drugs.
Linköping University	ArgusEye AB: A key enabling technology for next generation bioprocessing	3	Impact including spinout with 11 staff. New technology/ product. Company integrated system. Is at early stage with POTENTIAL impacts only - patient outcomes not yet realised; ArgusEye AB, a spinout based groundbreaking research on nanoplasmonic biosensors for biologics; Nanoplasmonic biosensors for real-time assess protein concentration, contamination, and quality without sample preparation. Not yet proven paradigm value. Reach somewhat unclear from the text.
Lund University	Novel peptides for treatment of hair loss	3	Huge potential, if this works - too early to see the real impact; FOL-005. FOL-026 - some research not published and only negligible impacts to date; Company Follicum AB (now Coegin Pharma) funded. G48FLO005 peptide clinical good safety profile and stimulation of hair growth. Market admission 2025; Sounds very interesting, with oustanding impact (if clinically successful). Hence, a bit too early to tell.

Evaluation unit	Title	Final grades	Final comments
			Large potential; 5 RCTs, good safety profile and stimulation of hair growth plus a first-in-class animal study in cardiovascular plus chronic ulcers in diabetes.
Lund University	Development of a stem cell therapy for Parkinson´s disease	3	Still at an early phase, the true impact remains to be seen; Some impacts (product/ innovation, industry collaboration, public debate) but details on actual benefits outside academia and for whom/what are vague; Great tradition in stem cell /regenerative medicine. Pioneering work, high clinical and social impact, large collaborative network, excellent relevant papers; Dopamine cell replacement stem cell derived neuronal progenitors to reverse symptoms of PD plus a clinical trials/implementation environment for ATMPs.
Lund University	Implementation of precision medicine in diabetes	3	There is a lot of activity in this same field globally, thus the impact caused by several labs. Great work anyway at Lund; Impacts including public awareness, instrumental (e.g. classification), patient outcomes. Precision medicine approach to diabetes risk stratification through lifestyle, genetics, CV information. Collating information and discovery research together; Research changing standard of care in diabetes. Lacks impact data. Includes potential impact and academic impact (not counted).
Lund University	Discovery of overproduction of viral-induced epithelial TSLP paved the way to a new personalized treatment for severe asthma	3	The role in clinical development remains unclear; Influential in new asthma drug development (approved - FDA, EU and Sweden) and now available. Company benefits (AstraZeneca). Provides an AstraZeneca contact to corroborate impact; Treatment of severe asthma cases. Contribution to clinical trials for Tezepelumab to reduce exacerbations. Improves quality of life, global, raising awareness.
Lund University	Implementation of DNA-based blood group typing in clinical practice	3	DNA-based blood group typing, i.e. a microarray-based blood group genotyping platform approved for clinical diagnostic use; Generation of microarray-based blood group phenotyping platform approved for diagnostic use. Global impact affecting patients dependent on blood transfusions. Still most labs use the serology; Difficult to follow the contribution of the research and the impacts that resulted. Specific impact data and evidence is vague.

Evaluation unit	Title	Final grades	Final comments
Lund University	Advancing IL1RAP-targeting therapies into clinical trials	3	IL1RAP is a key target for controlling alarmin signalling and has significant impact in both cancer and inflammatory disease. Successful spin out. Superb; IL1RAP as a therapeutic target in leukemia upcoming clinical trial plus ongoing clinical trials for inflammatory and autoimmune conditions (Cantargia AB). Promising, but still more clinical trials needed to confirm the impact; Innovation, clinical development, spinout, job creation, investment. Other impact is potential, teaching or academic. Lacked details on timing and patient outcomes.
Lund University	A new immunotherapy modality based on cellular reprogramming	3	Great science, long way to go to see the real impact; Innovative cancer gene therapy. Company continuation, job creation, significant investment. Global impact for cancer through cellular reprogramming. General cancer therapy, founding of company to deliver therapeutic compounds, groundbreaking science. Limited corroborating evidence, timings and impact data.
Lund University	SCAN-B and SAGA, two success stories from the bench to bedside for breast cancer patients	3	Cancer prognosis and diagnostics. Changed practice (Skane), company ongoing, jobs and significant investment; Good quality but not cutting-edge technologies to build breast cancer diagnostic database. Using available omics tool kit well but not high on innovation. Not yet widely in use, clinical impact still developing; Otherwise, is potential impact and lacks timings and impact data.
Umeå University	Research on Amyotrophic Lateral Sclerosis at Umeå University	3	The drug based on SOD1 mutation is not very effective in ALS; Stated beneficiaries including pharma (drug development) and patients. Longitudinal research on epidemiology, enzymology, genetics & neuroscience is foundation for the interdisciplinary research that has facilitated ALS advances; Transgenic mouse models and anti-SOD1 antibodies for familiar ALS plus clinical testing of new drugs and improved diagnostic and prognostic tools. But pathways to impact and details are very vague, no corroborating impact evidence.
University of Gothenburg	Increased knowledge about gut microbiota and type 2 diabetes has paved the way for novel strategies to develop next generation probiotics	3	Clinical trials still ongoing, not yet known, whether the therapy works; Innovation (patents), spin-out, 10 employees (economic impact), public understanding (inferred), co; many acquisition. Some impact evidence sources; Outstanding impact in the field of microbiota and probiotics. Concrete developments have been achieved based on outstanding research in human health; Absolutely great studies have been conducted that score very highly but as we are considering impact they have not yet been used as treatment; Patient gut

Evaluation unit	Title	Final grades	Final comments
			bacteria missing in treatment naïve T2D being trained for aerobic production - company formed and acquired by BioGaia.
University of Gothenburg	Treatments for Mitochondrial Disorders	3	Novel therapies for mitochondrial disorders and company with strong investment support to develop therapy for rare and common disease. Global reach. All evidenced; Spin-off company, Pretzel Pharmacuticals plus high-throughput screening identifying small molecules to restore mtDNA synthesis in cells (POLG mutations). Clinical trials will be started only 2025, thus the real impact not yet realized; Impacts by company set-up and focus, investment and jobs. Otherwise, it is potential impact (so not counted). Could be much stronger with details of jobs (economic impact).
University of Gothenburg	Ultrasensitive mutation detection in cancer management and beyond	3	Ultrasensitive mutation detection in cancer management assessing ctDNA in liquid biopsies, commercialized plus exploring forensic and environmental applications; Significant contribution to cancers´ diagnostics and management (and beyond), potentially improving outcomes (earlier detection/personalized treatments). The impact still developing; Innovation, new technology, commercialisation, changed guidelines, changed practice, building capacity, range of beneficiaries. Corroborating evidence sources.
Uppsala University	Lecanemab – the first disease modifying treatment for Alzheimer’s disease	3	An important preclinical development was carried out at Uppsala University, which later led to the clinical development programme of Lecanemab for Alzheimer disease; Lecanemab – the first disease modifying treatment for Alzheimer’s disease. Approved in US, Japan, China, South Korea, Hong Kong, Israel, UAE, Great Britain, Mexico and Macau. Commercialised through Swedish company Bioarctic and Japanese Eisai. Please note that Lecanemeb only moderately benefits a restricted population of patients who showed a slight improvement in cognitive and functional symptoms (CDR-SB scale) after 18 months of treatment. The use of Lecanemeb has been linked to increase risk of brain bleeds, and during clinical trials several patients endured painful symptoms and at least 5 died or suffered severe brain injury. Also, many other players, the drug is not very effective, and this compromises impact; Innovative treatment, drug development, FDA approval, new product, company involvement. The rest is extrapolation and potential impact (so discounted).

