Europäisches Patentamt
European Patent Office
Office européen des brevets

Patents and innovation against cancer

Evidence from patent and company data

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epo.org

Foreword

Medical advances are helping many of us to live longer. This means that we are more likely to encounter cancer in our own lives or in those of our closest family and friends. In the European Union, no fewer than 31% of men and 25% of women are expected to be diagnosed with cancer before reaching the age of 75.

Innovation can give us hope for the future. Over 5 million lives have already been saved in the EU alone thanks to inventions in oncology.[1] The fight against cancer is also increasingly at the forefront of research and innovation, spurred by recent technological breakthroughs and greater commitment from both the private and public sectors.

Drawing on the EPO's expertly curated patent data, this study highlights a significant surge in innovation aimed at combatting cancer in recent years: with patenting rising by over 70%, or almost 10% annually between 2015 and 2021. This report offers policymakers and investors key insights into the drivers behind this trend and their impact on the overall approach to innovation in related industries.

The surge in cancer innovation is mainly driven by new technologies – from immunotherapy and gene therapy to digital technologies such as AI – that are opening up promising new avenues for diagnosis and treatment. It also largely stems from fundamental research, with universities and public research organisations alone accounting for almost a third of patenting activities.

So intellectual property rights (IPRs) play a more important role than ever in supporting the commercialisation of next generation technologies against cancer. Indeed, IPRs not only protect inventions and attract investors, they also support collaboration and technology transfer between research institutions and industry.

According to our results, the US enjoys a clear lead in the field of cancer research, accounting for nearly 50% of all IPFs (International Patent Families) from 2002 to 2021, a position boosted in recent years by strong innovation ecosystems and massive public funding. While Europe is in second position, the gap to the US is widening and China is catching up at an impressive pace. The challenge now facing Europe – and its policymakers – is to increase investment, better exploit its research potential, and to grow its vibrant pool of startups. The newly established Unitary Patent will be instrumental in this endeavour.

The EPO is committed to playing its role through inclusive collaboration and the dissemination of patent knowledge. For the first time, we are launching a study together with a new, free online platform, "Technologies combatting cancer". The platform will make it easier for cancer researchers and innovators to access the know-how and technical information contained in patents. This is the fourth such platform from the EPO, following those on coronavirus, clean energy technologies and firefighting.

Both the study and the platform were developed in the framework of the EPO's newly created Observatory on Patents and Technology, allowing EPO experts to collaborate with ten national patent offices from our member states, namely Austria, Bulgaria, Denmark, France, Greece, Italy, Norway, Sweden, Switzerland and Türkiye.

The success of this joint endeavour provides a model for future collaboration to offer unique business intelligence on promising technologies for decision-makers in government and industry, shedding light on how innovation can pave the way towards a smarter, safer and healthier future for all of us.

António Campinos
President, European Patent Office

1 Darmartello, M. et al., 2022: https://www.sciencedirect.com/science/article/pii/S092375342104881X?via%3Dihub

Table of contents

List of tables and figures

Tables

Figures

List of abbreviations

ADC	Antibody drug conjugates
AI	Artificial intelligence
ARIPO	African Regional Intellectual Property Organization
API	Active pharmaceutical ingredients
BNCT	Boron neutron capture therapy
BCMA	B-cell maturation antigen
CAGR	Compound annual growth rate
CAR T	Chimeric immunoreceptors, chimeric T-cell receptors or artificial T-cell receptors
CML	Chronic myeloid leukaemia
CNN	Convolutional neural networks
CRISPR	Clustered regularly interspaced short palindromic repeats
CT	Computed tomography
CTCs	Circulating tumour cells
ctDNA	Circulating tumour DNA
DNA	Deoxyribonucleic acid
EAPO	Eurasian Patent Organization
EPR	Enhanced permeability and retention
EV	Enfortumab vedotin
FDA	US Food and Drug Administration
GAN	Generative adversarial networks
GCCPO	Gulf Cooperation Council Patent Office
HCC	Hepatocellular carcinoma
HDI	Human development index
HIFU	High-intensity focused ultrasound
HIS	Human immune system
HER2	Human epidermal growth factor receptor 2
ICT	Information and communication technology
IPF	International patent family
LV	Ladiratuzumab vedotin
mAbs	Monoclonal antibodies
miRNA	Micro ribonucleic acid
MRI	Magnetic resonance imaging
mRNA	Messenger ribonucleic acid
ncRNA	Non-coding ribonucleic acid
NCT	Neutron capture therapy
OAPI	African Intellectual Property Organization
PBD	Pyrrolobenzodiazepine
PDC	Peptide-drug conjugate
PDT	Photodynamic therapy

PEG	Polyethylene glycol
PEI	Poly(ethyleneimine)
PET	Positron emission tomography
PKI	Protein kinase inhibitor
PLGA	Poly(lactic-co-glycolic acid)
PRO	Public research organisation
PROTACs	Proteolysis targeting chimeras
PRRT	Peptide receptor radionuclide therapy
R&D	Research and development
S-TIR	Specific total immune remodulation
SVM	Support vector machines
TCMM	Traditional Chinese medicinal materials
TCR	T-cell receptor
TIL	Tumour-infiltrating lymphocytes
TTF	Tumour treating fields
VMAT	Volumetric modulated arc therapy
WHO	World Health Organization

List of countries

AL	Albania
AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CN	P.R. China
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
JP	Japan
KR	R. Korea
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
NO	Norway
Other Europe (countries)	Member states of the European Patent Organisation that are not part of the EU27, i.e. AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK.
PL	Poland
PT	Portugal
RO	Romania
RoW	Rest of world
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovakia

SM	San Marino
TR	Türkiye
UK	United Kingdom
US	United States

Executive summary

With an estimated 19.3 million new cancer cases and almost 10.0 million cancer deaths in 2020, cancer is a major global health threat. There is an ongoing race for innovations to fight this devastating disease, reduce the side effects of cancer treatment, improve the quality of life for cancer patients, and most importantly to save people from dying. These efforts help achieve the United Nations Sustainable Development Goal 3 target of reducing deaths from non-communicable diseases by one-third by 2030. Advancements in cancer diagnostic and treatment technologies have played a pivotal role in reducing cancer mortality rates, contributing to a 12% reduction in cancer-related deaths, or over 5 000 000 lives saved in the EU, between 1988 and 2022.

Rapid progress is currently being driven by advances in biotechnology and information and communication technology (ICT), as well as increased investment, international collaboration, data sharing, and regulatory incentives. Technologies such as gene therapy or immunotherapy, and targeted therapies are revolutionising cancer treatment and care. Moreover, advances in cancer diagnostics, such as new imaging and molecular biology techniques, are improving early detection rates and are crucial for effective cancer management.

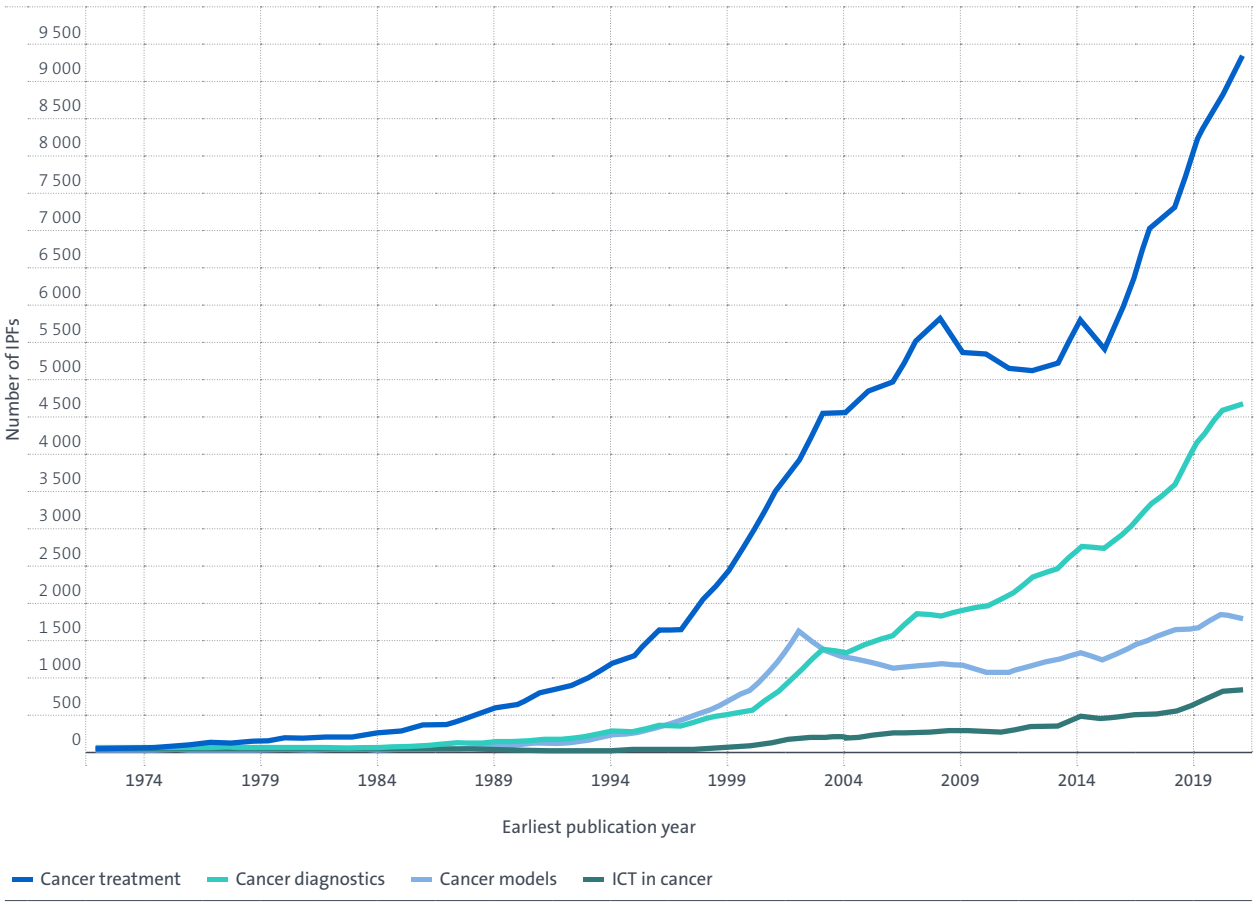
Aimed at decision-makers in both the private and public sectors, this study by the European Patent Office is a unique source of intelligence on the technology landscape and the most recent innovation trends for combatting cancer. Using global patent data as a measure of innovation, it provides the most comprehensive investigation of cancer-related patenting up to this point in time, spanning a broad range of technologies that underpin developments in the diagnosis, prevention, treatment, and, ultimately, curing of the collections of diseases that are covered by the umbrella term of cancer. Besides providing a unique window into the latest inventions that will help humanity in its fight against cancer, it documents ongoing transformations of the technology landscape, highlighting the respective contributions of the leaders in cancer-related innovation across the world.

1. Dramatic surge of 70% for innovation against cancer since 2015

Since the 1970s, over 140 000 inventions against cancer have been disclosed to the public. Between 2015 and 2021, the annual count of international patent families (IPFs[2]) rose by more than 70%, equivalent to a compound annual growth rate (CAGR) of 9.34%, and exceeded 13 000 IPFs in 2021. This growth was driven by accelerated new technology developments in cancer treatment technologies such as immunotherapy, gene therapy, and non-coding nucleic acids, but also in cancer diagnostics, especially in liquid biopsies, and healthcare informatics. Cancer-related IPFs constituted over 3% of worldwide patenting in 2021.

Figure E1

Trends in IPFs in cancer-related technologies, 1972–2021



Source: EPO

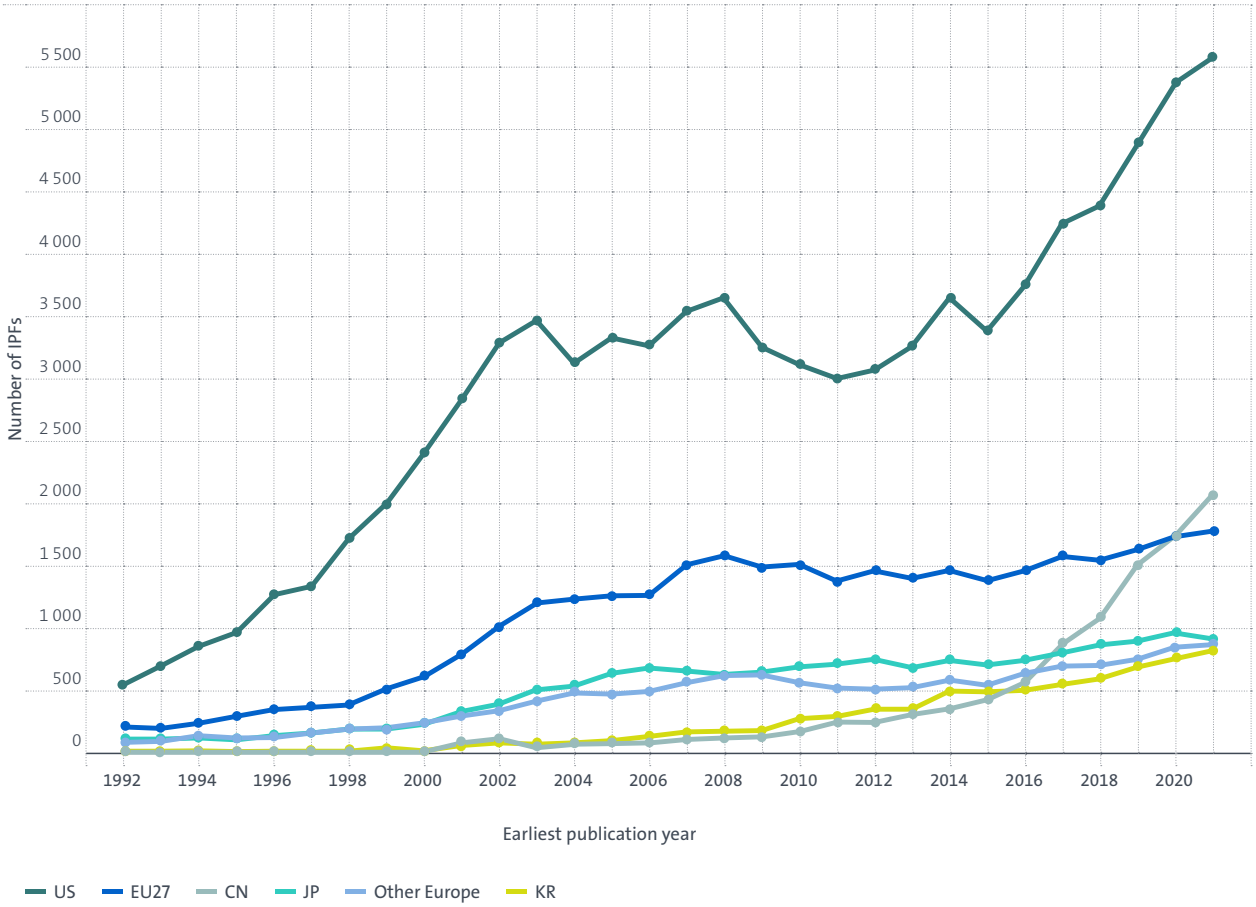
2 Each IPF covers a unique invention and includes patent applications targeting at least two countries. More specifically, an IPF is a set of applications for the same invention that includes a published international patent application, a published patent application at a regional patent office, or published patent applications at two or more national patent offices. It is a reliable proxy for inventive activity because it provides a degree of control for patent quality by only representing inventions for which the inventor considers the value sufficient to seek protection internationally.

2. The US is a strong leader, far ahead of Europe and China

The US stands out as the pre-eminent leader in cancer-related innovation, with nearly 50% of all IPFs being attributed to US applicants from 2002 to 2021. US applicants have further reinforced their lead since 2015, contributing disproportionately to the acceleration of cancer-related innovation in the period 2015–2021. The EU27 is second with an 18% share, followed, at a distance, by Japan with 9%. In recent years, the dynamic growth in cancer-related IPFs has primarily been driven by applicants from the US and P.R. China. In 2021, Chinese applicants took a significant step, surpassing the EU27 with an impressive tally of over 2 000 IPFs, thereby securing China's position as the world's second-largest contributor to cancer innovation for the year.

Figure E2

Trends in IPFs in cancer-related technologies by country of origin, 2002–2021



Source: EPO

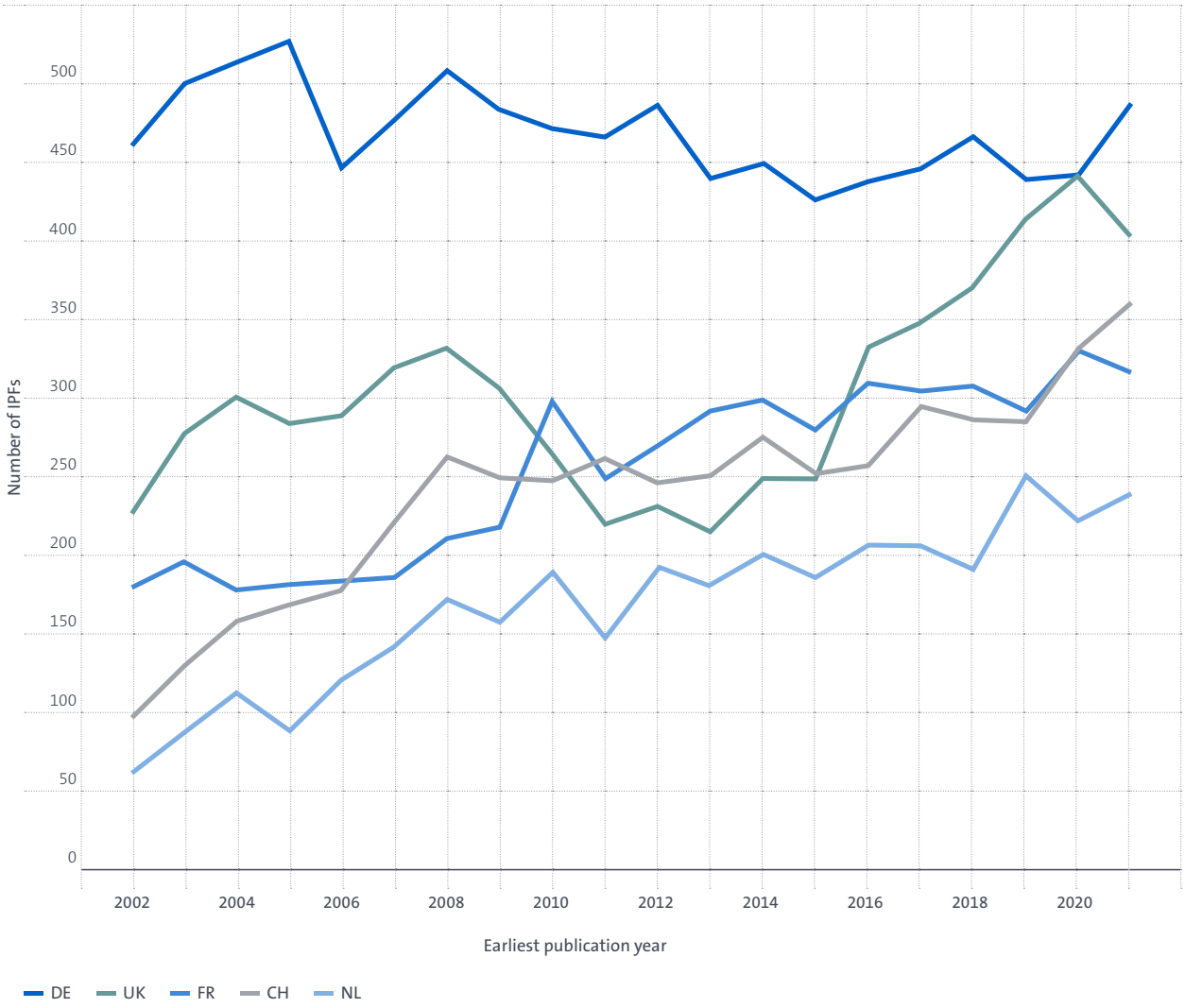
3. Germany remains in the lead among the European countries, but the UK, France, Switzerland and the Netherlands are catching up quickly

Among European nations, German applicants have maintained their position as leaders in cancer-related innovation over the past two decades, amassing over 9 000 IPFs from 2002 to 2021. However, the annual numbers of IPFs originating from German applicants decreased slightly over this period.