Evaluation unit	Title	Final grades	Final comments
Uppsala University	A novel blood-based ex vivo method for predicting human-specific reactions to biological drugs	3	Limited impact so far and will be challenging to mimic what happens in vivo; Innovative new widely used method for safer drug development and regulatory requirements, global customers, variety of beneficiaries, company set-up; Reliable prediction of unwanted reactions to biological drugs. The ID. Flow system is used by many companies and researchers worldwide; A novel method for predicting human-specific reactions to biological drugs. A small start-up company has been established; Multiplexed prediction of infusion reactions of biological drugs on non-manipulated blood, GLP certified plus industrial driven drug development study.
Uppsala University	Selection of resistant bacteria at very low antibiotic concentrations	3	MSC - influential regarding national/international regulations and policies, multiple beneficiaries, impacting different sectors, spinout & jobs. Important findings, but concrete impact remains somewhat unclear; Sub-inhibitory concentrations of antibiotics create resistant bacteria. Although the novelty has faded since 2010, it remains a major discovery; In terms of pure science and attempts to be translational this paper scores very high but in context of real impact, it is not there yet; MSC adopted worldwide, low concentrations of antibiotics promote resistance if released into environment or in bodies of humans/animals after treatment. Not evidenced present.
Uppsala University	CAR-T cells for the Treatment of Cancer	3	CAR-T cell tech not originally developed in Sweden, but UU has successfully pioneered its use in Sweden and Europe: first patient outside of the US. Support to CAR-T therapy implementation plus trials, first patient outside of the US. Heading the National CAR-T cell group and co-founded SWECARNET. Multiple patients treated, network, NAP innovation, company set-up. Claim of increased survival is vague. Lacked clarity and evidence of impact. Still only working for blood cancers so no new solid tumour applications - yet.
Uppsala University	Fast Antibiotic Susceptibility Testing – The right drug for the right bug	3	Researchers have developed a rapid and efficient diagnostic tool for urinary tract infections. Ongoing research lacks novelty in the international competition; Yet another case where the science is simply TOP NOTCH but the absolute entry into practice is not yet there; Fast susceptibility test, resistance patterns in urinary tract infections produced/marketed across EU, evaluated at 17 UK health centres, AMR prize. Still

Evaluation unit	Title	Final grades	Final comments
			in an expansion phase; Innovative test, company benefits and 70 employees, PA-100 is on the market, building capacity for physicians, undergoing evaluation. Lacks impact evidence.
Uppsala University	Development of novel tumour microenvironment (TME) gene engineering therapies as a new treatment for cancer	3	Development of novel tumour microenvironment (TME) gene engineering therapies as a new treatment for cancer evaluated in four clinical trials; The Uppsala team contributed significantly to the development of the gene engineered therapy with process high potentials; In this case novel tumour microenvironment (TME) gene engineering therapies were developed as treatment for cancer. These therapies have not yet been approved. The real impact will be seen after randomized trials; Innovation, therapeutics development, acquired by biotech company, first case study to share clinical trial patient outcomes (high significance/small number);
Uppsala University	Pharmacometric modelling to improve global policy and to identify novel treatment of multi resistant tuberculosis in children	3	New modelling - tuberculosis dosing in children, changed WHO global guidelines, changed practice regarding permanent WHO advisory group. Some corroborating evidence sources; Very important work that helps more efficient drug regiment to be applied and tuberculosis is one of the most pressing problems right now worldwide; They established in silico pharmacokinetic models of anti - tuberculosis drugs used in children. If validated, this could have a significant impact on future treatments; Pharmacometric modelling to improve WHO policy plus identify novel treatment of multi-resistant tuberculosis in children. Also, many other players.
Uppsala University	DMRT3 mutation as a diagnostic test for gait control used in horse breeding	3	Overstated, also other genes control locomotion; Innovation, horse-breeding impacts and claims international reach and use, other beneficiaries including DNA labs, company and patent licensing. Highly relevant veterinary work, DMRT3 test is used worldwide in horse-breeding industry, very good publications; The role of the DMRT3 gene/DMRT3 neurons for spinal cord function locomotion led to genetic test for gait control. Impact on horse-breeding. Lacks specifics and evidence.
Uppsala University	Self-sampling and repeat testing for Human papillomavirus (HPV) to	3	Self-sampling for HPV to increase coverage and inclusiveness of population-based cervical cancer screening; Part of the larger eradication of HPV and Cervical cancer. Reaches novel population in a deft way. Uptake international (South Africa). Still in an expansion phase; stated impacts including contributions

Evaluation unit	Title	Final grades	Final comments
	increase coverage and inclusiveness of population-based cervical cancer screening		to HPV sampling innovation (test/methods), policies (e.g. WHO recommendations) and implementation. Lacked clarity and impact evidence.
Örebro University	Evaluation basic medicine, case study 1: A new treatment for gonorrhoea	3	There is potential impact to come but - in their own words "we cannot show the impact now."; A research that is highly impactful as it targets populations that are largely neglected. The development of resistance also to zoliflodacin prevented 4 star; Important discovery in the treatment of gonorrhoea. However, the real impact of this discovery on human health will depend on ongoing phase III trials; RCT phase III study of first-in-class against gonnorhoea. Nice metabolomics studies, but where is the impact on treatments or other aspects?; Not published yet, but results include non-inferiority to present last resort treatment.
Linköping University	Precision medicine in action: Enhancing thiopurine therapy through pharmacogenetic testing	2	Developing methodologies to identify patients risking severe side effects from thiopurine drugs. Impact in Sweden and to standards internationally. Discovery and central studies mainly done elsewhere; Lacks data/evidence on how many patients have benefitted. Other impacts not justified e.g. national change regarding pharmacogenetic testing to tailor drug treatment; 10 per cent patients have resistant genotype to TPMT. The impact here is to use pharmacogenetics to improve efficacies for ALL and autoimmune diseases in Sweden.
Linköping University	Cell-Based Skin Grafting: A novel approach for difficult-to-heal wounds management	2	Refine culture conditions for cell-based skin grafting. Cost effective treatment for wound care without adverse effects. Potential global societal impact; pre-clinical-clinical research on the verge to reach clinical practice. Still early days for clinical impact of a novel cell therapy in wound care. Impact unclears in comparison to current methods, at an early phase; New approach and seems to have benefitted 20 patients (details scarce). Is at very early stage with potential but very modest benefits outside academia.
Umeå University	Streptococcal IgG degrading proteases: Important virulence	2	Partially shared by LU; Innovation, biotech tools development, commercialisation. Queries regarding eligibility and regarding research (part 1) supported by HEI. Lacks impact details and evidence; This work is identical with that described in the case study by Lund University. This work is similar to that described in

Evaluation unit	Title	Final grades	Final comments
	factors and biotechnological tools		the case study by Lund University; Researchers are involved in the discovery of a bacterial enzyme which is now commercially available from the company Genovis; Understanding of immunoglobulin cleavage by bacterial Ig proteases used by Hansa and Genovis.
Umeå University	Targeting Non-Canonical Four-Stranded DNA Structures - Novel Approaches in Cancer Treatment	2	Possible therapeutic targets in cancer and in inhibiting infectious agents. There have been some research prizes associated with this pre-clinical work; Company Vinnova grant - early days; Great work, the real impact remains to be seen; Innovation (patents), progress regarding drug development, investment, job creation, public and media engagement. Some corroborating evidence sources provided.
University of Gothenburg	Application of pleasant touch in healthcare	2	Demonstrate physiological basis for affective touch and highlighted its social impact; Very important first publication, strong publication record; Pleasant touch in healthcare, a neurophysiological foundation and scientific support for implementation in palliative care; Not justified. Use of pleasant touch in palliative care was influenced by the research, contribution to public understanding inferred, rest is academic impact;
Uppsala University	Super rolling circle amplification assays for detection of relapse in malignancy – commercialized by Rarity Bioscience AB	2	This played a crucial role in the development of super RCA technology, foundational work on padlock probes RCA technology for cancer diagnosis and monitoring; Multiplex assay detects rare nucleic acid sequences in liquid biopsy with orders of magnitude greater sensitivity than current test assessing cancer relapse.; Still at an early phase, the full impact remains to be seen; Innovation, new technology, services developed, company set-up but early stage.
Uppsala University	Drug delivery to the brain – to measure is to know	2	Good for initial screening in mouse and rats. How well does this reflect what finally happens in patients?; Unbound brain to-plasma partition coefficient (Kp,uu,brain) was of great importance to measure drug brain delivery. High translational impact. Method to understand/assess how drugs are transported to and within the brain (Kp,uu,brain; Impacts including increased understanding in pharma (but outside impact period...) and resurgence of CNS drug development. But lacked clarity and corroborating evidence;

Evaluation unit	Title	Final grades	Final comments
Lund University	Next-generation peptide-based therapies for infection and inflammation	2	Targeting both infection and inflammation through peptide-based immunomodulatory therapies addressing complex wounds in Phase I and gearing up for a Phase II; This is an excellent example of translational research from bench to bedside. This approach has great potential and received already intensive media coverage; This case sets out to develop novel peptide-based therapies for infection and inflammation. Treatment not yet approved. Two small biotech companies involved. At an early phase, clinical impact remains to be seen; Innovation and new product/therapy development. Company benefits (assumed), some media engagement (public awareness - assumed). Otherwise, is potential impact.
Örebro University	Evaluation basic medicine, case study 2: Tackling the complexity and challenges of 'chemical exposome'	1	High profile toxicological work on PFAS. But mainly impact in research landscape and not really beyond, yet; Interesting, timely topic, part of two EU initiatives, publications output not outstanding, no applications (yet), very diverse biological contexts; Correlation/association between PFAS and type 1 diabetes plus other autoimmune diseases. Publications and some progress towards methodologies to assess links. The impact has not been demonstrated; The case study focuses on the research. There is no mention of any changes/benefits outside of academia.

8 Appendix 5 Term maps

The following figures show term maps with frequently used terms in Swedish publications in basic medicine from 2018 to 2022. The distance between two terms is an indication of the relatedness of the terms. The size of the sphere illustrates how often the term have been used and the lines indicates where two terms have been used in the same publications. The different colours represent clusters of terms that often occurs in the same publications.

Figure 46. Term map made from title words in Swedish publications in neurosciences.

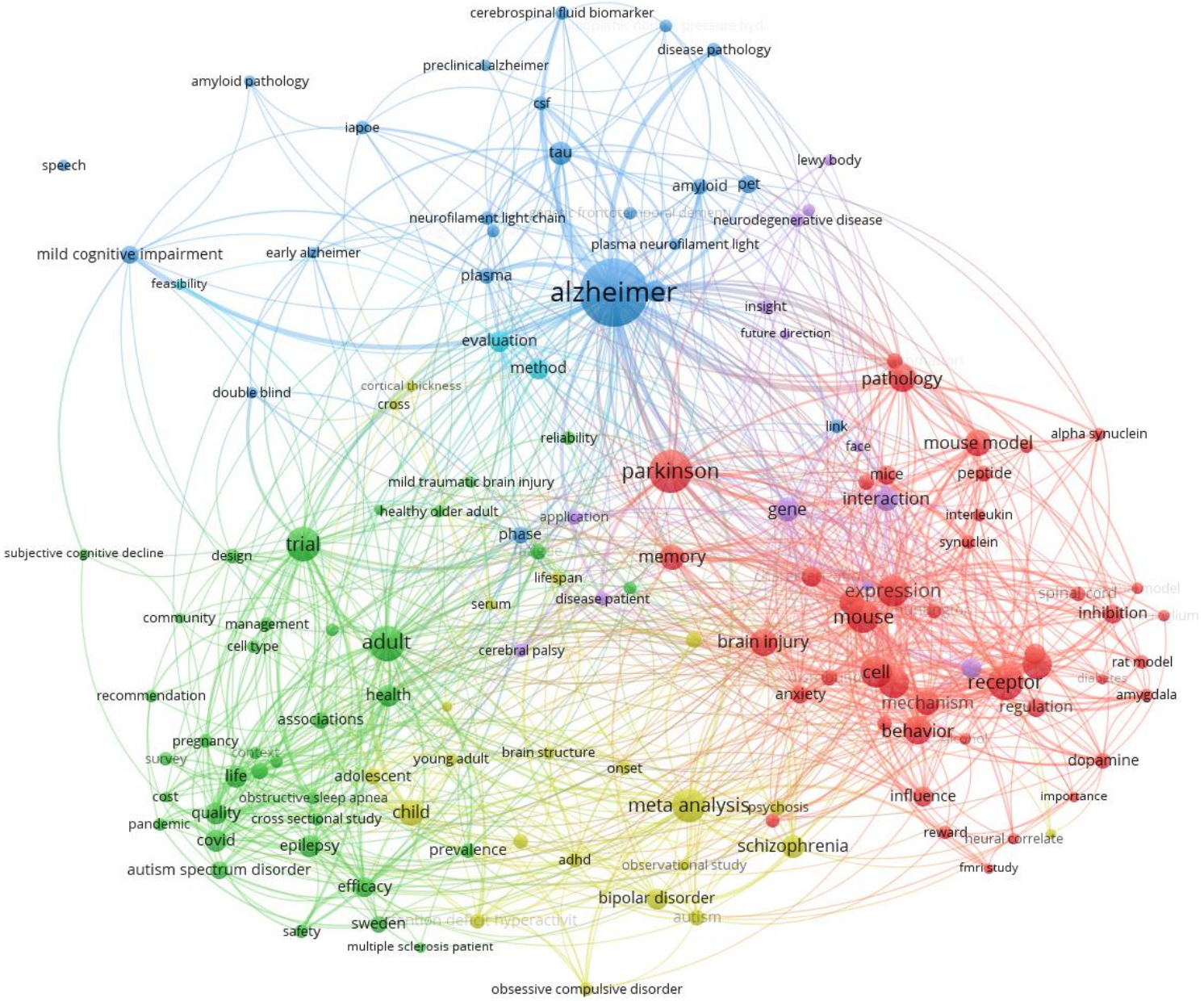


Figure 47. Term map made from title words in Swedish publications in biochemistry and molecular biology.