In contrast, the UK has recorded strong growth over the last decade (a doubling) to emerge in recent years as the second-largest contributor of IPFs, closely behind Germany. Additionally, France, Switzerland and the Netherlands have also recorded steady increases in cancer-related innovation.

Figure E3

Trends in IPFs in cancer-related technologies for the top five European countries, 2002–2021



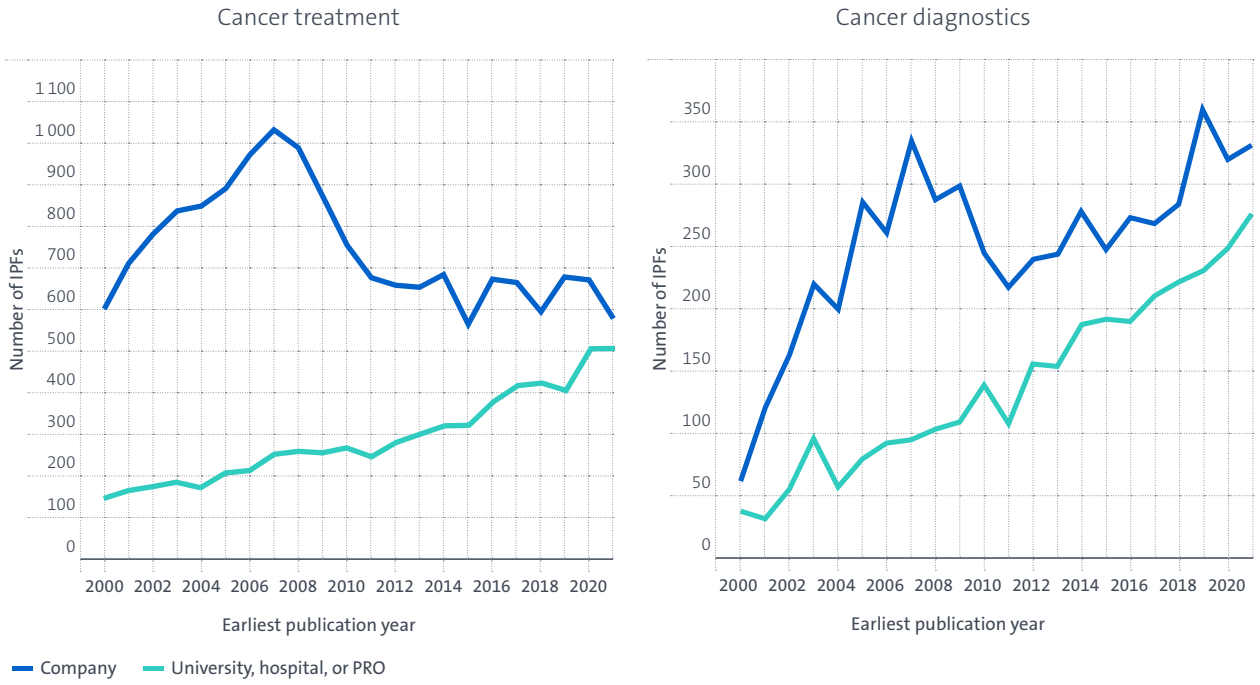
Source: EPO

4. Universities and public research organisations play an increasing role in cancer-related innovation

Universities and public research organisations (PROs) generate an impressive proportion of all IPFs in cancer-related technologies. Between 2002 and 2021, they accounted for almost one in three IPFs in these technologies at a global level, and for up to 35% of all IPFs in the US. They are also well represented among the top applicants, with seven institutions (including five US ones) featuring in the global top 20 for the period 2002–2021. These top scientific institutions generated almost half of the global top 20 applicants' IPFs in 2021 in both cancer treatment and cancer therapy, with a steady growth of IPFs over the last 20 years. Interestingly, the trend for top corporate applicants in cancer treatment diverges from that for top scientific institutions. It shows a strong decrease in the annual number of IPFs from corporate applicants after 2007 followed by a stagnation over the last decade. This suggests a shift in the organisation of innovation in cancer treatment, with pharmaceutical companies increasingly reliant on science-based pre-clinical research stemming from universities and PROs.

Figure E4

Comparison of trends among top 20 applicants: company applicants versus universities, hospitals and PROs



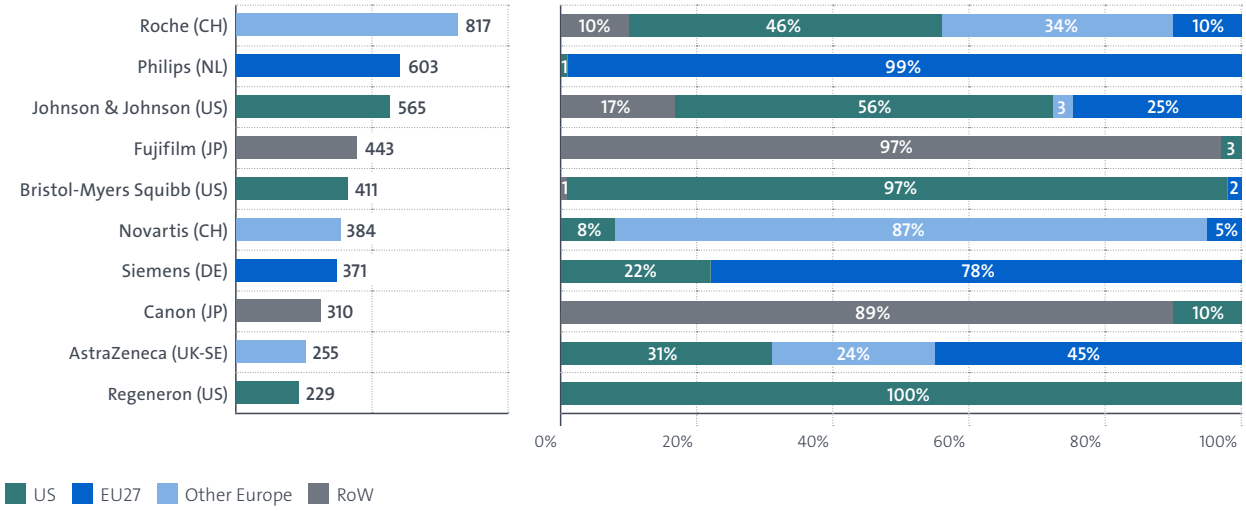
Source: EPO

5. Although top applicants have diverse geographical origins, patenting activities in cancer treatment are largely localised in the US

The list of the top 10 global corporate applicants over the period 2017–2021 includes five European, two Japanese, and three US companies. A Swiss company, Roche, tops the ranking. Most of these applicants are pharmaceutical companies focused mainly on innovation in cancer treatment. However, there are also several companies, such as Philips, Fujifilm, Siemens and Canon, which specialise in diagnostics. Although European companies are well represented in the ranking, a closer analysis shows that significant shares of the IPFs attributed to Roche (46%) and AstraZeneca (31%) originate from their US subsidiaries. Among US top companies, only Johnson & Johnson shows a sizeable share of IPFs filed from Europe, mainly by its Belgian subsidiary Janssen. In areas such as immunotherapy, up to 30% of the top applicants' portfolios consists of IPFs obtained via the acquisition of (mostly US-based) biotech startups, which confirms their transition towards an open-innovation model linking university ecosystems to the pharmaceutical industry.

Figure E5

Top 10 company applicants and the origin of their patenting activity, 2017–2021



Source: EPO

1. Introduction

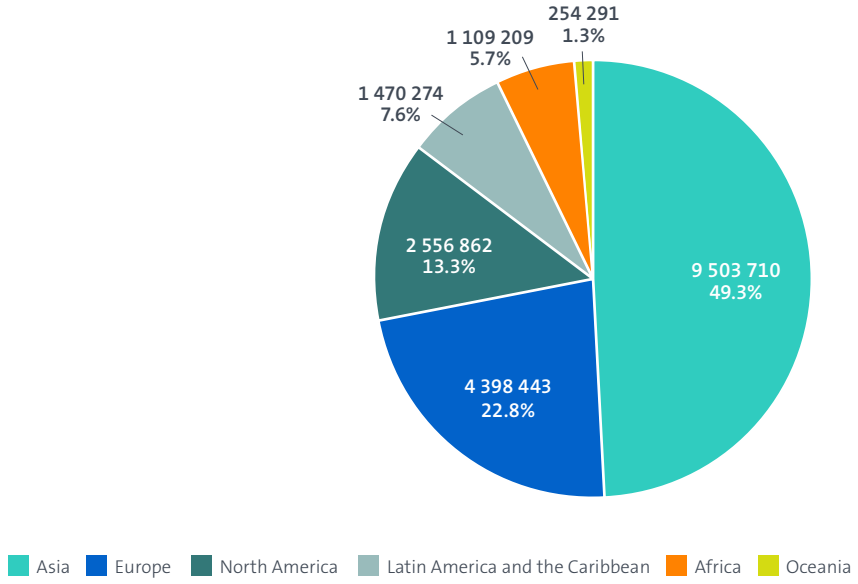
1.1 What are cancer-fighting technologies?

Cancer is a group of diseases characterised by the uncontrolled growth and spread of abnormal cells. It can develop in almost any organ or tissue in the body when genetic changes interfere with the normal process of cell growth and division. Cancer is dangerous and poses a significant threat to humanity because it can impair vital organ functions, invade nearby tissues, and spread to other parts of the body through a process called metastasis. According to estimates of the World Health Organization[3], in 2020, almost 20 million new cancer cases occurred, of which 4.4 million were in Europe, and, with almost 10 million deaths, cancer was the second leading cause of death globally, second only to cardiovascular diseases (Figure 1). In 57 countries, including most European countries, the US, Canada, Japan, P.R. China, Australia, Chile and Argentina, cancer was even the leading cause of death before the age of 70 years.

In a global context, the burden of cancer, characterised by increasing incidence and mortality rates, is following an upward trajectory. This phenomenon can be attributed to several interrelated factors, including the ageing of and increase in the world's population, alongside shifts in the prevalence and distribution of primary cancer risk factors. It is notable that many of these risk factors are intertwined with socio-economic development. Beyond the human toll in terms of lives lost, cancer has a substantial and far-reaching economic impact on society. This impact primarily stems from the considerable expenses associated with cancer treatment and the consequential loss of productivity.

Figure 1

Estimated number of new cases in 2020, all cancers, both sexes, all ages



Source: "Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries", 2021

3 The Global Health Observatory, "Global health estimates: Leading causes of death", Geneva, WHO, 2020: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death AND Sung H., Ferlay J., Siegel RL, Laversanne M., Soerjomataram I., Jemal A., Bray F., Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021: 71: 209–249.

The main drivers of cancer research, also known as oncology, have been the desire to understand the causes of cancer, develop effective treatments, and improve patient outcomes. It is a complex and heterogeneous disease that requires continued research to understand its underlying mechanisms, identify new targets for treatment, and develop efficient therapies. Over time, significant milestones in cancer treatment have been achieved, such as the development of chemotherapy, radiotherapy, and the use of high-energy beams such as X-rays and protons. With the help of new screening and diagnostic techniques, in combination with new therapies, it has been possible to reduce the mortality rates for many different cancers for men and women and thus prevent over 5 million deaths over the last three decades in Europe.

Nevertheless, despite advances in research and technology, cancer remains a major global health threat, and further innovation is needed to combat this devastating disease, to reduce the side effects of cancer treatment and improve the quality of life for cancer patients. Using patent data as a measure of innovation, this study by the European Patent Office is intended to inform decision-makers in both the private and public sectors and the broader public about the technology landscape and most recent trends in innovation against cancer. The study focuses on the technologies underpinning the developments in safe and effective methods to diagnose, prevent, treat, and, ultimately, cure the collections of diseases that are called cancer and provides a window into the latest inventions that will help humanity in its fight against cancer.

Patents play a crucial role in the translation of research results into diagnostic and therapeutic tools. They provide incentives for innovation, protect the rights of inventors, and ensure that inventions are commercially applied. In the field of cancer, patents are particularly important due to the high costs and long timelines associated with the development of new drugs and technologies. They provide a period of market exclusivity that allows companies to recoup their investment and fund future research and development efforts.

1.2 Why this report?

The landscape of cancer-related technologies is undergoing rapid innovation, driven by advances in biotechnology, information and communication technology (ICT), increased investment, international collaboration, data sharing, and regulatory incentives. These factors have fostered an environment conducive to discovery and innovation in cancer research and treatment.

Technologies such as gene therapy or immunotherapy, and targeted therapies are revolutionising cancer treatment and care. Moreover, advancements in cancer diagnostics, such as new imaging and molecular biology techniques, have improved early detection rates and are crucial in effective cancer management.

Investment in cancer research and technology is growing, with general cancer research receiving significant funding. Analysing just global public and philanthropic cancer research funding between 2016 and 2020, McIntosh S. et al. (2023) identified 66 388 awards for cancer research with a total investment of EUR 22.4 billion.[4] This investment is crucial for maintaining momentum in the field and for the development of new therapies. The global market for cancer-related technologies is also expanding rapidly, surpassing EUR 182.5 billion, which reflects the increasing financial commitment to this area.

Several countries and organisations have launched initiatives to combat cancer. The European Union's Europe's Beating Cancer Plan and the US Cancer Moonshot are examples of such initiatives. These programmes aim to improve the understanding of cancer, facilitate earlier diagnosis, optimise treatment, and improve cancer patients' quality of life. The World Health Organization's Global Action Plan for Prevention and Control of Non-Communicable Diseases also aims to reduce premature death due to cancer and other diseases by around 25% by 2025.

Patent data can provide valuable insights for monitoring developments in this field. The study of this data, complemented by market and industry research, can enable businesses, policymakers, and other stakeholders to make informed decisions and implement strategies that leverage cancer-related technology effectively for the benefit of society.

4 Exchange rate on 19 December 2023 provided by the European Central Bank: 1 EUR = 1.0962 USD.

1.3 Structure of the report

Chapter 2 discusses the societal and economic aspects of cancer, as well as the main drivers of cancer innovation, and sets out a methodology to study trends in cancer-related technologies based on patent data. Chapter 3 provides an overview of the main patenting trends in cancer-related technologies covering a period of up to 50 years. Chapter 4 focuses on the origin of cancer-related innovation and its main actors. Chapter 5 presents further in-depth explanations of selected cancer-related technologies. This study also presents three case studies of promising European startups developing and commercialising technologies to combat cancer.

Box 1: Patents support innovation, competition and knowledge transfer

Patents are exclusive rights that can only be granted for technologies that are new, inventive and industrially applicable. High-quality patents are assets that can help to attract investment, secure licensing deals and provide market exclusivity. Inventors pay annual fees to maintain those patents that are of commercial value to them. Once they lapse, the technical information in them becomes free for everyone to use. A patent can be maintained for a maximum of 20 years.

In exchange for these exclusive rights, all patent applications are published, revealing the technical details of the inventions in them. Patent databases therefore contain a wealth of technical information, much of which cannot be found in any other source, which anyone can use for their own research purposes. The EPO's free Espacenet database contains over 150 million documents from over 100 countries, and comes with a machine translation tool in 32 languages. Most of the patent documents in Espacenet are not in force, so the inventions are free to use. The legal status of a patent document can easily be checked within Espacenet.

Box 2: EPO Observatory on Patents and Technology and the Deep Tech Finder

In October 2023 the EPO launched the Observatory on Patents and Technology, which serves as a vital digital hub for transparent and informed debate on innovation, offering comprehensive insights into emerging technology trends and fostering a collaborative environment for IP professionals and stakeholders from industry, finance, and academia. The objective of the Observatory is to democratise innovation to create a safer, smarter, more sustainable world and to provide an expanding collection of digital tools, in-depth analyses, and studies, such as this one on innovation against cancer, alongside interactive online seminars and discussions, leveraging the EPO's extensive patent data and expertise.

The Observatory has launched the Deep Tech Finder (DTF), a digital platform designed to make it easier to find and analyse startups in European Patent Organisation member states that have filed European patent applications. Tailored to companies, investors, researchers, and other participants in the innovation ecosystem, this innovative and free tool offers advanced search capabilities based on various industry and technology parameters, enabling users to pinpoint emerging ventures with the potential to launch new technologies on a European scale. On publication of this study the Deep Tech Finder will enable the identification of European startups that have filed patent applications for cancer-combatting technologies.

Leveraging the EPO's extensive patent information, the tool offers detailed insights into the development of inventions in specific technological fields and their protection using the European patent system. This enhances the assessment of both innovation trends and the scope of intellectual property protection in the deep tech landscape.

2. The cancer burden

2.1 The history of cancer research: milestones and key drivers

The history of cancer research is a testament to human ingenuity and perseverance, propelled by a multitude of drivers, ranging from scientific curiosity to pressing societal demands. It is marked by numerous significant milestones that have shaped our understanding of the disease and its treatment. The earliest accounts of tumours and rudimentary, mainly surgical, treatments, are documented in the Edwin Smith Papyrus which originates from Ancient Egypt and is dated circa 1600 BC. Yet, for centuries, cancer remained a mystifying affliction, with limited insights into its biological and genetic origins. The first modern discoveries began in 1775 when Percivall Pott identified a relationship between exposure to chimney soot and the incidence of squamous cell carcinoma of the scrotum among chimney sweeps.[5] This marked the first clear link between environmental exposure and cancer development. In 1863, Rudolph Virchow made the first connection between inflammation and cancer when he identified white blood cells in cancerous tissue. He also coined the term "leukaemia". In the late 19th century, developments accelerated and triggered the beginning of modern cancer research. In 1882, William Halsted performed the first radical mastectomy to treat breast cancer, in 1895, Wilhelm Roentgen discovered X-rays, which would later be used in cancer treatment, and in 1898, Marie and Pierre Curie discovered the radioactive elements radium and polonium, which began to be used in cancer treatment within a few years and marked the advent of radiotherapy. The early 20th century also saw the dawn of chemotherapy, thanks to Paul Ehrlich's concerted efforts to develop chemicals that would cure cancer. In the mid-1960s, major advances were achieved with the first firm evidence that childhood leukaemia and advanced Hodgkin's disease in adults could be cured by combination chemotherapy.

The latter half of the 20th century saw pivotal discoveries, including the identification of oncogenes and tumour suppressor genes, and in this way revealed the genetic essence of cancer. The advent of advanced imaging technologies, such as MRI (magnetic resonance imaging) and PET (positron emission tomography) scans, has enabled more precise diagnosis and monitoring of cancer. The rise of biotechnology, including the advent of recombinant DNA technology, heralded the start of targeted therapies and monoclonal antibodies, reshaping the landscape of cancer therapeutics. During recent decades, the focus has been on understanding the fundamental mechanisms of cancer, how it forms, why it persists, and what causes it to spread. The completion of the Human Genome Project in 2003 initiated a more profound understanding of the genetic basis of cancer, paving the way for personalised treatment strategies. Targeted therapies epitomised the potential of precision medicine. Immunotherapies, including checkpoint inhibitors and CAR T-cell therapies, emerged as transformative modalities, harnessing the body's immune system to combat cancer. In the current decade, artificial intelligence and big data analytics have emerged as potent tools in cancer research, accelerating scientific investigations and enabling precise diagnostics and treatment.

5 "Milestones in Cancer Research and Discovery", originally published in National Cancer Institute: https://www.cancer.gov/research/progress/250-years-milestones.