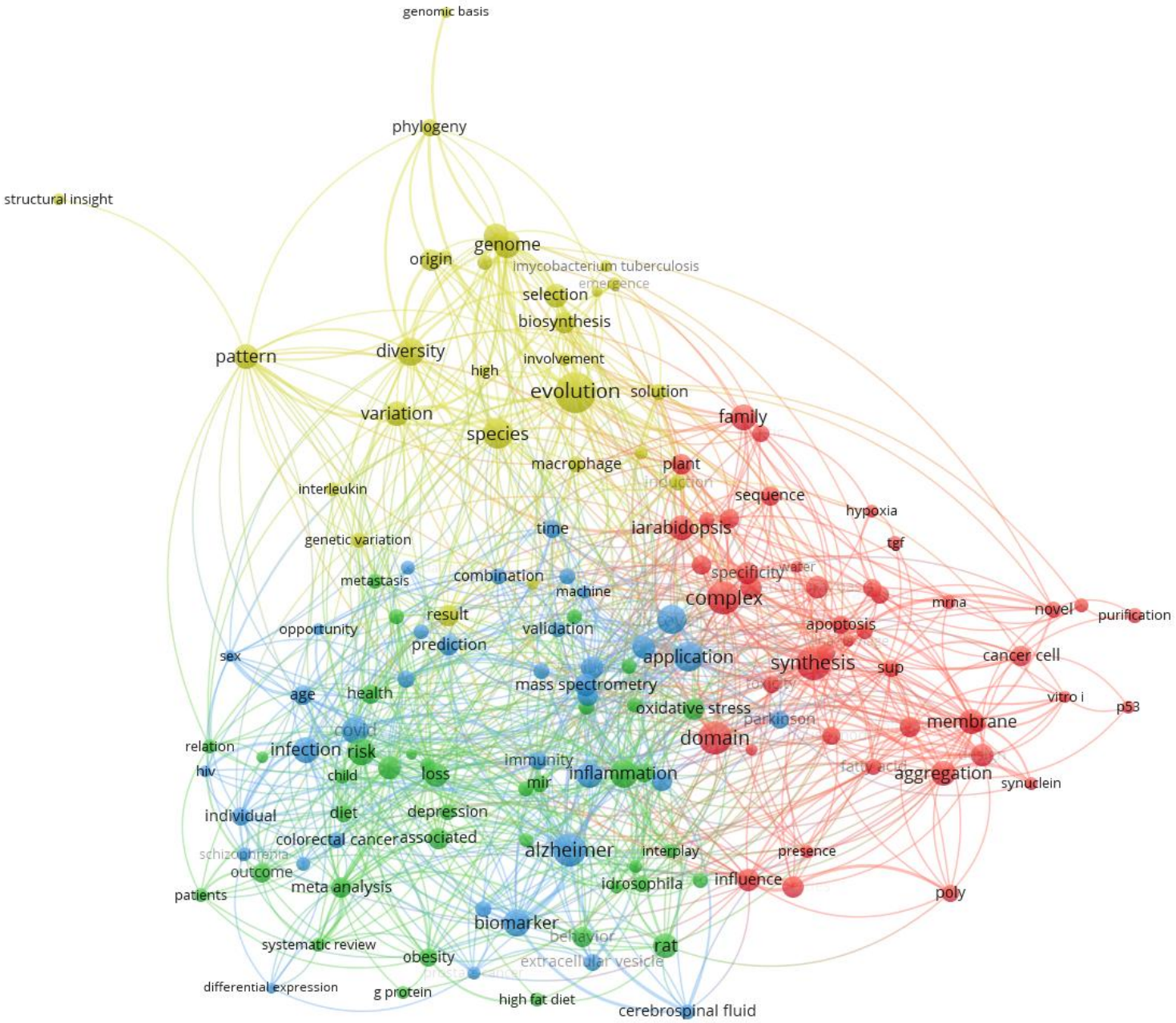


Figure 48. Term map made from title words in Swedish publications in cell biology.