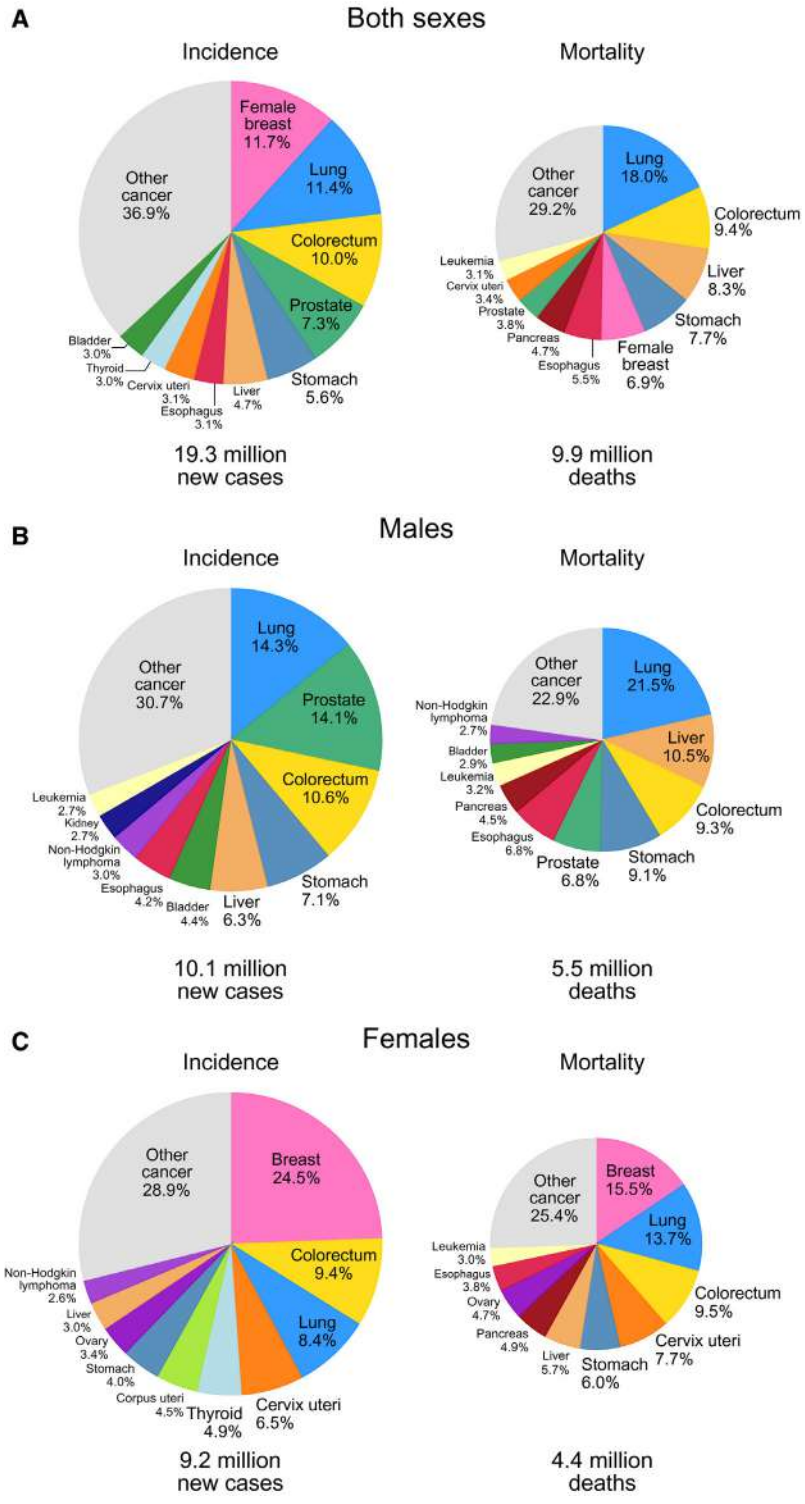
2.2 Global cancer statistics

2.2.1 Incidence and mortality rates

Despite the scientific and technological advancements of the last centuries, and especially recent decades, worldwide, an estimated 19.3 million new cancer cases and almost 10.0 million cancer deaths occurred in 2020 (Sung et al., 2021). As can be seen from Figure 2, among newly diagnosed cancer cases, female breast cancer is now the most prevalent, surpassing lung cancer, with an estimated 2.3 million new cases (11.7% of all diagnosed cancers). It is closely followed by lung cancer (11.4%), colorectal cancer (10.0%), prostate cancer (7.3%), and stomach cancer (5.6%). Where cancer-related mortality is concerned, lung cancer remains the leading cause, accounting for an estimated 1.8 million deaths yearly (18% of all cancer-related deaths). Colorectal cancer ranks second (9.4%), followed by liver cancer (8.3%), stomach cancer (7.7%), and female breast cancer (6.9%).

Figure 2

Distribution of cancer incidence and mortality rates in 2020, by cancer type and sex



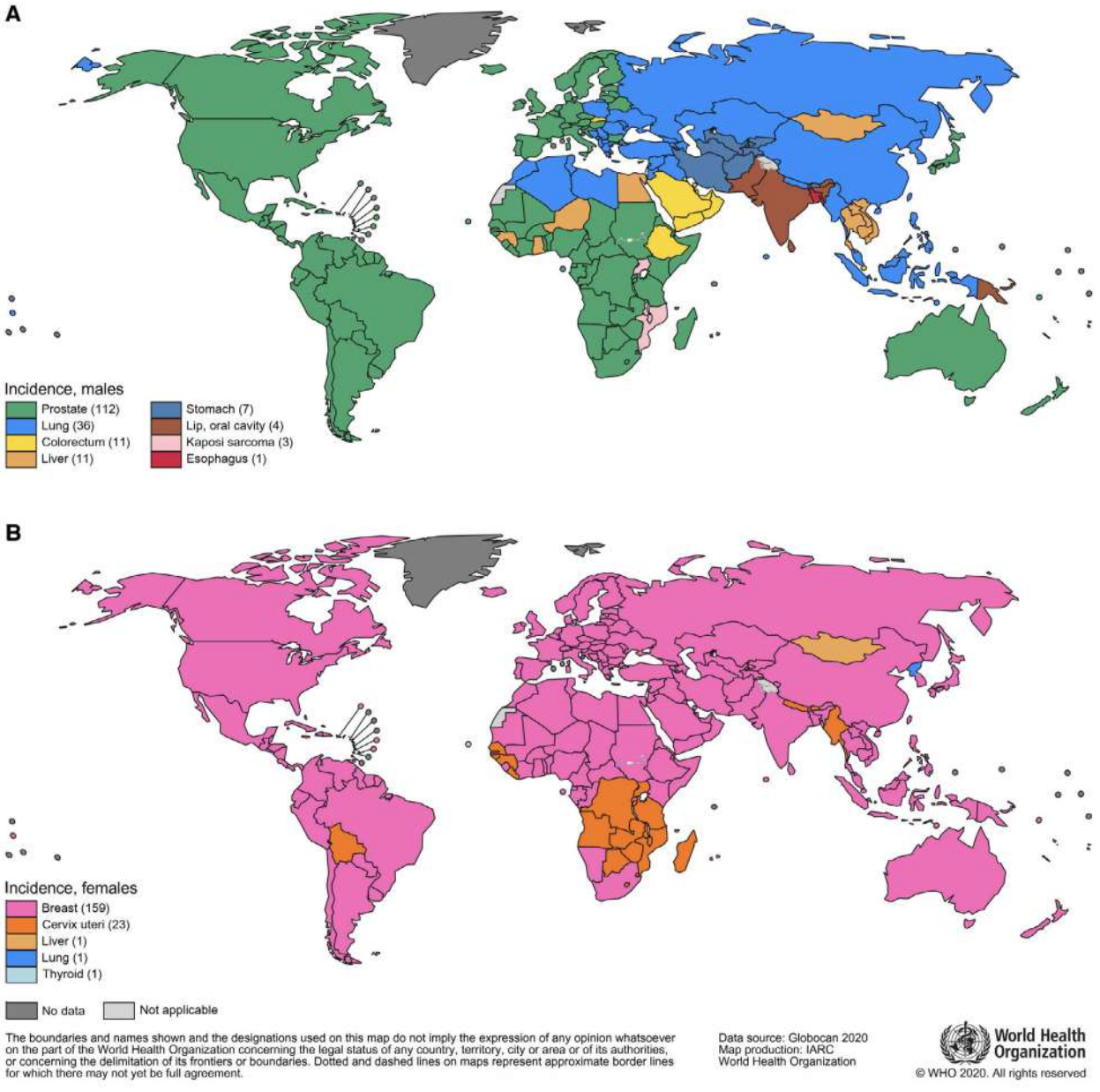
Note: Distribution of cases and deaths for the top 10 most common cancers in 2020 for (A) both sexes, (B) men, and (C) women. For each sex, the area of the pie chart reflects the proportion of the total number of cases or deaths; non-melanoma skin cancers (excluding basal cell carcinoma for incidence) are included in the "other" category.

Source: GLOBOCAN 2020

However, the statistics vary by sex and nationality. In men, prostate cancer is the most frequently diagnosed cancer in 112 countries, followed by lung cancer in 36 countries, and colorectal and liver cancer in 11 countries each (Figure 3). However, lung cancer is the leading cause of cancer mortality in men in 93 countries, due to its high fatality rate, followed by prostate cancer (48 countries) and liver cancer (23 countries). For women, the most commonly diagnosed cancer is either breast cancer (159 countries) or cervical cancer. However, the leading causes of cancer mortality in women are more varied, with breast cancer the highest cause in 110 countries, followed by cervical and lung cancer in 36 and 25 countries, respectively.

Figure 3

Geographical distribution of the most common type of cancer incidence in 2020, by sex



Note: Most common type of cancer incidence in 2020 in each country among (A) men and (B) women (excl. non-melanoma skin cancer). The numbers of countries represented in each ranking group are included in the legend.

Source: GLOBOCAN 2020

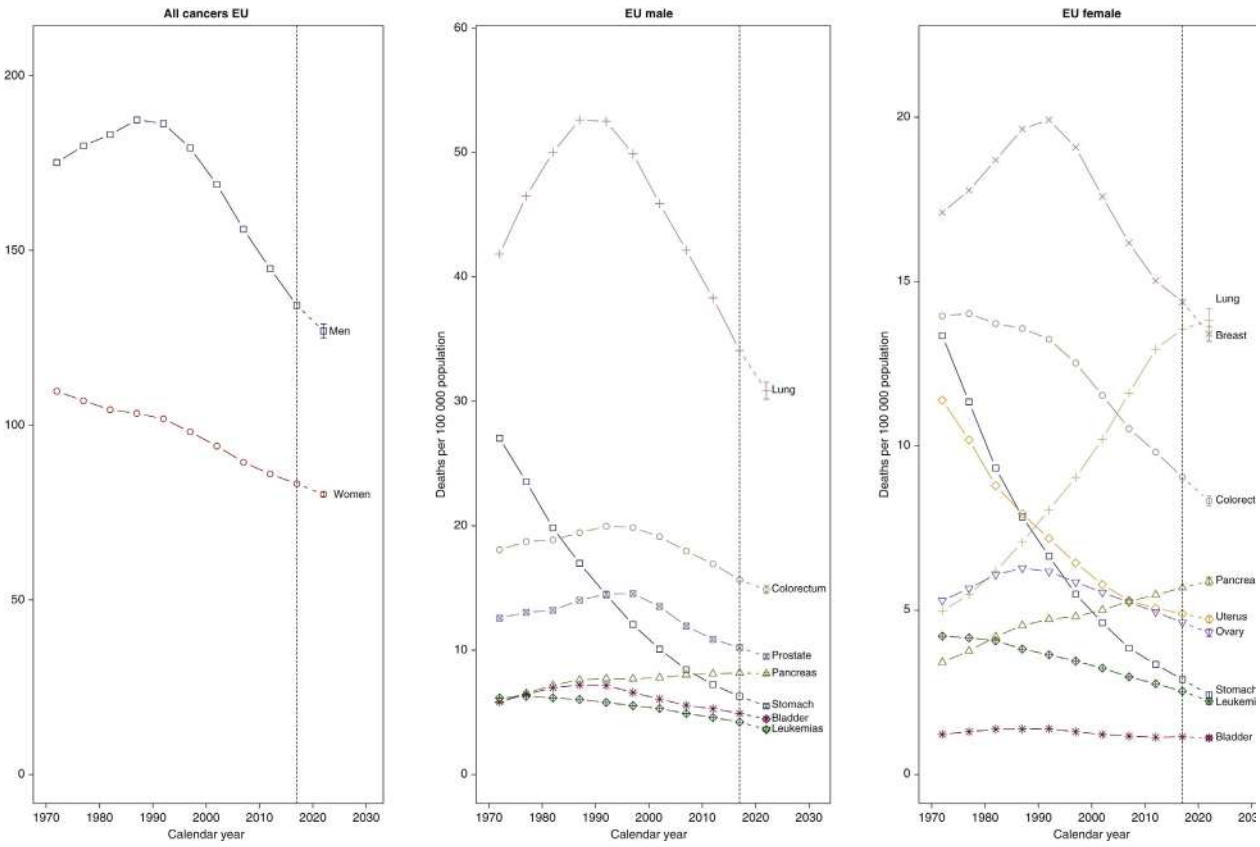
2.2.2 Cancer survival rates

Everyone faces the risk of developing cancer, although the likelihood is significantly amplified by age and certain behavioural and modifiable factors such as smoking, excess body weight, alcohol consumption, and following an unhealthy diet. Recently, notable strides have been made against cancer. In 1970, almost half of those diagnosed with cancer in the US would have survived for at least five additional years (McKinsey, 2020). For those diagnosed in 2009, the percentage was about 70%. Public-health measures such as smoking education, along with advancements in diagnostics and cancer therapies, have contributed to this improvement in outcomes.

The most accurate indicator of progress in this field is the variation in cancer mortality rates as they are less susceptible to changes in detection practices when compared to incidence and survival rates. Dalmartello M. et al. (2022) reported a consistent decline in cancer mortality rates in Europe over the past 30 years (Figure 4). Male cancer-specific mortality rates have decreased since the late 1980s, predominantly due to the reduction in lung cancer-related mortality. A decline in the incidence of gastric (stomach) cancer has been observed from the 1970s onwards. In contrast, pancreatic cancer has increased over this period. It is anticipated that pancreatic cancer will soon surpass breast cancer as the third most frequent cause of cancer-related death in the European Union. This projection can be attributed, to a large extent, to the absence of major therapeutic breakthroughs in treating the disease among men, underscoring the crucial importance of research into cancer. In fact, relatively few improvements in diagnosis and treatment have been achieved in recent years (Nevala-Plagemann C. et al., 2020).

Figure 4

Age-standardised (world population) cancer mortality rate trends in the EU by cancer type and sex



Note: Age-standardised (world population) cancer mortality rate trends in quinquennia from 1970-1974 to 2010-2014 and the central year 2017, and predicted rates for 2022 with 95% prediction intervals, for all neoplasms and both sexes (left) and each cancer site under study for men (centre) and women (right), in the European Union (EU).

Source: Dalmartello M. et al. (2022)

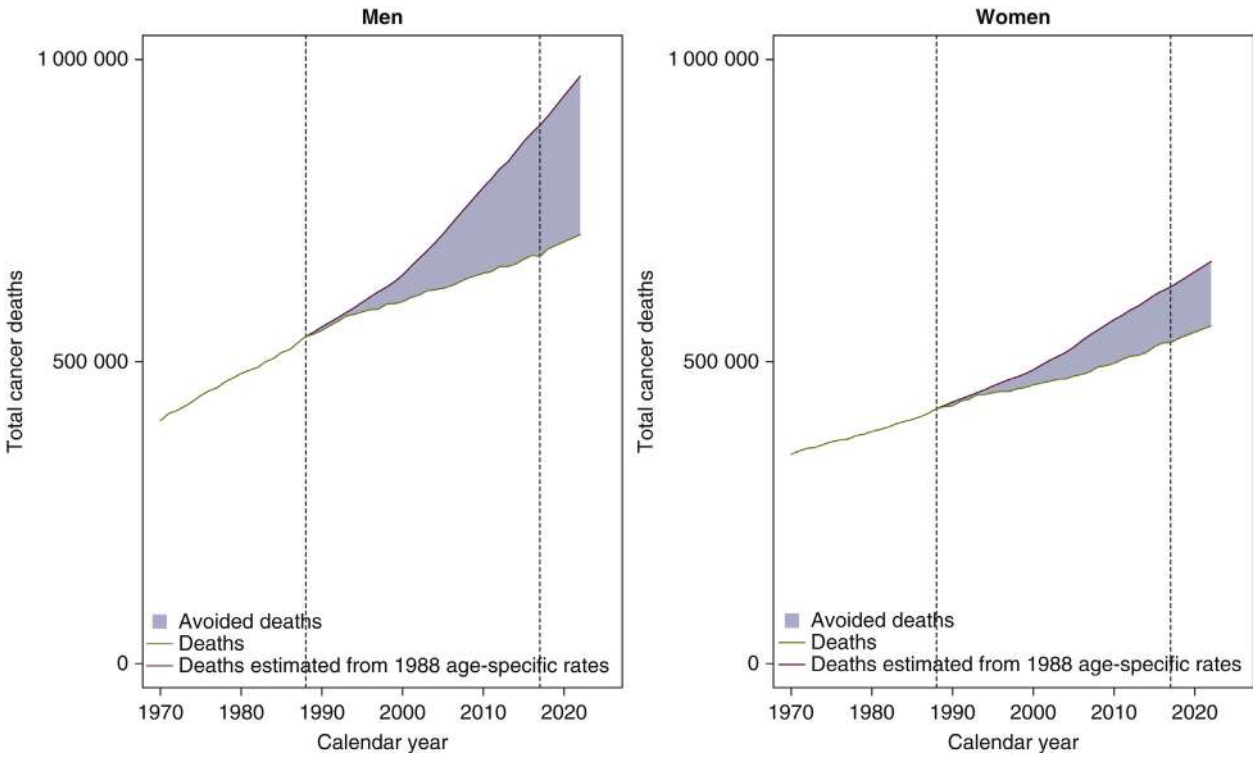
Over the past four decades, a consistent, albeit slightly less pronounced, decrease has also been observed in the incidence of all cancers combined in women. Beginning in the early 1990s, there was a noticeable decline in the frequency of breast cancer, largely resulting from improved treatment and screening initiatives. Significant decreases were also observed in colorectal, stomach, and uterine cancers. These positive trends can primarily be attributed to advances in early detection, screening, treatment, and disease management. From the 1990s onwards, there was a favourable trend in the incidence of ovarian and bladder cancers as well as leukaemia. However, female mortality rates associated with pancreatic and lung cancers have continued to increase over time. In particular, lung cancer was expected to surpass breast cancer in the EU in 2021, despite the more gradual increase observed in recent years. Nevertheless, a reduction in the mortality rate was projected to occur (Dalmartello M. et al., 2022).

These reductions in cancer mortality rates have resulted in a direct decrease in fatalities in the EU. Between 1988 and 2022, an estimated 5 394 000 deaths were averted, of which 3 660 000 in men and 1 734 000 in women (Figure 5). In 2022, 369 000 deaths were prevented, impacting 262 000 men and 106 000 women.

Similar estimates for the UK show that a total of 1 085 000 deaths were averted over the period under consideration, of which 735 000 among men and 350 000 among women, including 73 000 averted deaths in 2022, of which 49 000 in men and 24 000 in women. In the US, the reduction in the mortality rate over the period from the peak in mortality rate in 1991 until 2020 corresponds to 3.8 million fewer cancer-related deaths (American Cancer Society: Cancer Facts and Figures, 2023).

Figure 5

Total avoided cancer deaths in the EU, by sex



Note: Total avoided cancer deaths for European Union men and women between the top rate in 1988 and 2022; observed numbers of cancer deaths from 1970 to 2017 and predicted cancer deaths from 2018 to 2022 (green line); estimated numbers of total cancer deaths by applying 1988 age-specific peak mortality rate (red line). During the 34 years period 5 394 000 cancer deaths have been avoided (3 660 000 in men and 1 734 000 in women). In 2022 alone, 262 000 in men and 106 000 in women are predicted to be avoided, for a total of 369 000.

Source: Dalmartello M. et al. (2022)

2.2.3 Future burden of cancer

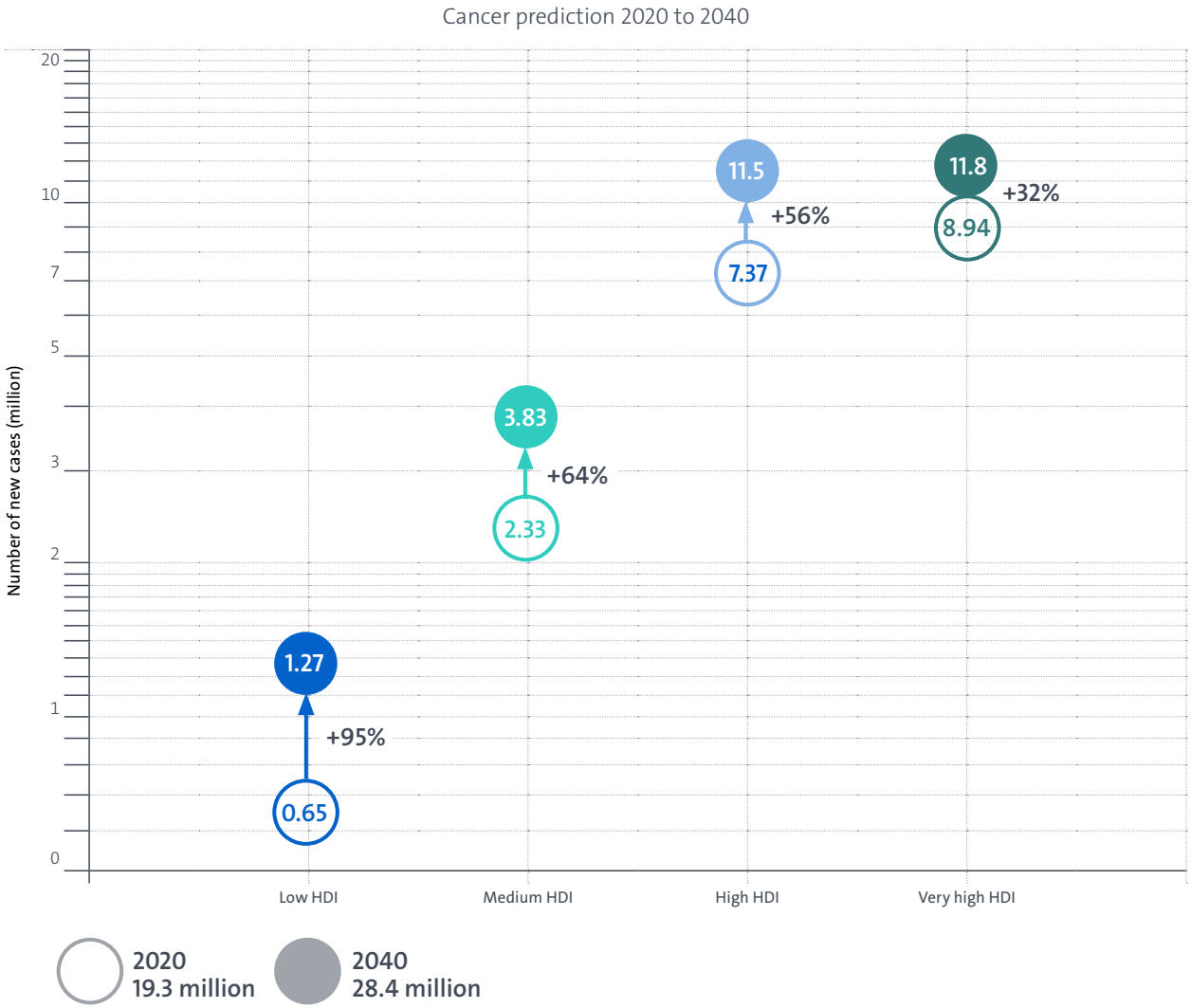
Although the cancer mortality rates in Europe, the US and many other parts of the world are clearly declining, it is projected that by 2040, there will be 28.4 million new cancer cases worldwide, a 47% increase from the 19.3 million cases in 2020 (see Global Cancer Statistics 2020). As illustrated in Figure 6, this increase in cancer incidence is most striking in low Human Development Index (HDI) countries (+95%) and medium HDI countries (+64%). However, high HDI countries are expected to experience the greatest increase in absolute numbers, with 4.1 million new cases more in 2040 than in 2020. This projection is primarily a result of population growth and aging, and could potentially be worsened by a rising prevalence of risk factors in numerous regions across the globe.

The burden of cancer is rising across all HDI levels, but emerging HDI countries are undergoing a significant shift in cancer patterns due to increasing disease prevalence and changing profiles of common cancer types. Low and medium HDI countries are witnessing a notable uptick in well-known cancer risk factors prevalent in high-income western nations, including smoking, unhealthy diets, excess body weight, and physical inactivity. Notably, infection-related and poverty-related cancers are giving way to cancers commonly found in highly developed countries, necessitating changes in national cancer control priorities.

The most prominent example of such a transition is in P.R. China. In 2022, China is estimated to have had approximately 4 820 000 new cancer cases and 3 210 000 cancer deaths (Xia, Changfa, et al., 2022). The country is experiencing a shift in its cancer patterns, with a rise in cancers that were previously more prevalent in countries with a very high HDI, including lung, colorectal, breast, and prostate cancer, and a decline in the incidence of liver, stomach, and oesophageal cancer. This increasing rate of cancer burden can largely be attributed to an aging population, with China projected to detect 6.9 million new cancer cases per year by 2040 (24% of worldwide new cases) (Cancer Tomorrow, IARC, 2020).

Figure 6

Projected numbers for all cancers for 2040



Note: Projected number of new cases for all cancers combined (both sexes combined) in 2040 according to the 4-tier Human Development Index (HDI).

Source: GLOBOCAN 2020

2.3 Innovation response to cancer

The global oncology market, encompassing both diagnostics and therapy, is poised for significant growth in the coming decade. In 2022, the oncology market's value stood at EUR 185.6 billion, with a projected surge to over EUR 429.3 billion by 2032, marking a robust compound annual growth rate (CAGR) of 8.8%, according to insights from Precedence Research. Notably, oncology therapeutics account for approximately 20% of global pharmaceutical sales.

This growth trajectory can be attributed to several key factors. Firstly, the escalating prevalence of cancer worldwide and increasing awareness of cancer among the population are expected to drive the adoption of oncology diagnostics and treatments across the globe, thereby bolstering the overall oncology market. Additionally, governmental and non-profit initiatives aimed at raising the awareness of cancer prevention are expected to further fuel market expansion. The biopharmaceutical industry's continued investments and advances are fostering the development of innovative drugs and therapies, in turn boosting the demand for oncology treatments and diagnostics. Consequently, the burgeoning significance and profit potential of the oncology sector are attracting increased investments from market players.

In terms of market segmentation, cancer treatment claimed the lion's share of the oncology market in 2022, representing approximately 56% of the total market. This dominance can be attributed to the widespread adoption of classical chemotherapy. However, there is a discernible shift towards targeted therapy and immunotherapy, driven by their convenience, efficacy, and reduced side effects compared to traditional chemotherapy. Conversely, the cancer diagnostics segment is the most opportunistic, fuelled by the growing desire among individuals to detect cancer during its earliest stages. The availability of non-invasive and convenient diagnostic tools is expected to further boost the growth of this segment over the foreseeable future.

As a region, North America held a dominant position in the global oncology market in 2022, claiming approximately 46% of market share. This continued prominence is attributed to the region's well-established healthcare infrastructure and increased healthcare spending. Europe can be seen as a highly promising market, driven by technological advancements in cancer diagnostics. China's oncology spending is still only a fraction of that of the US or Europe, but it has been growing at a similar pace in recent years (IQVIA Institute: Global Oncology Trends, 2023).

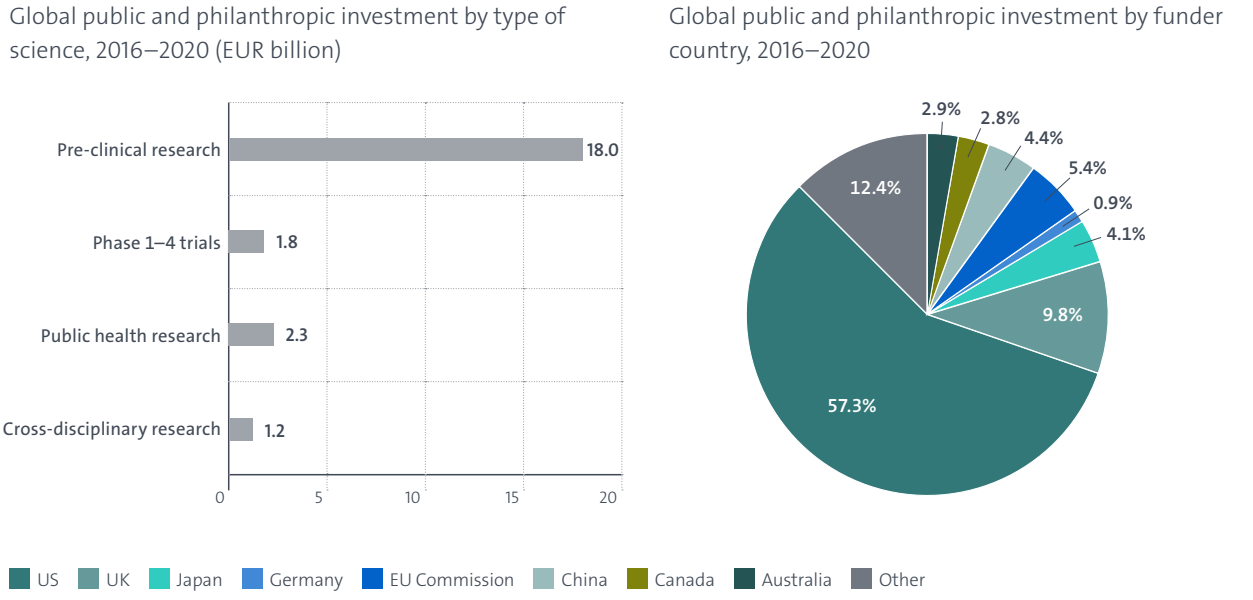
Oncology is a very R&D-intensive market. According to the IQVIA Institute (Global trends in R&D, 2023), over the last decade, it was the main focus of the clinical pipeline in life sciences. In 2022, its share of products in active development from Phase I through to regulatory submission was 38% of the 6 147 cases and this had been growing at a 10.5% CAGR over the previous five years. In the US, up to 49.2% of the total FDA pipeline was for new cancer treatments in 2021. Between 2016 and 2021, oncology drugs represented around 77.2% of the increase in Phase I drugs, 66.7% of the increase in Phase II drugs, and 54.6% of the increase in Phase III drugs within the US (Analysis Group, 2021).

While the pharmaceutical industry bears the bulk of the high costs and risks of clinical trials, public funding plays a significant role in supporting fundamental pre-trial research, thereby helping to fuel the technology pipeline with new potential solutions. This is illustrated by recent research on global patterns of public and philanthropic investment in cancer research, in which 66 388 awards with a total investment of about EUR 22.4 billion over the period 2016–2020 were analysed (McIntosh S. et al., 2023). As shown in Figure 7, pre-clinical research accounted for 73% (EUR 16.4 billion) of global public and philanthropic support for cancer research. Another 9.4% (EUR 2.1 billion) and 5% (EUR 1.1 billion) were directed towards public health research and cross-disciplinary research, respectively, leaving a relatively small share of 7.4% (EUR 1.6 billion) for clinical trials.

The US stands out as a major actor in this domain, accounting for 57% (EUR 12.8 billion) alone of global public and philanthropic investment in cancer research over the period 2016–2020. US public research funding was reinforced in 2016 with the launch of the Cancer Moonshot Initiative, allocating EUR 1.6 billion from fiscal year 2017 through to fiscal year 2023 in support of cancer research[6]. Most of this funding is funnelled via the US National Institutes of Health, which alone represent 43% (EUR 10 billion) of the global total – far ahead of the combined share of the next seven most important funders (30.3%) listed in Figure 7. Similarly, major funding agencies drive most of the public investment efforts in other countries, such as Cancer Research UK (4.8% of global public investment), National Natural Science Foundation in China (4.2%), the German Research Foundation (2.9%) or the Japan Society for the Promotion of Science (2.4%).

Figure 7

Public and philanthropic investment in cancer research



Note: The distribution of philanthropic investment by type of science excludes Cancer Research UK data.

Source: EPO, based on McIntosh S. et al., 2023

6 Between 2017 and 2021, projects underwritten by Moonshot-derived funding gave rise to >2 000 publications, 49 clinical trials, and >30 patent filings. In addition, Moonshot funding has supported several innovative projects, including, among others, the Immuno-Oncology Translational Network, the Pediatric Immunotherapy Discovery and Development Network, and the Human Tumor Atlas Network (Sindhu & Adashi, 2023).

2.4 The cancer technology landscape

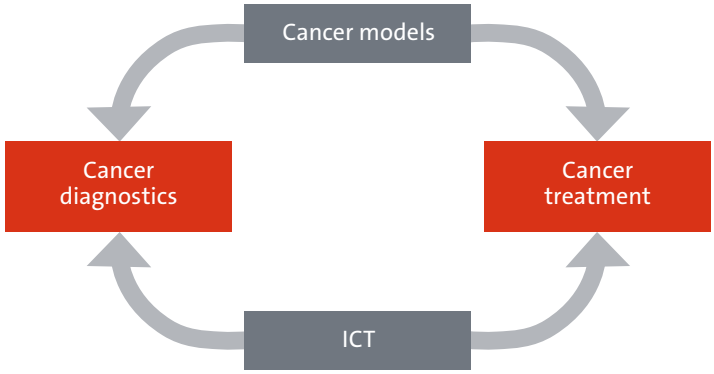
2.4.1 Overview

Cancer-related technologies encompass a wide range of innovative tools and methods used in the diagnosis, treatment, and management of cancer. The diversity of cancer-related technologies arises from the complex nature of cancer and the need for multifaceted approaches to combat it. Cancer is a heterogeneous disease with diverse molecular and genetic characteristics, requiring a wide array of technologies for accurate diagnosis and effective treatment.

For the purposes of this study, cancer-related technologies have been separated into two primary categories: cancer diagnostics and cancer treatment technologies. This distinction has been made to reflect their distinct purposes and applications. Diagnostic technologies focus on accurate detection, staging, and monitoring of cancer, while treatment technologies encompass a broad spectrum of interventions aimed at destroying or controlling cancer cells. In addition, the inclusion of cancer models and cancer-related information and communication technologies (ICT) is needed for a comprehensive and holistic view of relevant cancer-related technologies. Cancer models play a significant role not just in cancer treatment research but also in cancer diagnostics. They are used to understand the occurrence and development of cancer, explore the genetic basis of cancer, and to study biochemical and physiological processes related to cancer. ICT is revolutionising cancer research and care, providing new tools for early cancer diagnosis, the development of new treatment methods, personalised medicine, and more efficient treatment approaches.

Figure 8

Overview of main technology areas



Source: EPO

2.4.2 Cancer diagnostics

Technologies for cancer diagnosis encompass a wide range of tools and methods, including advanced imaging techniques and methods for analysing biopsy samples. These technologies are crucial for providing accurate information about a cancer's site of origin, determining the extent and stage of the cancer, identifying tumours and their specific molecular alterations, and assessing a patient's response to therapy.

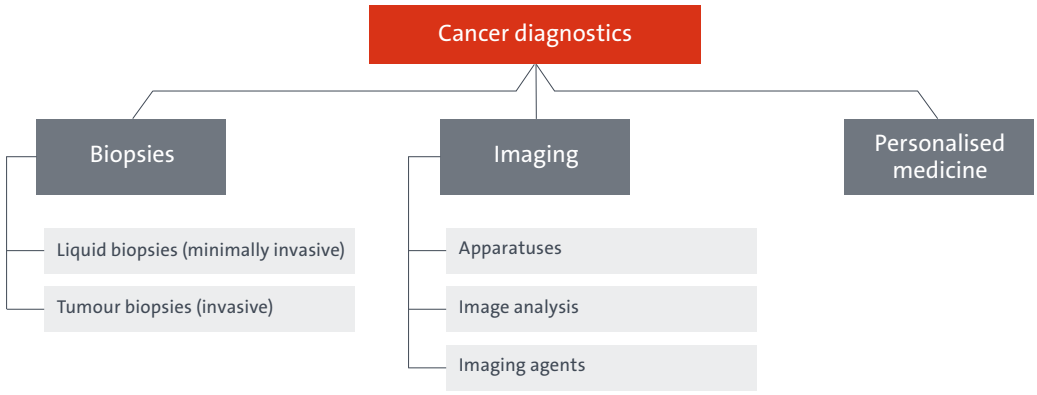
Biopsies: Two types of cancer biopsies are considered, liquid biopsies and tumour biopsies. On the one hand, liquid biopsies involve isolating tumour-derived entities such as circulating tumour cells, circulating tumour DNA, and tumour extracellular vesicles from body fluids, followed by an analysis of the genomic and proteomic data contained within them. They are best used for screening, identifying mutations in metastatic cancer, and tracking changes in mutations for treatment. On the other hand, tumour biopsies, also known as tissue biopsies, are fully utilised when a known tumour's location is confirmed and available for extraction. They are conducted by obtaining a sample of the tumour tissue for analysis through a needle, endoscopy, or surgery. Both biopsy methods have their strengths and are used in different clinical scenarios.

Imaging: Imaging technology for cancer diagnostics encompasses a range of techniques used to visualise the internal structures of the body for the detection, diagnosis, and monitoring of cancer. The main imaging technologies used for cancer diagnostics include X-ray (including mammography), computed tomography (CT) scan, positron emission tomography (PET) scan and scintigraphy, ultrasound, fluorescent and near-infrared imaging, photoacoustic, and optoacoustic. These imaging modalities provide detailed information about the location, size, and characteristics of tumours, aiding in the diagnosis and staging of cancer. It is important to distinguish between imaging apparatuses, image analysis technologies, and imaging agents because each plays a unique role in the diagnostic process. Imaging apparatuses are the machines or devices used to capture the images, such as X-ray machines, CT scanners, and MRI machines. Image analysis technologies are the tools and techniques used to interpret the images captured by the imaging apparatuses. This can include software for image reconstruction, as well as artificial intelligence algorithms that can help identify abnormalities and make diagnoses. Imaging agents are the substances used to enhance the images captured by the imaging apparatuses. These can include contrast agents used in CT scans and radiotracers used in PET scans. They help to visualise cellular activity and can provide additional information about the function and metabolism of tissues and organs. Each of these components contributes to the overall effectiveness of imaging in cancer diagnostics, and innovation in any of these areas can lead to improvements in the detection and treatment of cancer.

Personalised medicine: Also known as precision medicine, this medical approach tailors cancer treatment to the individual characteristics of each patient, taking

Figure 9

Overview of cancer diagnostic technologies



Source: EPO

into account their genetic, environmental, and lifestyle factors. It focuses on understanding the unique molecular and genetic characteristics of each patient's cancer, which can help in determining the most effective treatment strategies and may have fewer side effects. Personalised medicine relies both on cancer diagnostics and treatment technologies. However, it is more closely related to diagnostic technologies because of their focus on identifying genetic variations, predicting risk, and guiding treatment selection based on diagnostic information.

2.4.3 Cancer treatment

Cancer treatment technologies also encompass a wide range of methods and tools used to treat and manage cancer. These technologies can be divided into established and developing ones. Established cancer treatment technologies include surgery, chemotherapy, radiotherapy, hormone therapy, and photodynamic therapy, which have been widely used and studied for many years. These treatments have proven to be effective in many cases and form the basis of standard cancer care. Despite their maturity, there is still a lot of ongoing research in these fields of cancer treatment. This is due to the continuous advances in technology and improved understanding of cancer biology. Researchers are working to combat new cancer types with existing treatments, while at the same time increasing their effectiveness and reducing their side effects:

Classical chemotherapy[7]: Chemotherapy is a type of cancer treatment that uses drugs to destroy cancer cells. It works by stopping or slowing the growth of cancer cells, which grow and divide quickly. Chemotherapy can be used as the primary treatment for many types of cancer, and is often used in combination with other treatments such as surgery or radiotherapy. The main disadvantage of chemotherapy is its side effects, which occur because the treatment affects both cancer cells and healthy cells. These side effects can vary from person to person and depend on the type of chemotherapy, the dosage, and the individual's overall health. DNA damaging and alkylating agents, anti-metabolites, and anti-microtubule agents are the main classes of drugs used in chemotherapy to treat various types of cancer. They each have different mechanisms of action that interfere with the growth and division of cancer cells. DNA damaging and alkylating agents cause direct damage to the DNA of cancer cells, anti-metabolites trick cancer cells into using the drug instead of the molecules they need for DNA synthesis, and anti-microtubule agents disrupt the normal function of the mitotic spindle, preventing cell division.