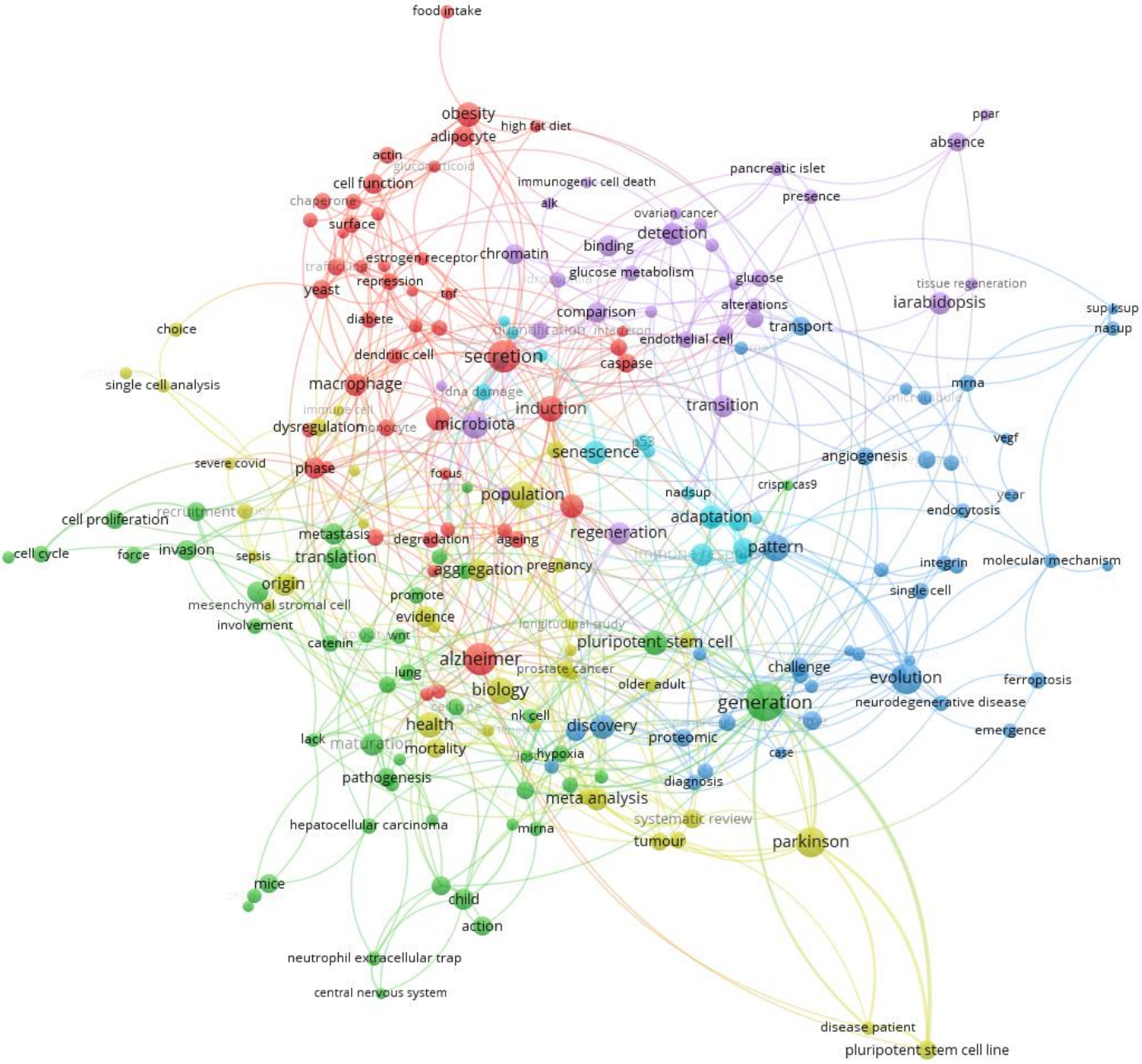


Figure 49. Term map made from title words in Swedish publications in microbiology.

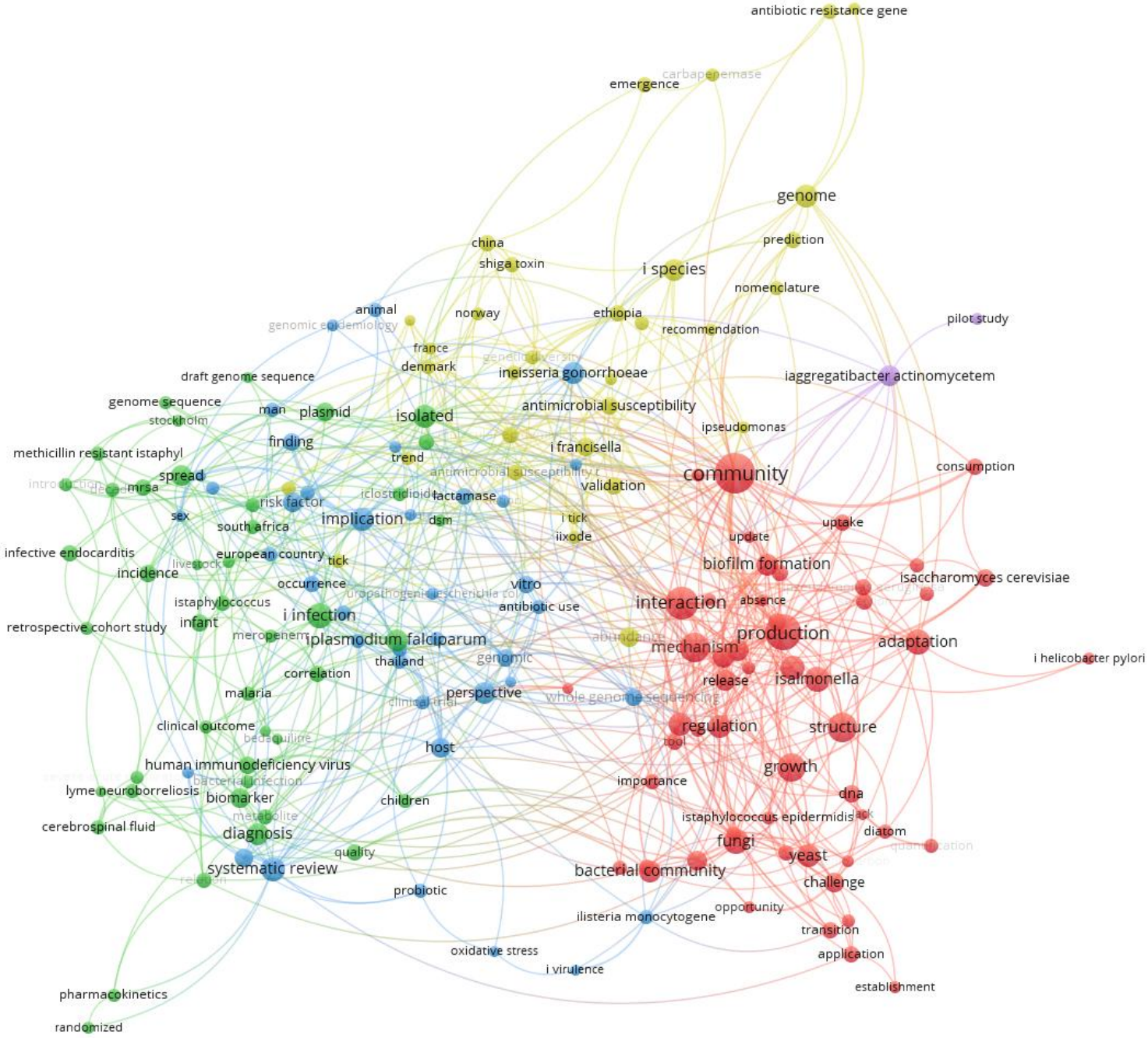


Figure 50. Term map made from title words in Swedish publications in immunology.