Hormonal therapy[8]: This type of cancer treatment slows or stops the growth of cancer that uses hormones to grow. It works by removing, blocking, or adding specific hormones to the body. Hormone therapy can be used to treat certain types of cancer, such as breast and prostate cancers, that require sex hormones to grow. It can be used alone or in conjunction with other treatments such as surgery, chemotherapy, or radiotherapy. It can also be used to decrease the size of a tumour prior to surgery or radiotherapy, to lower the risk that cancer will come back after the main treatment, or to destroy cancer cells that have returned or spread to other parts of the body. The main downside of using hormonal therapy is that it can cause a range of side effects, including sexual health concerns such as low sex drive and erectile dysfunction, changes in the menstrual cycle for women, increased risk of other health issues such as blood clots and stroke, and long-term effects such as weight gain and memory problems.

Surgery: Surgical technology in cancer treatment involves various techniques to remove cancerous tumours from the body. This includes traditional open surgery, minimally invasive procedures, such as cryosurgery and advanced methods such as robotic surgery and laser surgery that are used to remove a patient's cancer with more precision than conventional techniques.

Classical radiotherapy[9]: This uses high-energy particles or waves, such as X-rays, gamma rays, electron beams, or protons, to destroy or damage cancer cells. The therapy can be delivered externally, where a machine aims beams of radiation at the cancer, or internally, where radioactive material is placed into or near the cancer. The therapy is designed to target rapidly dividing cells, which is why it is effective against cancer cells, but it can also affect some healthy cells, leading to side effects such as fatigue, sore

7 "Chemotherapy to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/chemotherapy.
8 "Hormone Therapy to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/hormone-therapy.
9 "Surgery to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/surgery.

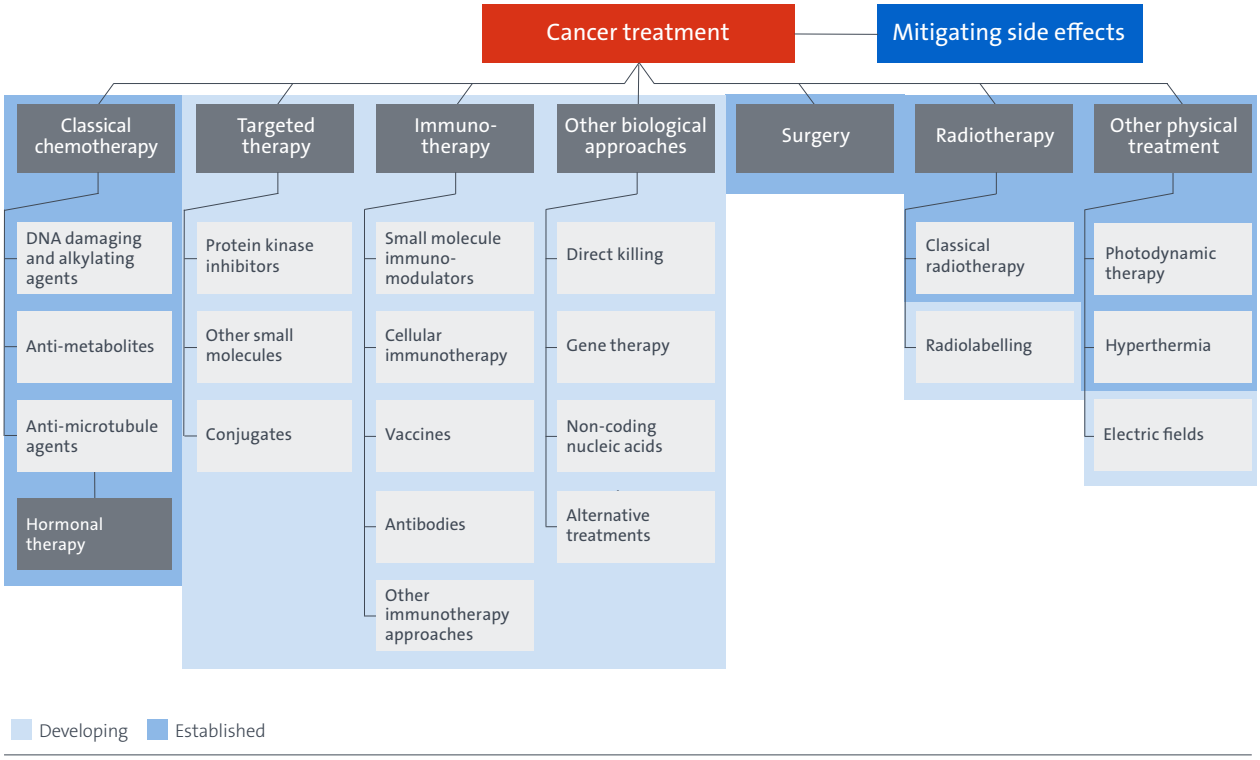
skin, and nausea. Despite these side effects, radiotherapy remains a crucial tool in cancer treatment, often used in combination with other treatments such as surgery or chemotherapy.

Photodynamic therapy[10]: Photodynamic therapy (PDT) is a cancer treatment method that uses a drug, known as a photosensitiser or photosensitising agent, which is activated by light to kill cancer cells. The light is emitted by a laser or other sources, such as LEDs. PDT is most often used as a localised treatment to treat a specific part of the body, for example, for symptoms caused by skin cancer, mycosis fungoides, or lung cancer.

Immunotherapy, targeted therapy, and other biological approaches – such as direct killing, gene therapy, non-coding nucleic acids and alternative treatments, but also radiolabelling and electric fields, are still considered as new or developing cancer treatment technologies. As research progresses and more evidence is gathered, these developing technologies may eventually become established treatment options, further expanding the range of tools available to fight cancer. However, some of these technologies are still undergoing medical trials and approval or may not yet be widely available to patients, which contributes to their classification as new or developing technologies.

Figure 10

Overview of cancer treatment technologies



Source: EPO

10 "Photodynamic Therapy to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/photodynamic-therapy.

Immunotherapy[11]**:** The immune system normally detects and destroys abnormal cells, potentially preventing or curbing the growth of many cancers. However, cancer cells have ways of avoiding destruction by the immune system, such as having genetic changes that make them less visible to the immune system or having proteins on their surface that turn off immune cells. Immunotherapy helps the immune system to respond better against cancer. Immunotherapy can be subdivided into several categories, including small molecule immunomodulators, cellular immunotherapy, vaccines, and antibodies, each with a unique mechanism of action. Small molecule immunomodulators are compounds that can modulate the immune response. They can either enhance the immune response against cancer cells or suppress elements of the immune system that may aid cancer growth. Cellular immunotherapy involves the use of immune cells to fight cancer. One example is T-cell transfer therapy, where immune cells found in and around tumours, known as tumour-infiltrating lymphocytes (TILs), are used. These cells are a sign that the immune system is responding to the tumour, and their presence often correlates with better patient outcomes. CAR T-cell therapy is a specific type of T-cell transfer therapy. In this treatment, T-cells are collected from the patient and then modified in a lab to produce special structures called chimeric antigen receptors (CARs) on their surface. These CARs enable the T-cells to recognise and bind to cancer cells and destroy them. Cancer vaccines are a form of active immunotherapy that aim to stimulate the immune system to attack cancer cells. These vaccines can be made from a variety of materials, including proteins or carbohydrates that are exclusively or overly expressed in tumour cells. By introducing these antigens into the body, the immune system can be trained to recognise and attack cells that express these antigens.[12] Therapeutic antibodies are immune system proteins created in the lab that are designed to bind to specific targets on cancer cells. Some antibodies mark cancer cells so that they will be better seen and destroyed by the immune system. Others, known as immune checkpoint inhibitors, work by blocking the proteins on cancer cells that turn off the response of immune cells, thereby allowing the immune system to destroy the cancer cells. Other immunotherapeutic approaches comprise techniques, such as oncolytic viruses, soluble TCR, or immunotherapy that uses cytokines, which are molecular messengers of the immune system.

Targeted therapy[13]**:** Targeted therapy is a type of cancer treatment that uses drugs to target specific genes and proteins that help cancer cells survive and grow. The main idea behind targeted therapy is to interfere with specific molecules and cancer-causing genes to slow the spread of cancer cells. This approach is based on the understanding that different types of cancer cells have different gene changes and proteins or enzymes that send messages to tell the cancer cell to grow and replicate. Targeted therapies are drugs that target these proteins or enzymes to block the messages, causing the cancer cells to stop growing or to destroy themselves. It is important to note that not all cancers have targeted therapies available.

Unlike traditional chemotherapy, which often kills all cells that grow and divide quickly, targeted therapy is more precise, focusing on the changes in cancer cells that help them grow, divide, and spread. This is a rapidly growing area of research, and many new targeted therapies are being studied in clinical trials. Targeted therapy technologies have been subdivided into protein kinase inhibitors, other small molecules, and conjugates based on their different mechanisms of action:

— Protein kinases are involved in various cellular functions including metabolism, cell cycle regulation, survival, and differentiation. Dysregulation of protein kinases is implicated in various processes of carcinogenesis. Protein kinase inhibitors interfere with these proteins, disrupting the processes that allow cancer cells to grow and divide.

— The group of other small molecules includes a variety of targeted therapies that are not protein kinase inhibitors, for example, Hedgehog Pathway inhibitors, some angiogenesis inhibitors, and epigenetic inhibitors. These drugs target specific molecular pathways that are crucial for cancer cell growth and survival. For instance, angiogenesis inhibitors block the growth of new blood vessels that tumours need to grow.

— Conjugates are drugs that are linked to a carrier molecule, which can help deliver the drug to the cancer cells. The carrier molecule can help increase the drug's effectiveness, reduce side effects, or allow the drug to bypass resistance mechanisms. Examples

11 "Immunotherapy to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/immunotherapy.

12 See a recent EPO insight report that provides an overview of important patent trends in the field of mRNA-based vaccines (incl. anti-cancer vaccines): https://link.epo.org/web/business/patent-insight-reports/mrna_technologies_2023_EN.pdf.

13 "Targeted Therapy to Treat Cancer", originally published by National Cancer Institute: https://www.cancer.gov/about-cancer/treatment/types/targeted-therapies.

include small-molecule carrier, oligomer/polymer non-peptidic carrier, peptide-drug conjugates, and antibody-drug conjugates.

Direct killing[14] with venoms and toxins: Direct killing with venoms and toxins from animals and plants in cancer treatment uses these substances to induce cell death in cancer cells. For instance, bee venom and its components have been shown to exert anticancer effects on human breast cancer cells (Kwon N., et al., 2022). Similarly, scorpion and spider venoms, or their isolated substances (toxins), have been found to affect cancer cells while other toxins from animal poisons and venoms have also been used in the design of new therapeutic agents due to their wide-ranging pharmacological activities.

Gene therapy[15]: This approach involves the introduction of new genes into a cancerous cell or the surrounding tissue to cause cell death or slow the growth of the cancer. Gene therapy can involve several strategies such as replacing missing or non-functioning genes, using the body's own immune system by inserting genes into cancer cells that then trigger the body to attack the cancer cells as foreign invaders, inserting genes into cancer cells so that chemotherapy, radiotherapy, or hormone therapies can attack the cancer cells more easily, creating "suicide genes" that can enter cancer cells and cause them to self-destruct, and preventing the formation of the blood vessels that tumours need to grow and survive. Gene therapy was originally based on the direct delivery of the therapeutic gene to the patient, preferably using (oncolytic) viral vectors. It now includes the rapidly developing new genome editing technologies (CRISPR and non-coding guide RNAs) that allow the precise editing of the genome of the patient's cancer or immune cells, inside or outside the body. Despite its potential, gene therapy is still a developing field and is currently still in the clinical-trial stage.

Non-coding nucleic acids[16]: Non-coding nucleic acids are parts of an organism's genome that do not code for proteins. Specifically, non-coding RNAs (ncRNAs or miRNAs) play crucial roles in cancer biology – in regulating gene expression and cellular functions – and are emerging as potential targets in cancer treatment. Therapeutic strategies targeting ncRNAs are being explored, with some ncRNA-based drugs being tested as adjuncts to traditional chemotherapeutics in clinical trials. They also identify artificial nucleic acids that are designed to interfere with cellular gene expressions, protein function, or sequence-specific gene editing. They cover interfering RNAs, antisense, aptamers, and guide RNAs.

Alternative treatments: There is an interest in plant and animal extracts in cancer treatment, both as standalone treatments and in combination with other therapies. Plant-derived compounds have demonstrated properties that inhibit cancer cell activity, such as inhibiting the proliferation of cancer cells and inducing apoptotic cell death (Greenwell and Rahman, 2015). Probiotics, such as live bacteria and yeast supplements, minerals, fibres, or vitamins, have also been studied for their potential role in cancer treatment and prevention. However, it is important to note that while individual plant and animal extracts have shown interesting effects in cancer care, more research is needed to investigate their efficacy and potential side effects.

Radiolabelling[17]: Radiolabelling technology in cancer treatment involves the use of radioactive substances, or radionuclides, that are attached to cancer-targeting molecules to create radiopharmaceuticals. These radiopharmaceuticals are designed to target cancer cells specifically, delivering radiation directly to the tumour and minimising damage to healthy tissues.

Electric fields[18]: Treatment with electric fields incorporates new approaches such as electroporation, a technique that uses electrical pulses to increase the permeability of cancer cell membranes, allowing more effective delivery of chemotherapeutic drugs, and Tumour Treating Fields (TTF) therapy, a treatment that uses low-intensity, alternating electric fields to disrupt the division of cancer cells, thereby slowing tumour growth and potentially causing cancer cells to self-destruct.

14 de Castro Figueiredo Bordon, K., et al, "From Animal Poisons and Venoms to Medicines: Achievements, Challenges and Perspectives in Drug Discovery", 2020, Sec. Translational Pharmacology, vol. 11, 2020: https://doi.org/10.3389/fphar.2020.01132.

15 Mayo Clinic, "Gene Therapy", https://www.mayoclinic.org/tests-procedures/gene-therapy/about/pac-20384619.

16 Le P., Romano G., Nana-Sinkam P., Acunzo M. "Non-Coding RNAs in Cancer Diagnosis and Therapy: Focus on Lung Cancer". Cancers 2021, 13, 1372, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8003033/pdf/cancers-13-01372.pdf.

17 Sgouros, G., Bodei, L., McDevitt, M.R. et al. "Radiopharmaceutical therapy in cancer: clinical advances and challenges", Nat Rev Drug Discov 19, 589–608 (2020). https://doi.org/10.1038/s41573-020-0073-9.

18 American Cancer Society "Tumor Treating Fields (TTF) Therapy for Adult Brain and Spinal Cord Tumors", 2023.

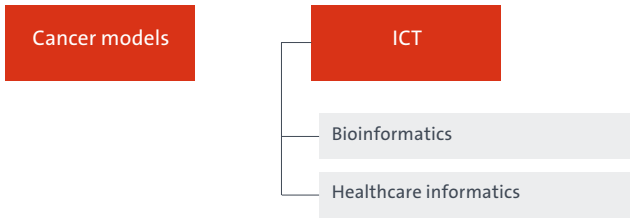
2.4.4 Cancer-related ICT technologies and cancer models

Information and communication technologies (ICT) play a significant role in cancer diagnostics and treatment, particularly through the fields of **bioinformatics** and **healthcare informatics**. Bioinformatics focuses on the analysis and interpretation of biological data, such as genomic and proteomic information, to better understand cancer biology and develop targeted treatments. Healthcare informatics deals with the management and analysis of health-related data, including electronic health records and medical imaging, to improve cancer diagnosis, treatment, and prevention. These technologies enable more precise and personalised approaches to cancer treatment, as well as providing an improved understanding of the genetic and molecular basis of cancer, which can help identify biomarkers for early detection of the disease. Additionally, the integration of artificial intelligence algorithms and the development of point-of-care technologies are revolutionising cancer diagnostics and treatment (Farina et al., 2022). In diagnostics, AI offers the potential for rapid and precise identification of cancer types, stages, and genetic features. These advancements are indispensable for improving cancer outcomes, enabling personalised treatment plans, and monitoring disease progression. In cancer treatment, AI aids in understanding how cancer cells develop resistance to anticancer drugs, which can inform drug development and usage. In radiotherapy, AI can assist in various stages of the radiotherapy process, including medical imaging, treatment planning, patient simulation, quality assurance, and radiation dose delivery. In oncologic surgery, AI-based navigating systems and surgical robots help surgeons to improve their results in terms of safety and efficacy.

Cancer models are essential for understanding the mechanisms underlying cancer, such as tumour growth and spread, and for developing new diagnostic, treatment, and prevention strategies. Primarily using mice, these models can be genetically altered to study the genetic causes of cancer and reproduce tumour types that occur naturally in humans. Cancer models have been successful in developing treatments for various cancer types thus benefiting many patients, and enabling the study of human cancer within a whole-organism context.

Figure 11

Overview of cancer-related ICT and cancer models



Source: EPO

3. Cancer-related patents: an overview

This chapter provides an overview of the general trends in cancer-related innovation and is based on the most recent published patent data. It presents the number of IPFs in the four main technology sectors – diagnostics, treatment, cancer models, and cancer-related ICT – together with the contributions from the major innovation centres. An analysis of the key applicants shows the main players and provides a landscape of innovation activity in the fight against cancer.

Box 3: Patent metrics

The identification of patent applications related to the different technologies in the fight against cancer was carried out using the knowledge of the EPO's expert patent examiners, together with scientific publications and studies published by various consultants and international organisations. This in-house knowledge has been built up over many years of working within the different technology fields relevant for cancer diagnostics and treatment and collected via networks of technology specialists within the EPO.

Published international patent families (IPFs) are used in this study as a uniform metric to measure patenting activity in the different categories of cancer-related technologies. Each IPF identified as relevant for cancer-related technologies is assigned to one or more technology sectors, or fields of the cartography, depending on the technical features of the invention.

Each IPF covers a unique invention and includes patent applications targeting at least two countries. More specifically, an IPF is a set of applications for the same invention that includes a published international patent application, a published patent application at a regional patent office, or published patent applications at two or more national patent offices.[19] It is a reliable proxy for inventive activity because it provides a degree of control for patent quality by only representing inventions for which the inventor considers the value sufficient to seek protection internationally.

The reference year used for all statistics in this report is the earliest publication year of each IPF, which usually is 18 months after the first application within the patent family.

The dataset was further enriched with information about the applicants of the IPFs. In particular, data was retrieved from Bureau van Dijk's ORBIS database, Crunchbase, and other internet sources, and was used to harmonise and consolidate applicant names and identify their type.

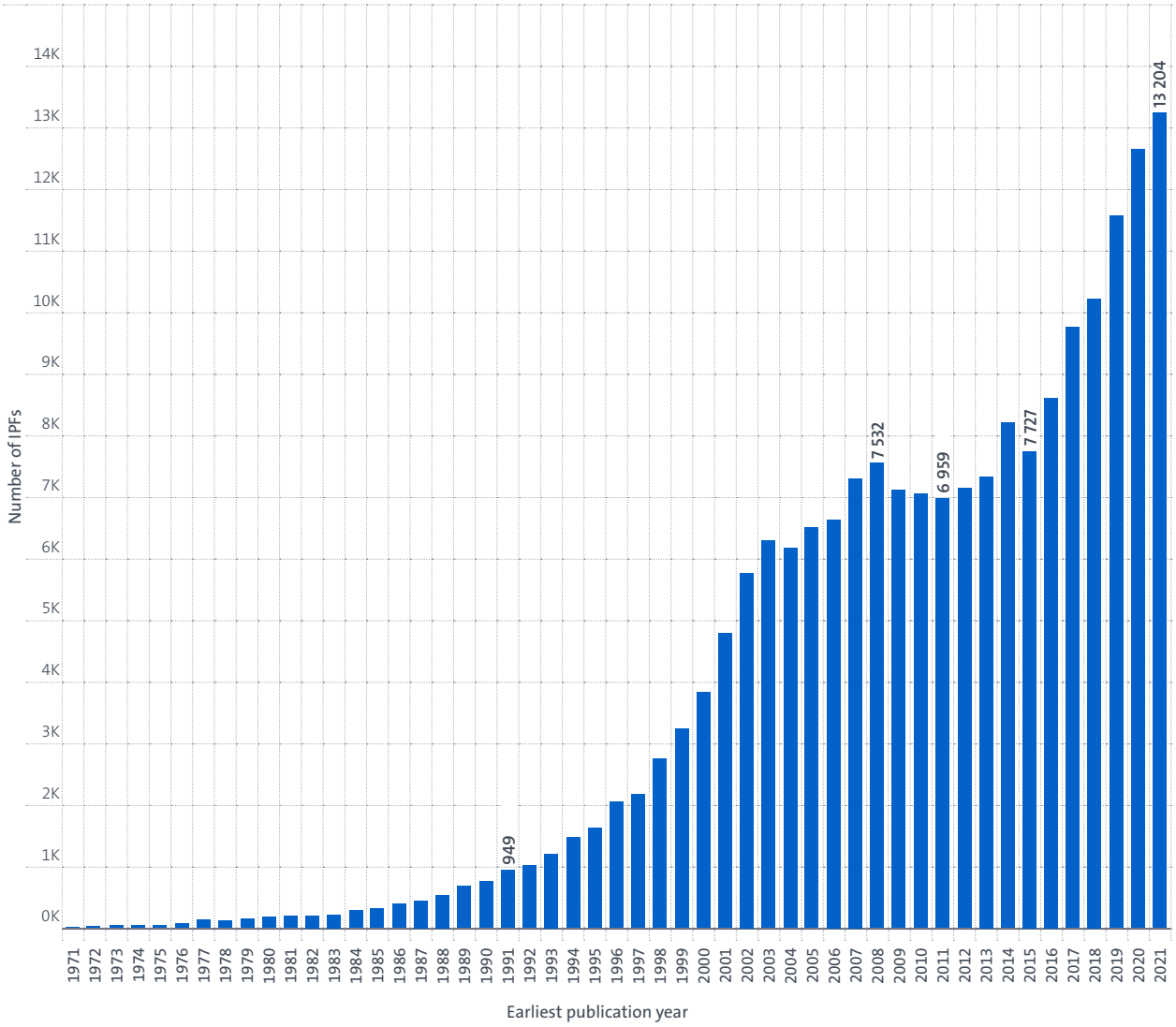
19 The regional patent offices are the African Intellectual Property Organization (OAPI), the African Regional Intellectual Property Organization (ARIPO), the Eurasian Patent Organization (EAPO), the European Patent Office (EPO), and the Patent Office of the Cooperation Council for the Arab States of the Gulf (GCCPO).

3.1 General patenting trends

Over the past five decades, more than 140 000 inventions have formed the foundation of IPFs in the battle against cancer. From the 1970s through to the early 2000s, the quantity of IPFs in cancer-related technologies grew strongly (Figure 12). In 1971, there were fewer than 50 IPFs, a figure which increased to over 1 000 as early as 1992, with almost 6 000 IPFs just ten years later. Growth subsequently decelerated over the following decade, fluctuating between 6 500 and 7 500 IPFs annually until the mid-2010s. However, patent data indicates a significant acceleration in cancer-related innovation during the more recent period. Between 2015 and 2021, there was a rise of over 70% in the annual number of IPFs, corresponding to a CAGR of 9.34% (Figure 15). This surge culminated in over 13 000 IPFs being filed in 2021, accounting for over 3% of the world's patent activity in that year.

Figure 12

IPF trends in all cancer-related technologies, 1972–2021



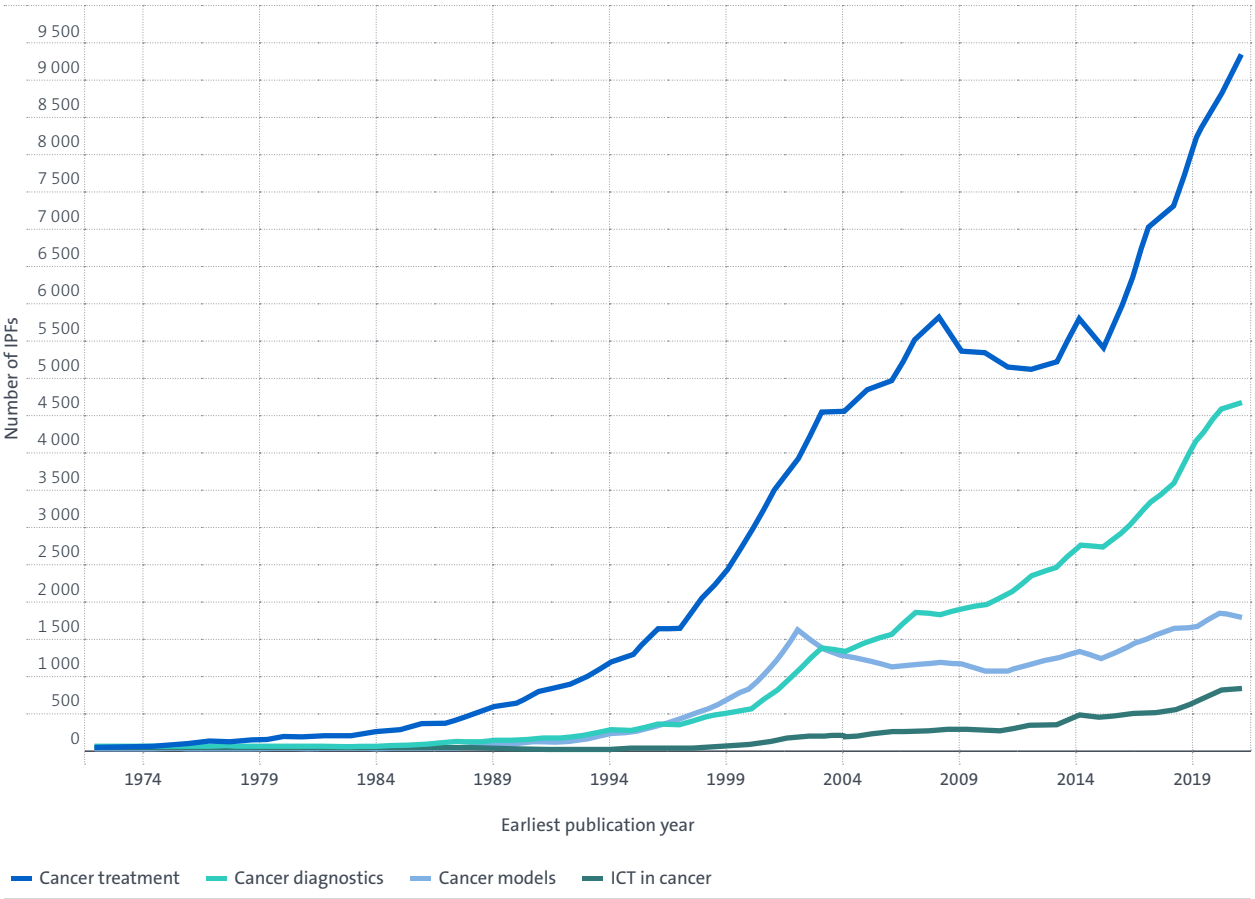
Source: EPO

Cancer treatment is the largest technology area in the field of cancer research, with almost 55 000 IPFs since the 1970s and 9 318 IPFs in 2021 alone (Figure 13). It is followed by cancer diagnostics, with over 31 000 IPFs over the last five decades and 4 660 IPFs in 2021, cancer models, with over 31 000 IPFs in total and 1 763 IPFs in 2021, and ICT in cancer, with almost 8 000 IPFs in total and 812 IPFs in 2021.

Cancer-related ICT, with a CAGR of over 11%, has been the fastest area of growth since 2015, although cancer diagnostics, with a CAGR of around 9.5%, has not been far behind. Cancer-related ICT is becoming increasingly important in oncology because it provides new, more efficient and cost-effective ways of diagnosing and treating cancer. Cancer treatment technologies as an area was characterised by two different growth paces. While established cancer therapies saw a more modest increase, with a CAGR of less than 5%, new and developing cancer therapies grew at a CAGR of almost 11%, from just over 5 000 IPFs in 2015 to over 9 000 IPFs in 2021 (Figure 14). Developments related to cancer models, after experiencing a real boom up until the early 2000s, experienced a decline in the following decade. Only more recently has growth been picking up again, with a CAGR of 6.4% since 2015. Cancer models are used to study the effects and progression of cancer, and to test potential treatments before they are used in vivo on humans.

Figure 13

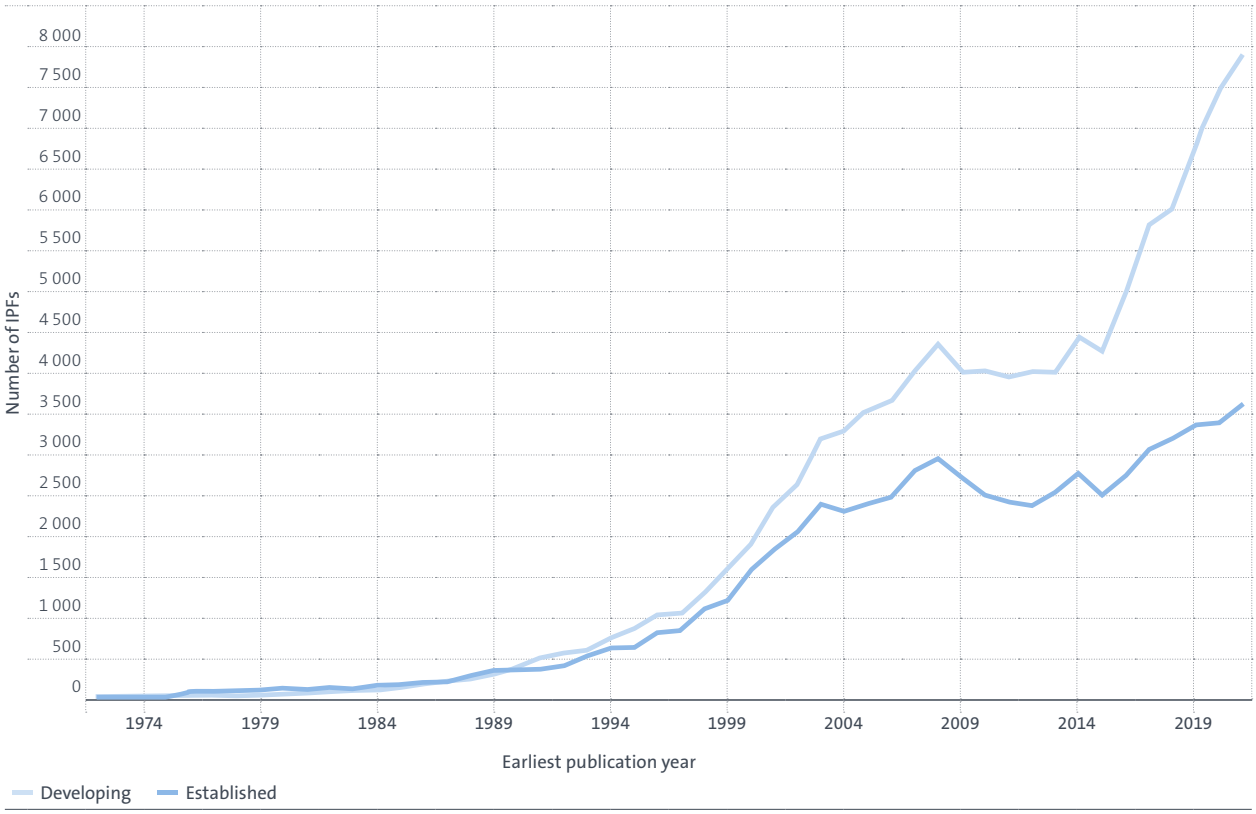
Trends in IPFs in cancer-related technology by main technology sector, 1972 - 2021



Source: EPO

Figure 14

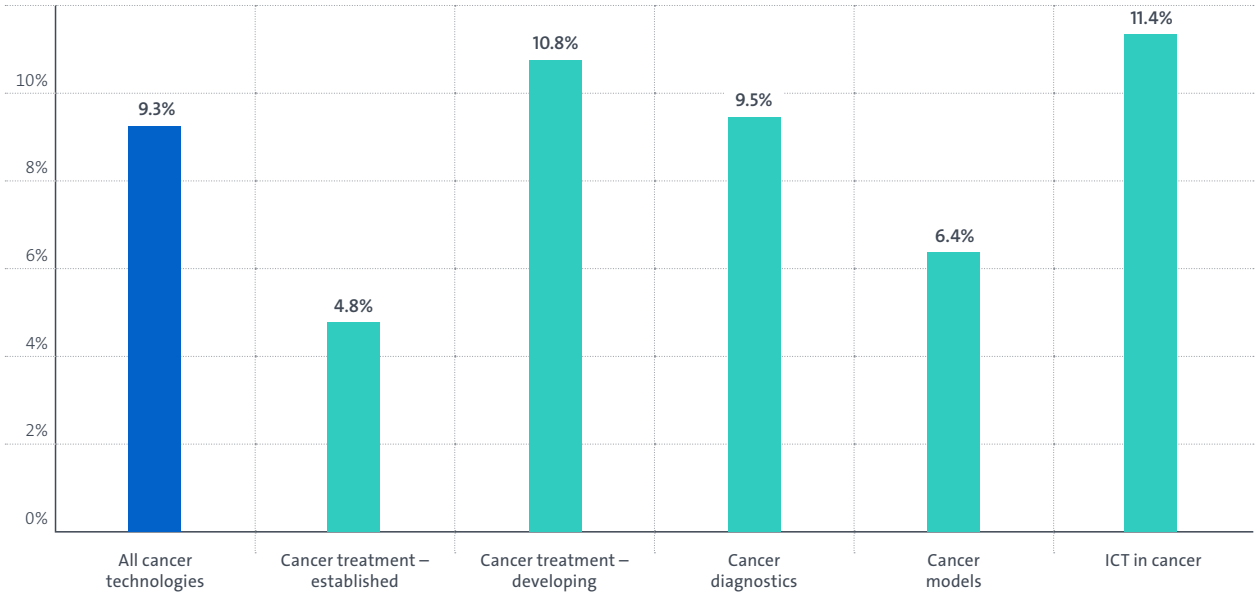
Trends in IPFs in developing and established cancer treatment technologies, 1972 - 2021



Source: EPO

Figure 15

Growth rates of IPFs in main cancer technology areas (CAGR 2015–2021)



Source: EPO

During the 1970s and 1980s, the field of cancer therapy was largely characterised by advances in classical chemotherapy, particularly in the development of anti-metabolites, alkylating agents, and hormonal therapies. The era saw significant progress in the use of these treatments for various types of cancer, including haematological and solid tumours.

In the realm of cancer diagnostics, the same period witnessed substantial improvements in imaging technologies. X-ray and ultrasound apparatuses were notably enhanced, while the introduction of the use of contrast agents greatly augmented their performance. These advancements enabled more precise determination of the location, size, stage, and molecular characteristics of tumours. In terms of biopsy techniques, the focus during this period was primarily on invasive tumour biopsies.

During the 1990s, there was a rapid growth in new and developing cancer treatment methods, particularly in targeted therapy and immunotherapy. By the early 2000s, the number of IPFs in these two fields was on a par with or even ahead of classical chemotherapy and hormonal therapy. In cancer diagnostics, there was a further increase in patenting related to imaging technologies, such as X-ray and ultrasound, as well as a stronger growth in IPFs related to tumour biopsies. Towards the end of the millennium, personalised medicine emerged as an expanding field. Nevertheless, the most significant progress occurred in the area of cancer models.

From around 2002 to 2015, there was a noticeable decrease in the number of IPFs related to cancer models. However, during the same period, there was a significant increase in patents related to ICT, particularly in the field of healthcare informatics. Despite the overall stagnation in cancer-related IPFs, there was continued growth in both established and developing cancer treatment technologies until 2008. This growth was largely driven by rapid advancements in targeted chemotherapy. However, this period of robust growth also came to a halt in subsequent years, with the most significant declines observed in classical chemotherapy and hormonal therapy. Notably, gene therapy and non-coding nucleic acids were exceptions to this trend, as they continued to experience growth.

Throughout the 2000s, cancer diagnostic technologies experienced consistent growth, with the number of IPFs increasing from fewer than 1 000 in the year 2000 to over 2 700 by 2015. This growth spanned all three fields: imaging, biopsies, and personalised medicine. In the realm of biopsies, liquid biopsies witnessed almost exponential growth between 2008 and 2015. In imaging, the growth was primarily driven by advancements related to imaging apparatuses, specifically X-ray and ultrasound technologies.

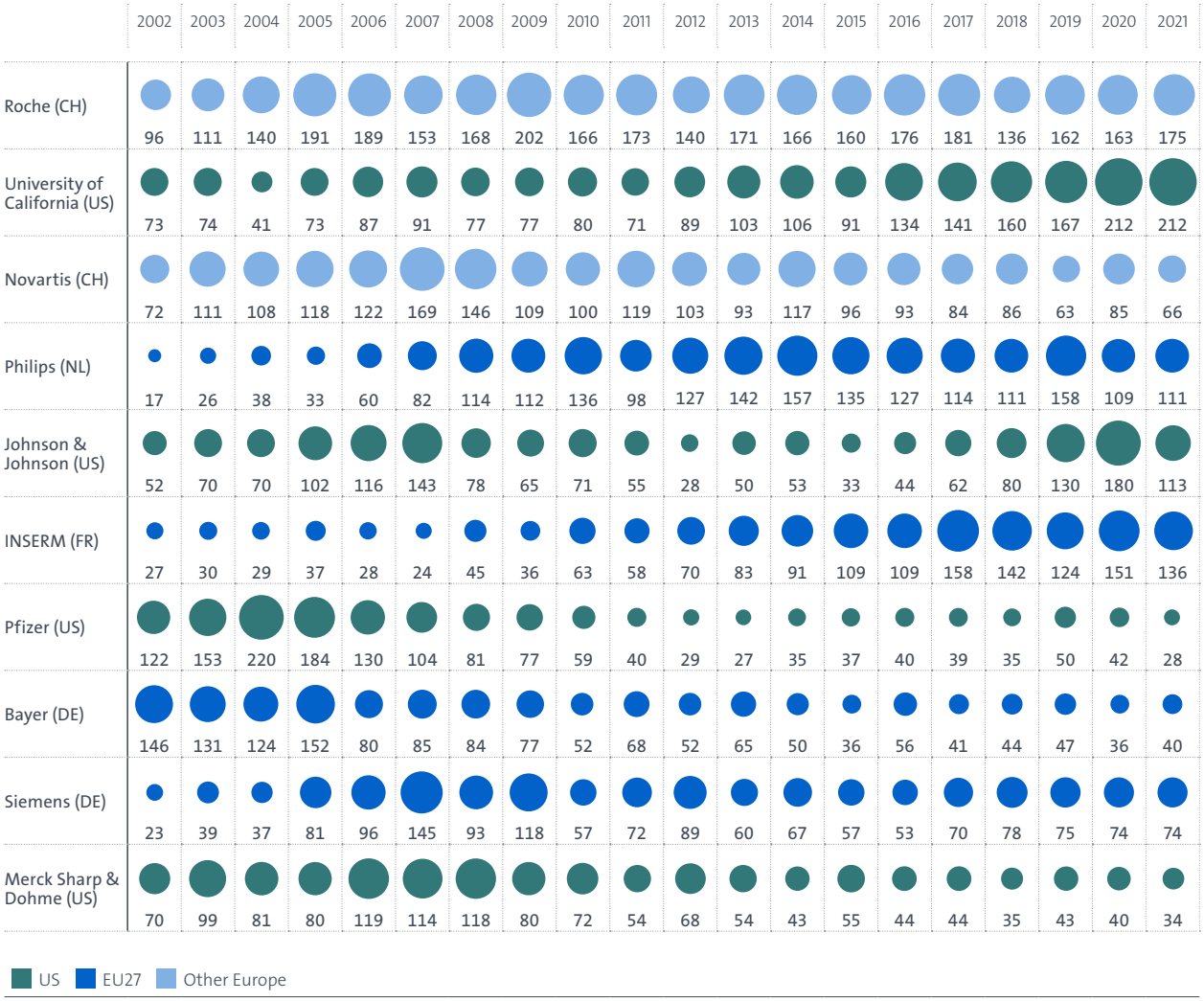
Since 2015, there has been renewed growth in patenting activity across almost all fields of cancer technologies. In cancer therapies, the growth has been driven by new and developing therapies. Targeted therapy has returned to a growth path, but the numbers of IPFs in immunotherapy, gene therapy, and non-coding nucleic acids have increased even more strongly. In the field of cancer diagnostics, there has been particularly strong growth in the area of liquid biopsies, which contrasts with the low growth in the number of IPFs for invasive tumour biopsies.