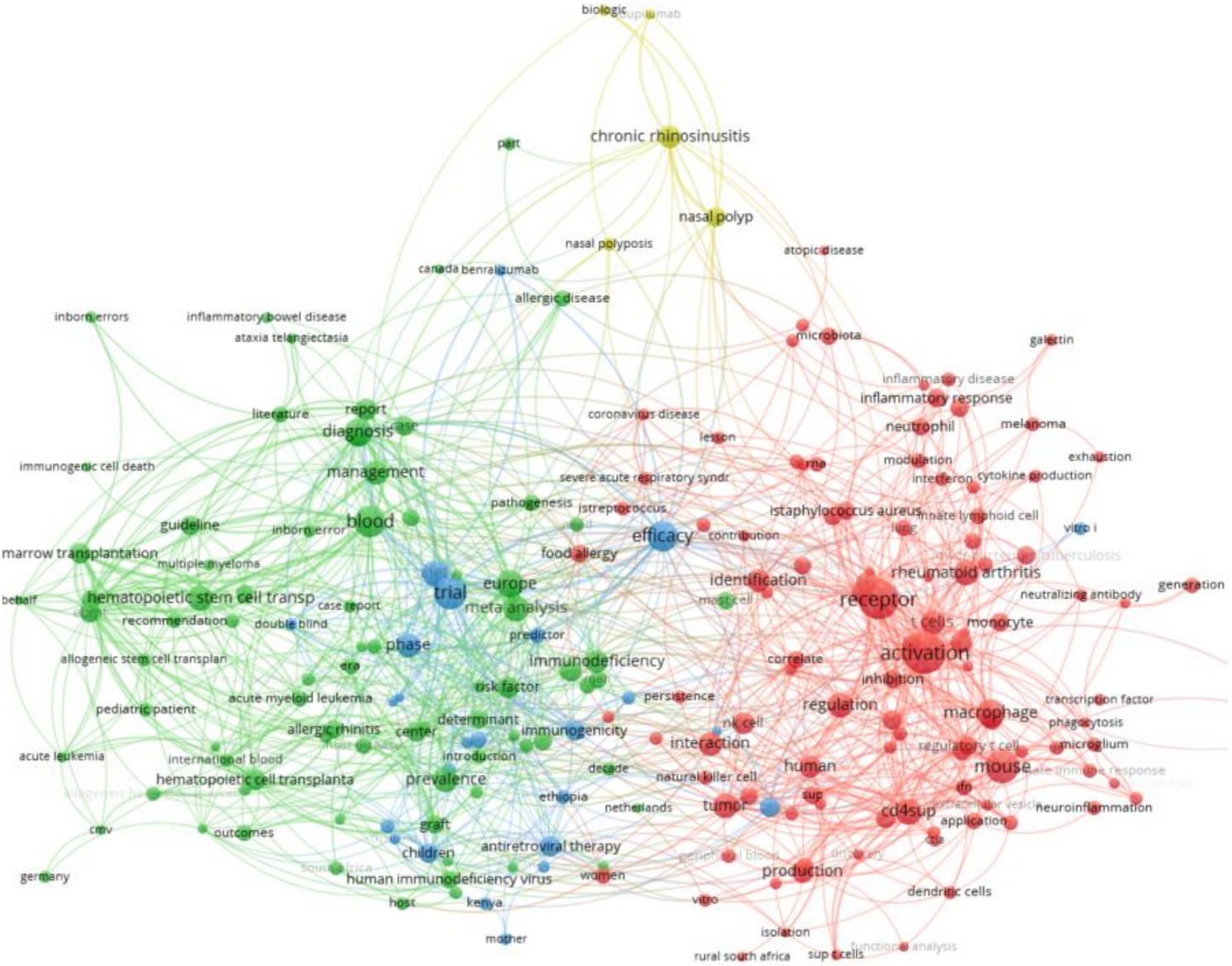


Figure 51. Term map made from title words in Swedish publications in cancer biology.

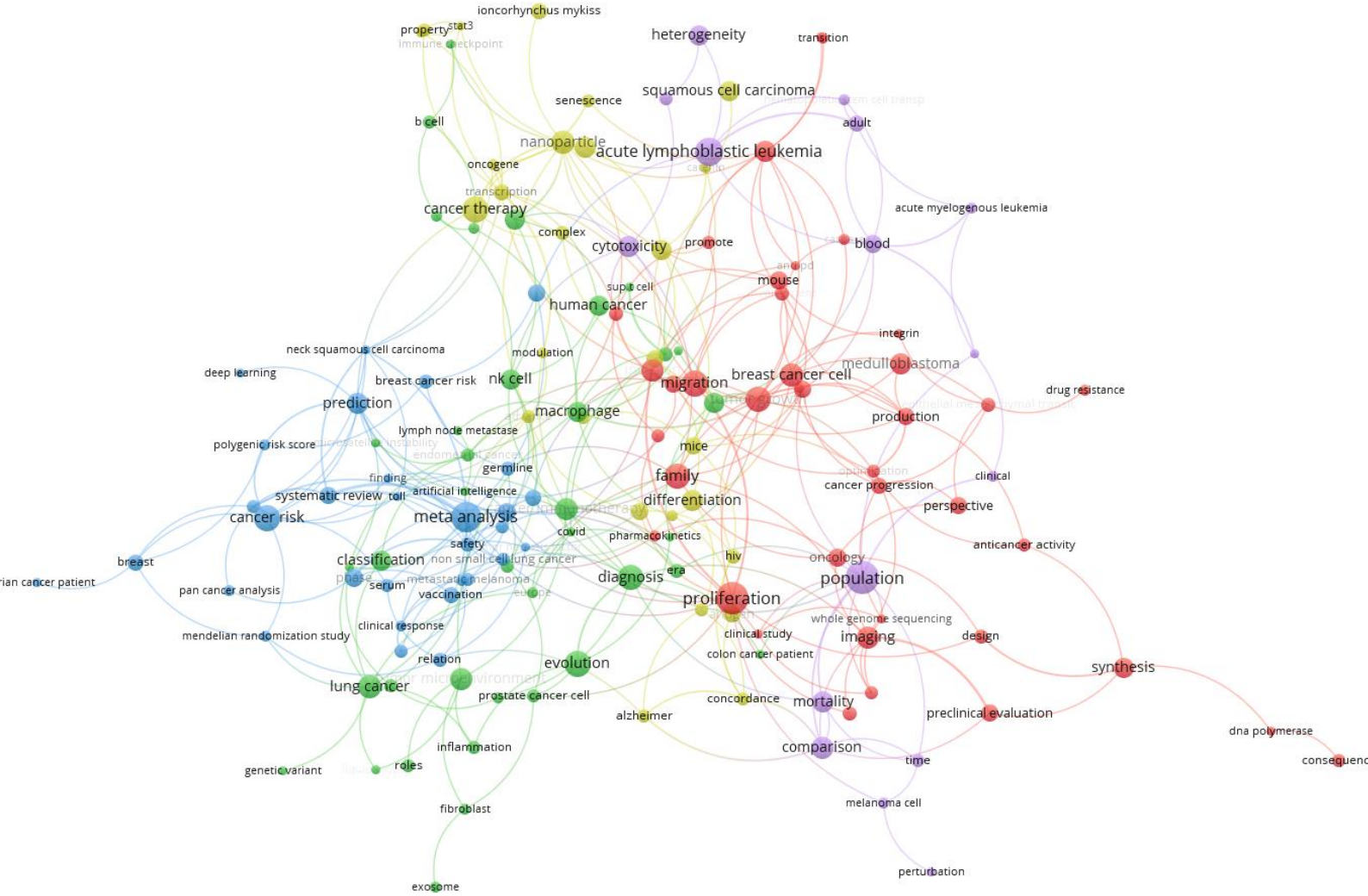


Figure 52. Term map made from title words in Swedish publications in pharmacology and pharmacy.