3.2 Top applicants

The list of the top ten applicants in cancer-related IPFs over the last two decades (between 2002 and 2021) consists of six large pharmaceutical companies, two healthcare technology providers, Philips and Siemens, one university and one public research organisation (Figure 16). Six of these top applicants have their headquarters in Europe and the remaining four are based in the US.

Figure 16

Top 10 applicants and their filing trends, 2002–2021



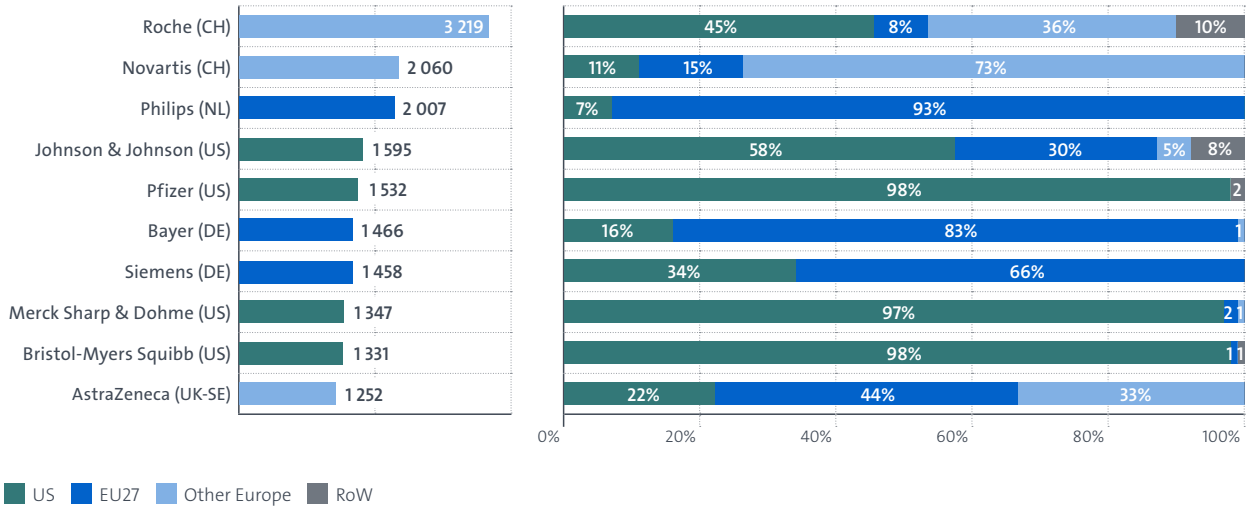
Source: EPO

Hoffmann-La Roche (Roche), one of the two Swiss pharmaceutical companies among the top three, was the applicant with the highest number of IPFs related to cancer. Its portfolio increased from nearly 100 IPFs in 2002 to over 200 by 2009 before stabilising at around 160 in subsequent years. The major part of Roche's patent portfolio is dedicated to cancer treatment, with a significant emphasis on immunotherapy (Figure 18). However, it is also one of the biggest candidates in cancer diagnostics, particularly in personalised medicine and biopsies, cancer models, and cancer-related ICT. Even though its head office is in Switzerland, almost half of its IPFs originate from the US, owing to previous acquisitions such as Genentech and Spark Therapeutics (Figure 17). Novartis, also headquartered in Switzerland, was the second largest company applicant and third overall. The company's primary focus is on cancer treatment, specifically targeted therapies. Philips, a Dutch company, is a dominant leader in cancer diagnostics, especially imaging technologies, bioinformatics, and healthcare informatics. In the field of cancer therapy, Philips is a significant player in cancer surgery and radiotherapy.

The University of California was the second largest applicant between 2002 and 2021, and together with INSERM, a French public research institution, it is a major player in cancer treatment and cancer diagnostics. Together with INSERM it made the largest contributions to IPFs related to gene therapy and non-coding nucleic acid therapy. It is also strong in other established and developing cancer treatment technologies and has the second largest IPF portfolio in cancer models.

Figure 17

Top 10 company applicants and the origin of their patenting activity, 2002–2021



Source: EPO

Figure 18

Top 10 applicants and their technology profiles, 2002–2021

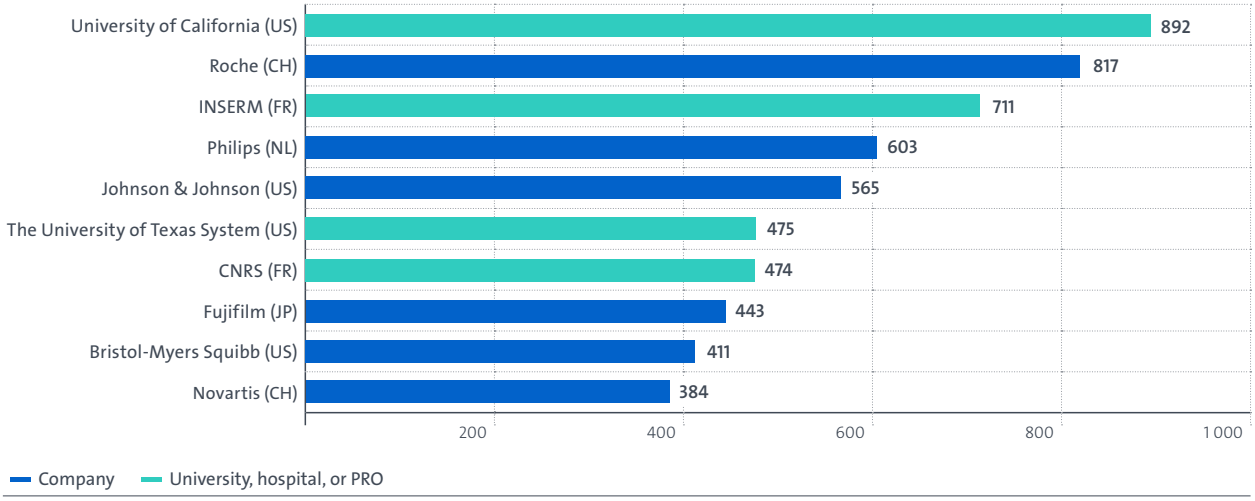
Source: EPO

Over the past two decades, a trend can be observed in which the annual contributions to patenting by the top pharmaceutical companies have either stagnated or declined (Figure 16). Notably, Pfizer and Bayer, who were the principal providers of cancer-related IPFs during the early 2000s, exhibited the most significant drops and are no longer among the top ten applicants in the five-year period 2017–2021 (Figure 19). Novartis dropped from second to tenth place.

In contrast, universities, hospitals and PROs among the top applicants have markedly increased the annual number of IPFs. The University of California has even become the applicant with the largest contribution to all cancer-related technologies with INSERM the third largest. The University of Texas System (US) and CNRS, another French PRO, were also able to enter the top ten. Interestingly, their recent contributions have not been focused on any specific therapy; rather they have encompassed a variety of cancer treatment and diagnostic technologies.

Figure 19

Top 10 applicants, 2017–2021



Source: EPO

Cepheid's GeneXpert platform, which will be used to deliver the OncoMasTR technology in the clinic

Case study: ONCOMARK

Company:	OncoMark
Headquarters:	Dublin, Ireland
Founded:	2012
Exit:	Acquired by Cepheid Inc in 2021
Products:	Multi-parameter prognostic test for early-stage breast cancer

"The OncoMasTR test is designed to enable a more personalised approach to patient care, helping clinicians to determine which patients should not receive chemotherapy, ultimately improving their quality of life."
Des O'Leary, CEO, OncoMark

OncoMark developed novel biomarker panels for an early-stage breast cancer test. The Irish company was spun out of University College Dublin in 2012 and spent a decade furthering its research, validating clinical data and finding the right balance of scientific expertise and business acumen. Ultimately, these factors contributed to OncoMark's acquisition by Cepheid, an established US-based molecular diagnostics company in 2021.

The chemotherapy Catch-22

According to the World Health Organization (WHO), 2.3 million women were diagnosed with breast cancer in 2020. Determining disease progression is a challenging task for clinicians and many prescribe endocrine therapy in combination with chemotherapy once a tumour has been removed. However, chemotherapy may only benefit around 30% of women with early-stage breast cancer and it often produces significant physical, emotional and psychological side effects. Clinicians are left with an impossible choice: prescribe a treatment that may cause harm or risk a patient's life.

Spinning out

In 2012, Adrian Bracken at Trinity College Dublin (TCD) and William Gallagher at University College Dublin (UCD) developed a diagnostic assay to detect early-stage breast cancer. Their assay uses gene expression signatures that correlate with tumour progression, enabling clinicians to rapidly, accurately and reliably stratify patients into low or high risk of cancer recurrence. The inventors called this assay OncoMasTR (**Onco**logy **Mas**ter **T**ranscription **R**egulators) and submitted an invention disclosure to the technology transfer offices (TTOs) at TCD and UCD.

The TTOs filed a joint priority patent application in the names of the two universities and concluded an agreement addressing issues such as patent fees and future revenue sharing. While both offices saw potential in the invention, they knew that commercialisation would be a challenge without supporting clinical validation data. The invention was rated at a low technology readiness level (TRL) and to overcome this hurdle, the TTOs advised partnering with a spin-out. The spin-out would secure investment and further develop the technology, with an eye to commercialisation.

Experience counts

In 2014, OncoMasTR was licensed to OncoMark, which Gallagher had co-founded seven years before. The company was a credible licensee from the perspective of the TTOs, and it offered an expert research team and extensive partner network to drive clinical validation. OncoMark received an exclusive royalty-bearing global licence, which covered the technology, the patent application and non-patentable technical details (such as an algorithm maintained as a trade secret). The agreement also gave OncoMark the right to acquire the technology after five years.

One year after concluding the agreement, Des O'Leary joined OncoMark as CEO. His extensive business experience proved vital because previously funding evaluators had felt that OncoMark lacked commercial experience. When the company re-applied for funding in 2015, it secured EUR 2.7 million. In 2017, it raised an additional EUR 2.1 million from private investors.

Gearing for success

As OncoMark continued validating its test for breast cancer, it drew the attention of Cepheid, a molecular diagnostics company in the US. The company wanted to broaden its oncology portfolio through strategic acquisitions. In 2016, Cepheid first invested in OncoMark to study whether OncoMasTR could be integrated into its GeneXpert platform. The agreement provided substantial funding and gave Cepheid an option to acquire OncoMark in the future.

While OncoMark had been poised to launch its own product, O'Leary knew the costs and risks involved. Cepheid's established diagnostics platform and partners within the US hospital system would enable rapid adoption of the OncoMasTR test. The cash injection from Cepheid enabled further clinical validation and the completion of a study showing that OncoMasTR could be integrated into GeneXpert. This gave Cepheid the confidence to move ahead with its acquisition of OncoMark together with its IP portfolio in March 2021.

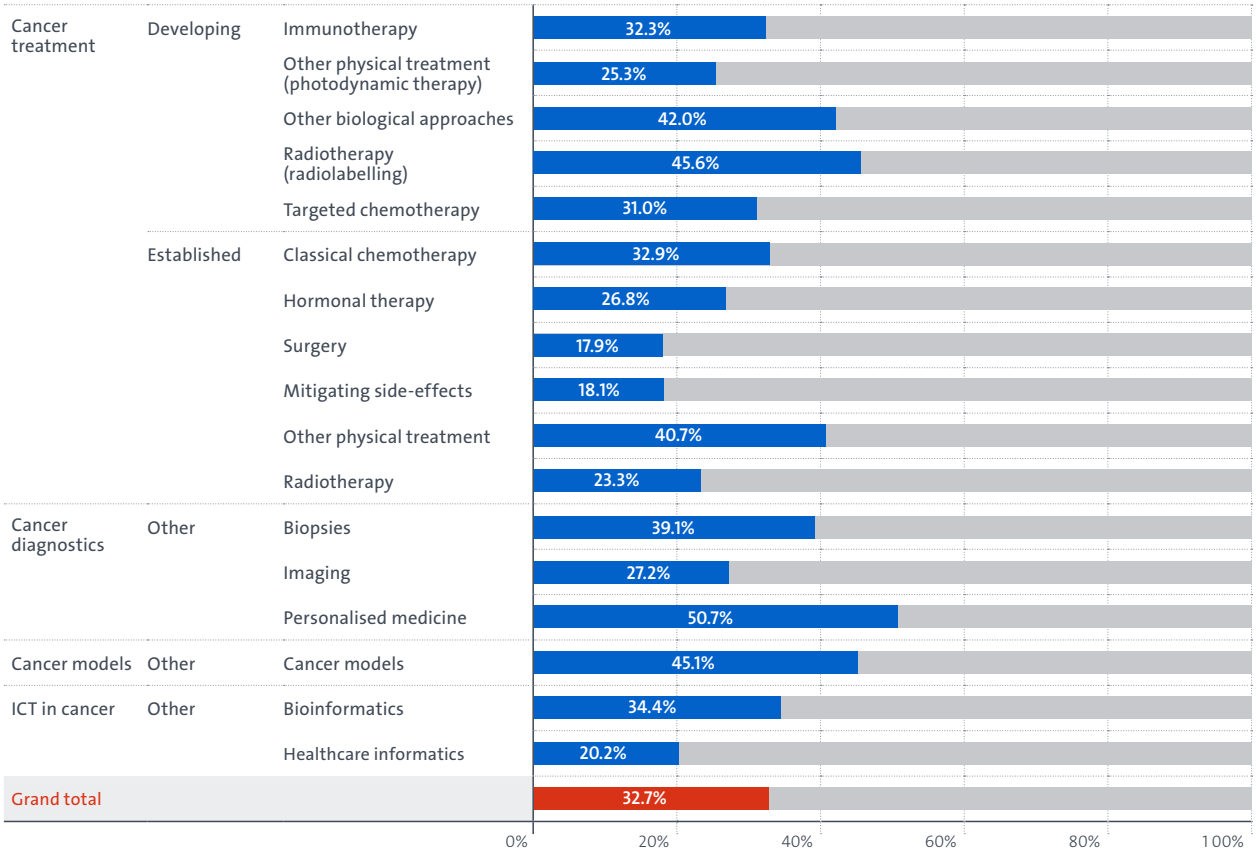
3.3 The role of universities, hospitals, PROs and startups

Between 2002 and 2021, universities, hospitals, and public research organisations (PROs) were the applicants for nearly one-third of all international patent families (IPFs) focused on combating cancer (approximately 26% in the EU27, 18.5% in other European countries, 33% in China, and 35% in the US). As shown in Figure 20, in fields other than cancer treatment, universities, hospitals, and PROs have contributed the most to personalised cancer medicine (over 50%), followed by cancer models (45.1%) and biopsies (39.1%). In the field of imaging, imaging agents exhibit the highest share of non-company IPFs. Of the two cancer-related ICT fields, these non-industrial actors have a substantially greater share of IPFs in bioinformatics (34.4%) than they do in healthcare informatics (20.2%).

In various established and developing cancer treatments, extensive participation from universities, hospitals and PROs can be observed. Radiolabelling, a constituent of radiotherapy, has the highest share at over 45%. Biological treatment methods, including gene therapy and non-coding nucleic acids, follow with 42%. One third of IPFs in immunotherapy and targeted therapy stem from universities, hospitals, and PROs. Classical chemotherapy also has a significant presence of IPFs from universities, hospitals and PROs, which account for almost 33%. Additionally, other established treatments such as hypothermia and dynamic therapy have shares of over 40%.

Figure 20

Share of universities, hospitals, and PROs by cancer-related technology, 2002–2021

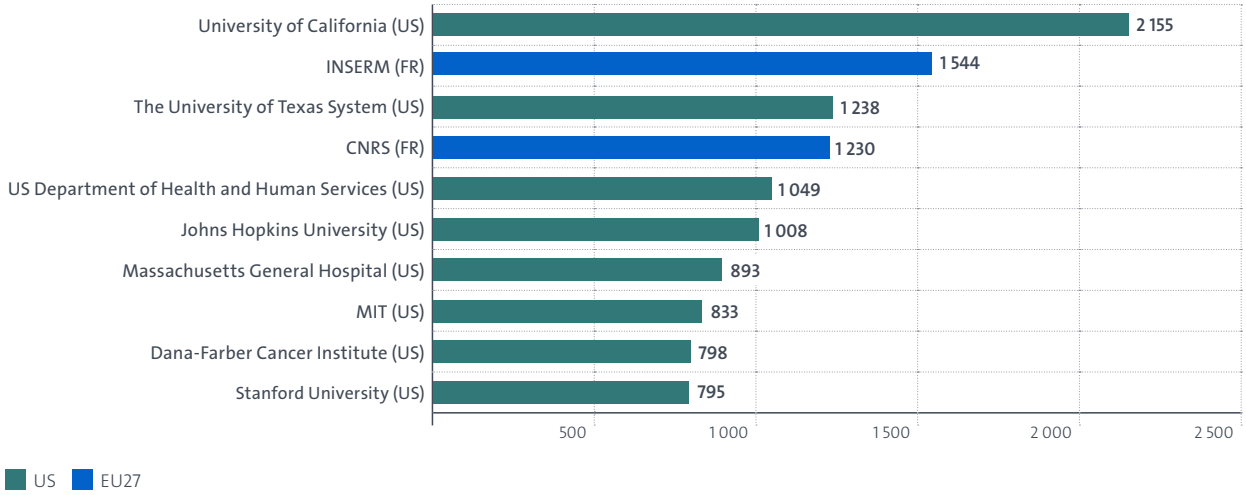


Source: EPO

There is further evidence of the significant role of universities, hospitals, and PROs – among the top 20 patent applicants over the same time period (2002–2021), 7 are universities or public research organisations, and 22 are among the top 50. Most of these universities and PROs are based in the US, with the exception of the two large French institutions INSERM and CNRS. Over the past years, most of these universities and PROs have increased their annual number of IPFs or at least kept them stable. This is a sign of the commitment of these institutions to contribute to research and innovation against cancer.