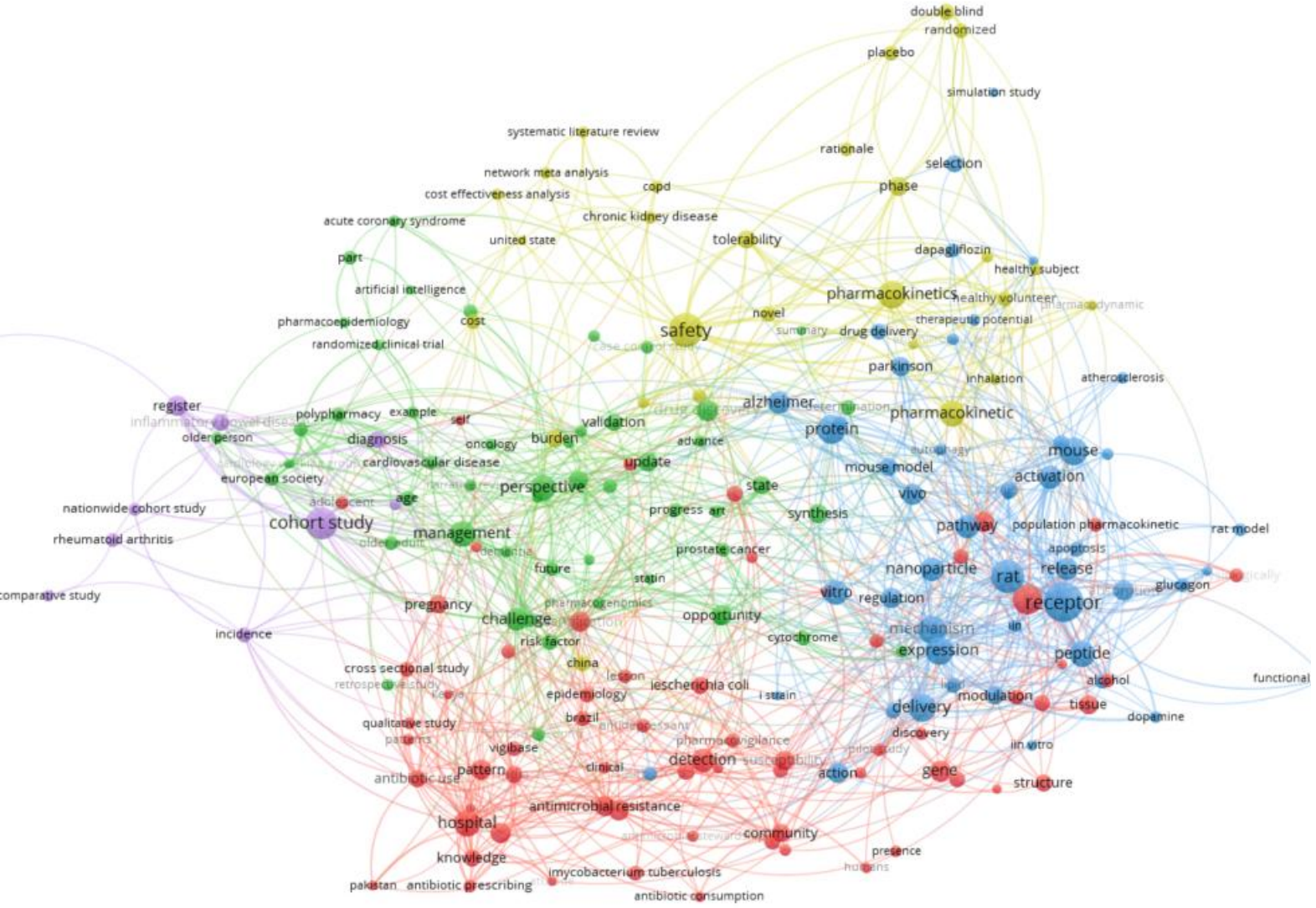


Figure 53. Term map made from title words in Swedish publications in genetics and heredity.

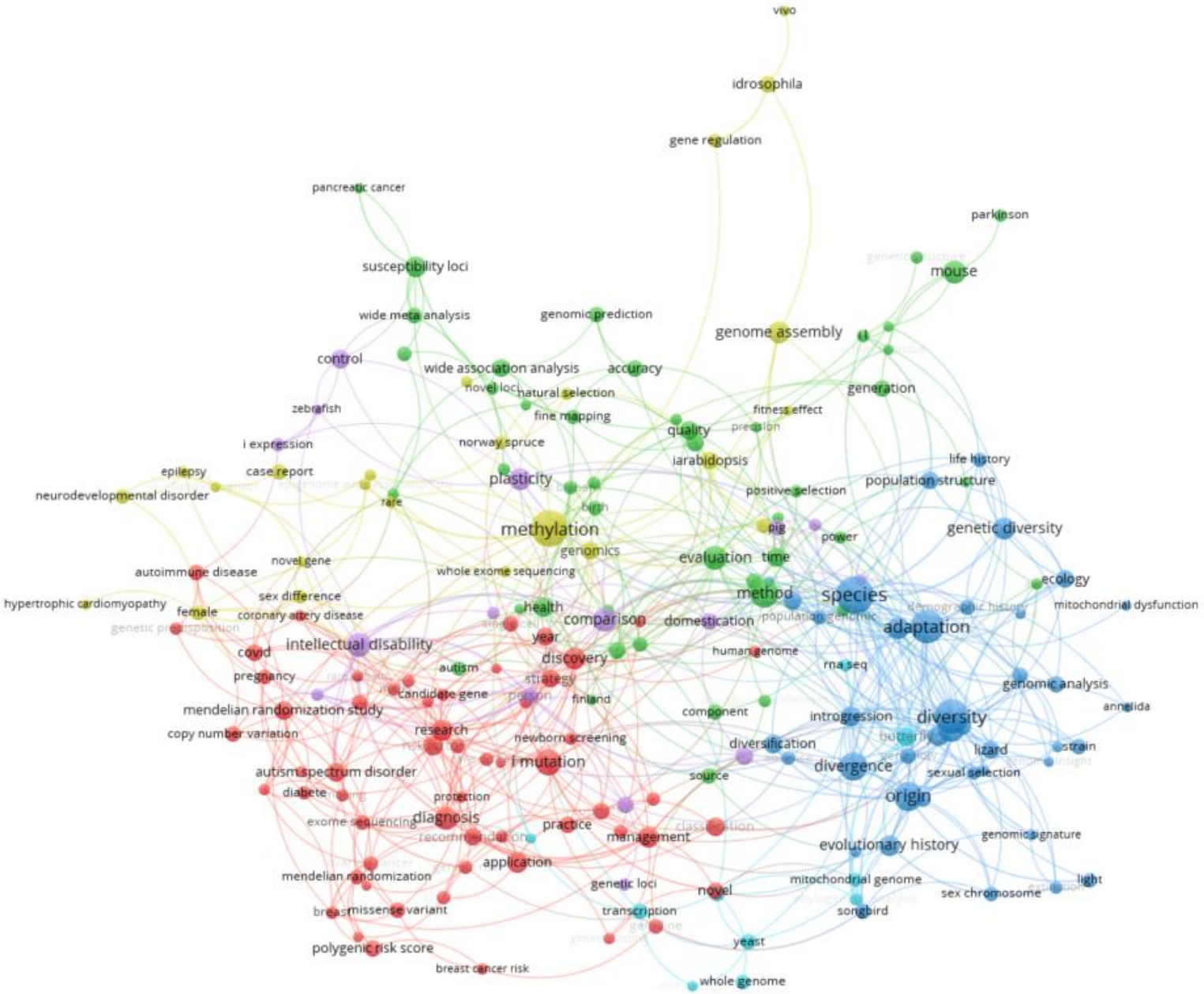


Figure 54. Term map made from title words in Swedish publications in physiology.

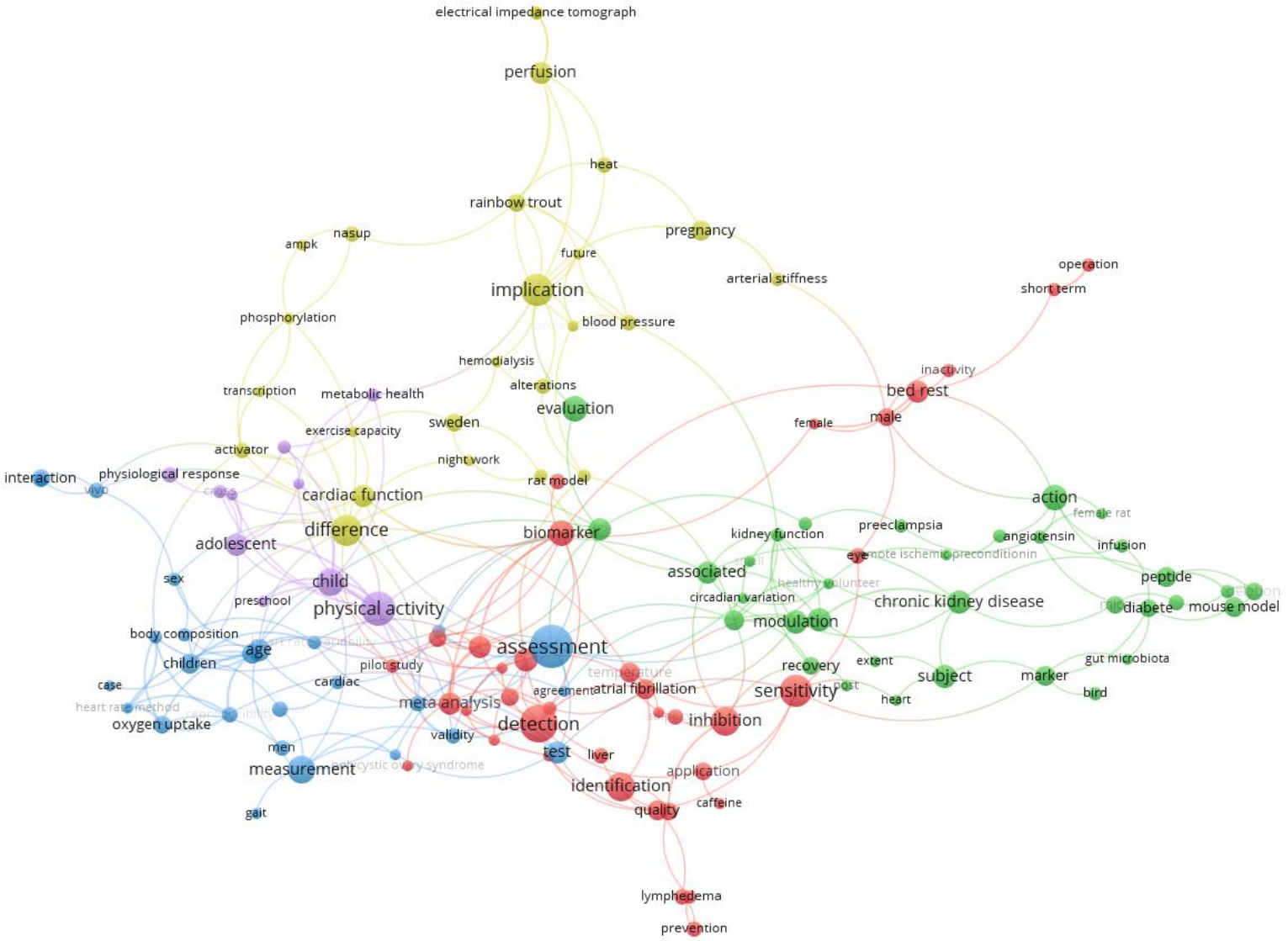


Figure 55. Term map made from title words in Swedish publications in toxicology.

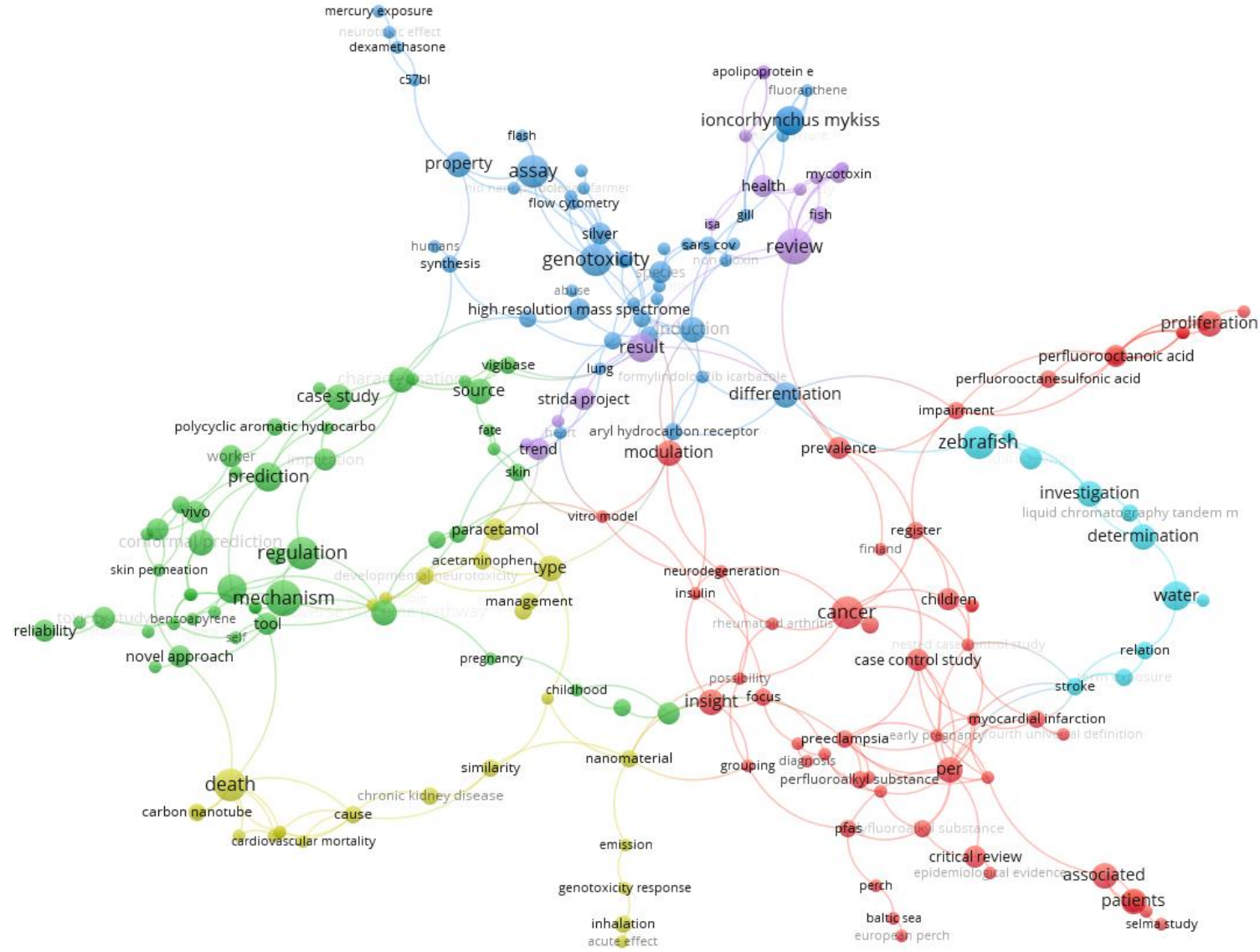


Figure 56. Term map made from title words in Swedish publications in medicinal chemistry.