Figure 21

Top 10 universities, hospitals, and PROs, 2002–2021

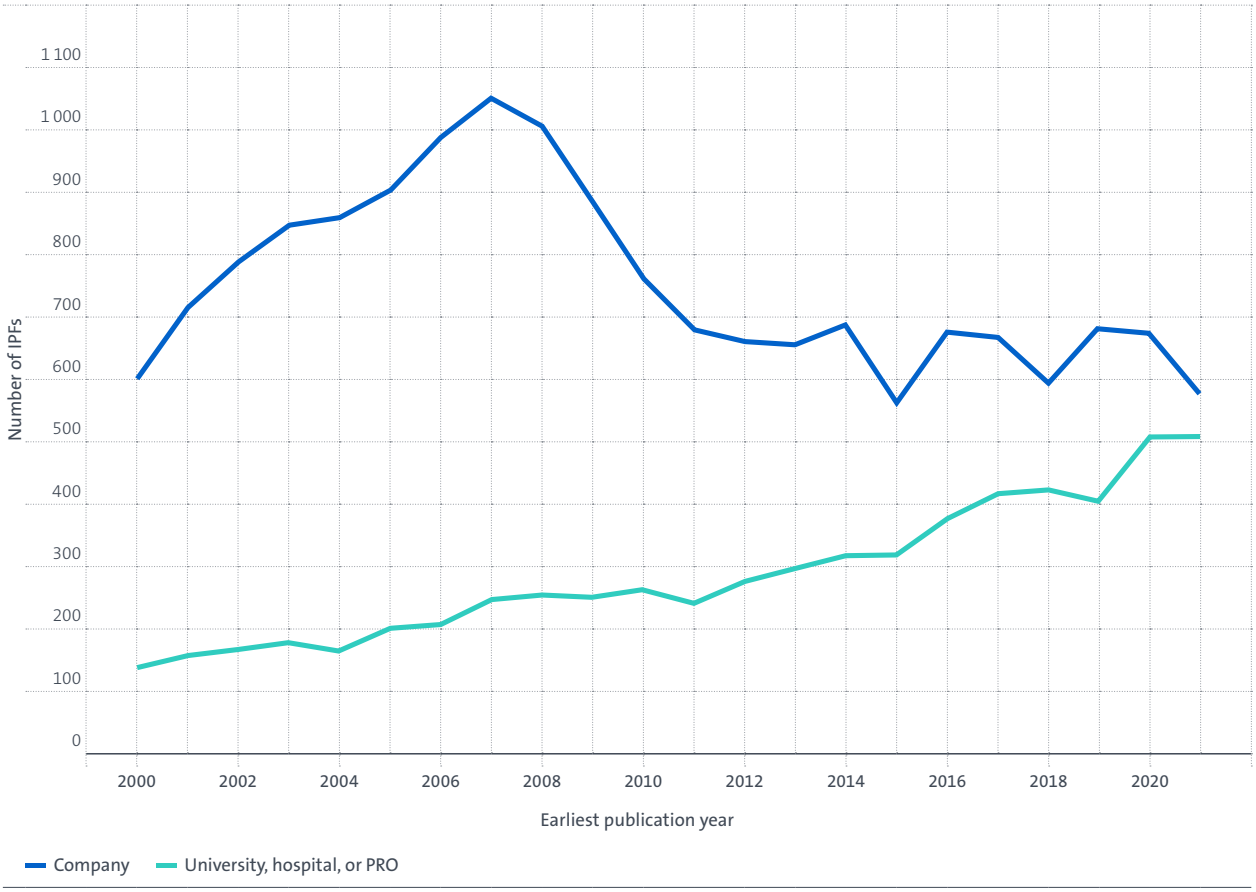


Source: EPO

A comparison of the patenting activity of top company applicants, mostly large pharmaceutical companies and medical technology providers, with the contributions of top universities, hospitals, and PROs over the last decades, reveals interesting developments. Figures 22 and 23 show that patenting in cancer-related technologies is increasingly being driven by non-industrial actors. This is particularly true in cancer treatment, where the number of IPFs from the seven universities and PROs who are among the top 20 applicants has grown considerably, while the annual number of IPFs from the top companies has gradually declined from its peak in 2007. In 2021, these seven institutions contributed almost the same number of IPFs to cancer therapies as the top 13 companies combined.[20] The development is somewhat different in cancer diagnostics. Here, the contributions by the top medical technology companies and by the group of top universities, hospitals and PROs have been growing in parallel since the early 2010s.

Figure 22

Comparison of trends among top 20 applicants: company applicants versus universities, hospitals and PROs – cancer treatment

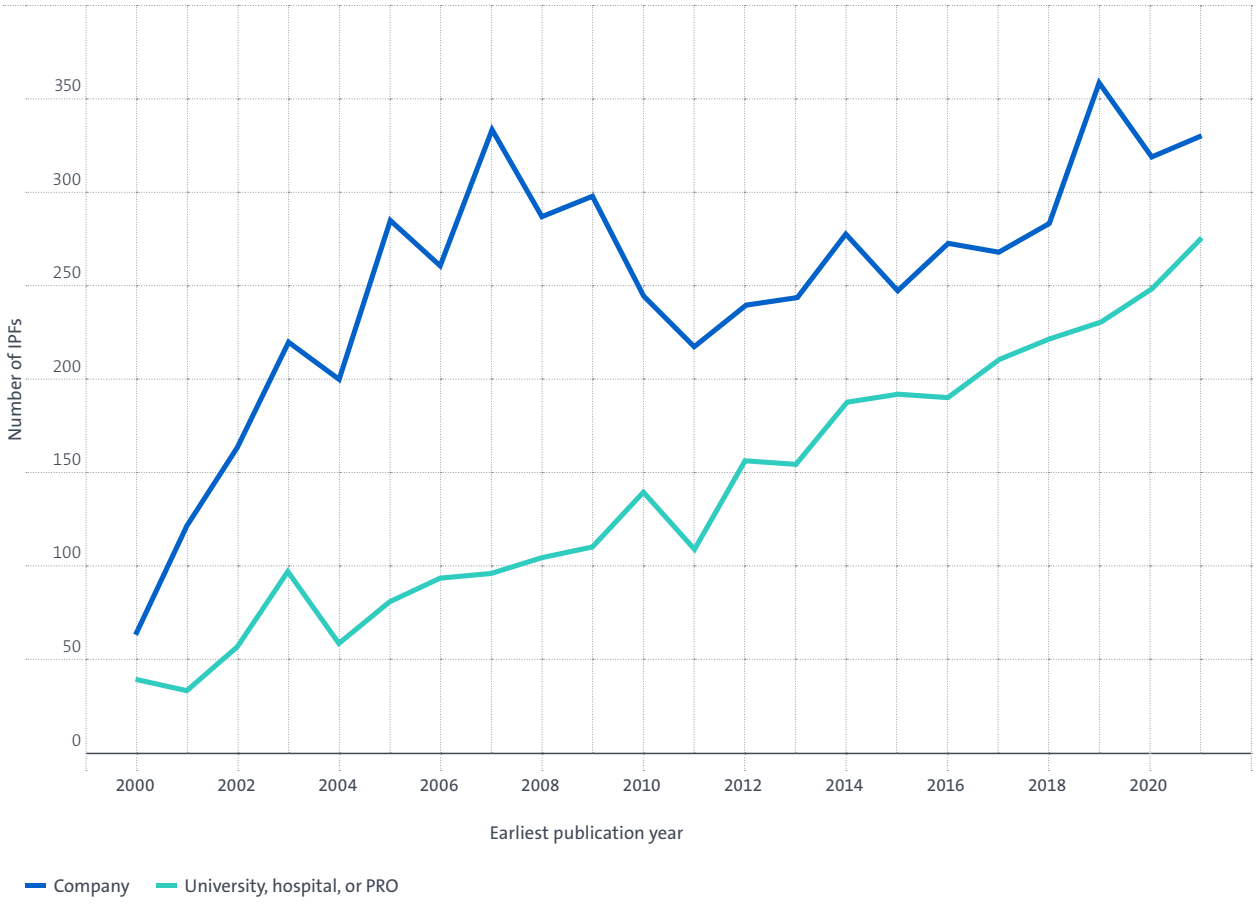


Source: EPO

20 The pattern persists for top 15, top 25, and top 50 applicants.

Figure 23

Comparison of trends among top 20 applicants: company applicants versus universities, hospitals and PROs – cancer diagnostics



Source: EPO

This shift in innovation towards universities, hospitals, and PROs among the large applicants, especially in cancer treatment, is indicative of a wider trend in the pharmaceutical industry, where companies are increasingly relying on external sources for their innovation pipeline. A recent investigation by Schuhmacher et al. (2023) of the origins of innovation of the 20 largest integrated pharmaceutical companies, revealed that the majority of new drugs launched by the companies, many of which were in oncology, were invented by biotech startups or within universities and PROs. The technology was acquired either through acquisitions, in-licensing, or collaborations. The authors interpret it as a shift in the business model of the large pharmaceutical companies, especially for new therapies, towards external innovation. Indeed, only 28% of drugs recently approved by the US Food and Drug Administration (FDA) were invented and developed internally by the large integrated pharmaceutical companies.

A zoom-in on the geographic and corporate origins of the IPFs filed by the top ten company applicants in immunotherapy, which are exclusively large pharmaceutical companies, illustrates this development (Figure 24). Although a significant share of the IPFs since 2016 originates from the internal R&D of big pharma companies, a comparable or sometimes even higher share of IPFs stems from biotech startups that these companies have acquired since 2005.[21] These startups often emerge from disruptive research conducted in universities, serving as a bridge for funnelling university and PRO innovation through big pharma to the market. One such example is Amal Therapeutics, a spin-out from the University of Geneva.[22] The biotech company, which invented a proprietary technology platform to progress therapeutic vaccines in oncology, was acquired by Boehringer Ingelheim for EUR 425 million in 2019, with the purpose being to develop the technology platform further and advance clinical trials and regulatory approvals before eventually achieving market entry.

Despite there being many European examples, most of these startups are based in the US, and big pharma companies, both from the US and Europe, have mainly been sourcing their innovation from US-startup acquisitions. Nevertheless, strategies among these companies are not always uniform – some companies, such as Novartis, GSK and Merck have been generating most of their immunotherapy-related IPFs in-house, as reflected in the patent data since 2017.

21 Only seven (out of 48) acquired biotech startups featured in Figure 23 were acquired before 2010. Among them, Genentech (acquired by Roche in 2009) contributed by far the largest number of IPFs and in turn acquired other biotech startups after 2010.

22 The founders of Amal Therapeutics, Madiha Derouazi and Elodie Belnoue, and their team were awarded the 2022 European Inventor Award in the SME category for the development of their therapeutic vaccine platform to treat cancer.

Figure 24

Geographic and corporate origins of the IPFs filed by the top ten company applicants in immunotherapy, 2017–2021

Note: Each row of the table shows the IPFs filed by the global top applicants in immunology in the period 2017–2021. These IPFs are distributed between the columns as a function of the geographic location of the affiliates of the top applicant that filed the IPFs. IPFs filed by the parent company are reported in blue, whereas each other coloured bubble indicates the IPFs filed by a biotech startup acquired by the top (parent) applicant since 2005.

Source: EPO

4. Geography of cancer-related innovation

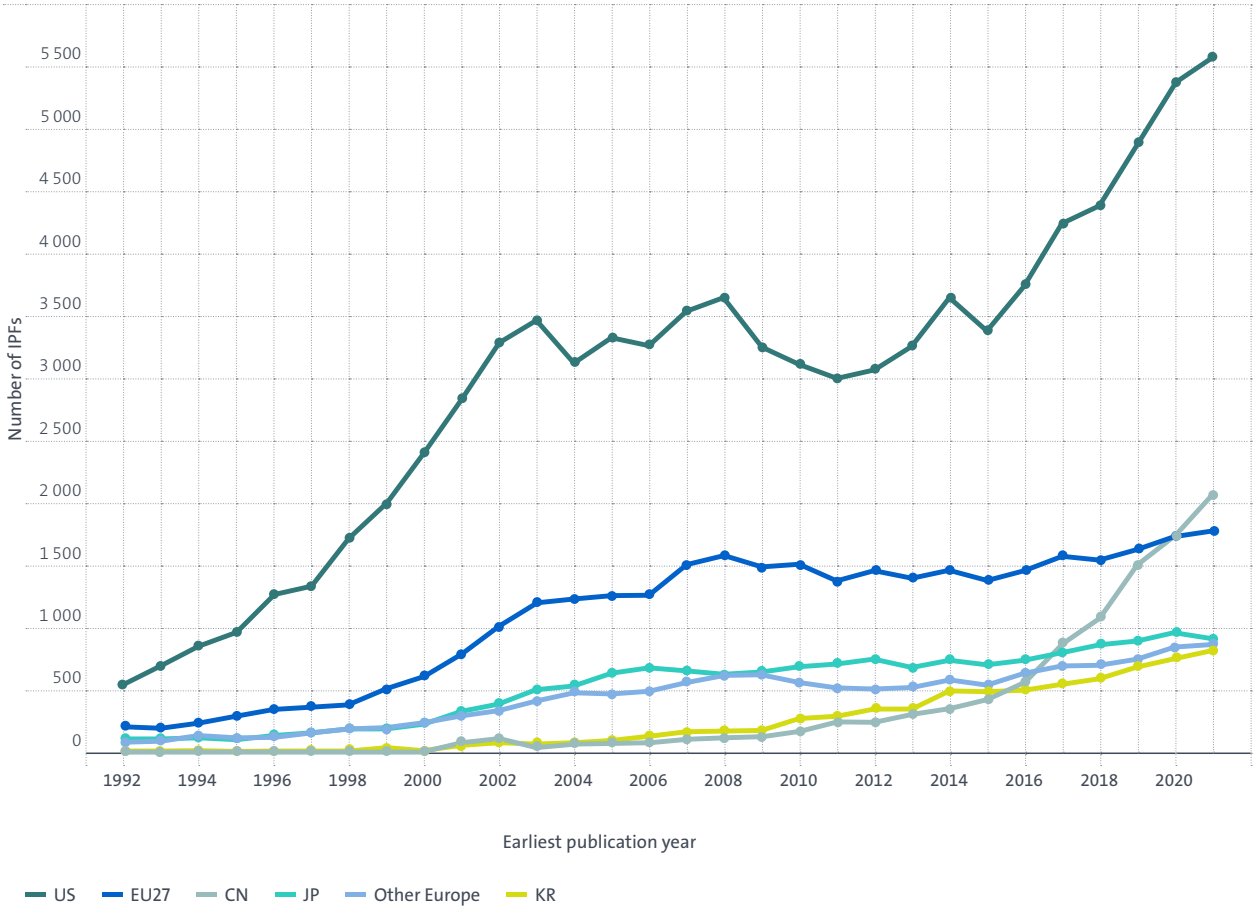
4.1 Global innovation regions

Throughout history, American applicants have been the dominant force in cancer-related innovation (Figure 25). Prior to 2002, almost 60% of all IPFs originated from US applicants. While the annual number of IPFs from the US plateaued before 2015, US applicants still maintained their lead with a 46% share of all IPFs in the period 2002–2021 (Figure 27). Since 2015, IPF growth from the US has gained significant momentum, with a CAGR of nearly 9% (Figure 26). As a result, in 2021, US applicants submitted over 5 500 IPFs.

Despite the absolute growth in IPFs from US applicants in recent years, US applicants' relative share has declined and currently stands at 43% (Figure 27). The decline is attributed to the strong increase in IPFs from Chinese applicants, whose contribution has grown at a CAGR exceeding 30% since 2015. This surge has been driven by Chinese universities, hospitals, and PROs, as well as strong contributions from Chinese companies. As a result, their share in all cancer-related IPFs in the five-year period between 2017 and 2021 was 13%. In 2021, China became the second leading contributor to cancer-related innovation with over 2 000 IPFs, surpassing the EU27, whose applicants contributed less than 1 800 IPFs in the same year. Within the top innovation regions list, IPFs from EU27 countries have exhibited the slowest growth since 2015, with a CAGR of 4.2%. This has resulted in the region's share declining to 15% during the latest five-year period of 2017 to 2021. IPFs from other European Patent Organisation member states, notably the United Kingdom and Switzerland, have exhibited robust growth with a compound annual growth rate (CAGR) of 8% since 2015. These nations have managed to maintain their share of IPFs at approximately 7%. Together, all European applicants contributed 22% of IPFs between 2017 and 2023. The number of IPFs from R. Korea nearly doubled between 2015 and 2021, while Japanese applicants experienced less dynamic growth, with a CAGR of only 4.4%.

Figure 25

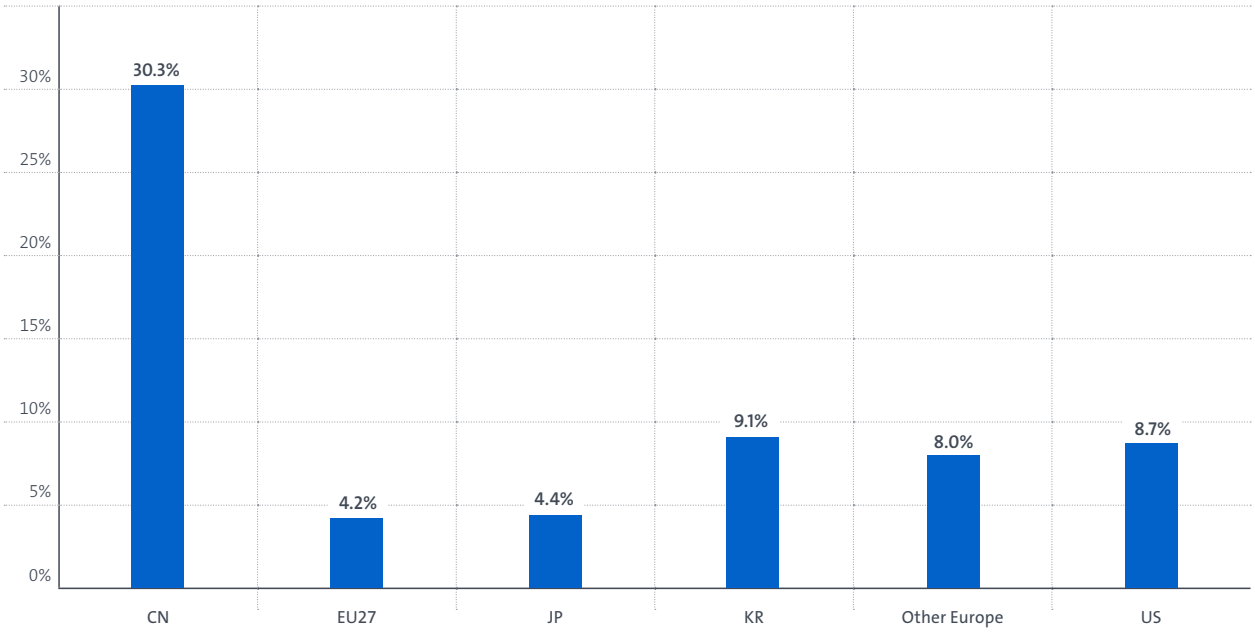
Trends in IPFs in cancer-related technologies by country of origin, 1992–2021



Source: EPO

Figure 26

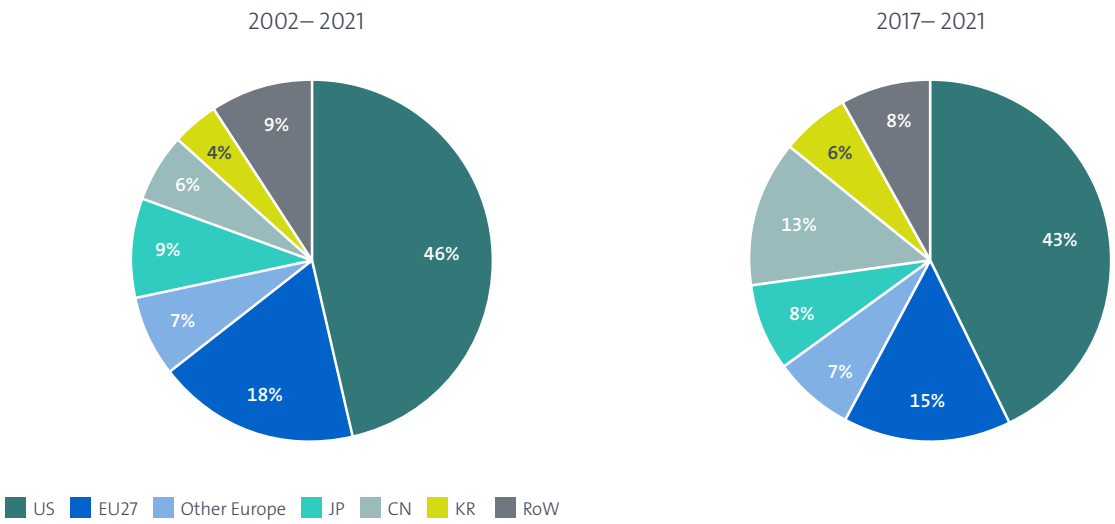
Growth rates in main cancer technology areas (CAGR 2015–2021)



Source: EPO

Figure 27

Shares in IPFs in all cancer-related technologies by country of origin



Source: EPO

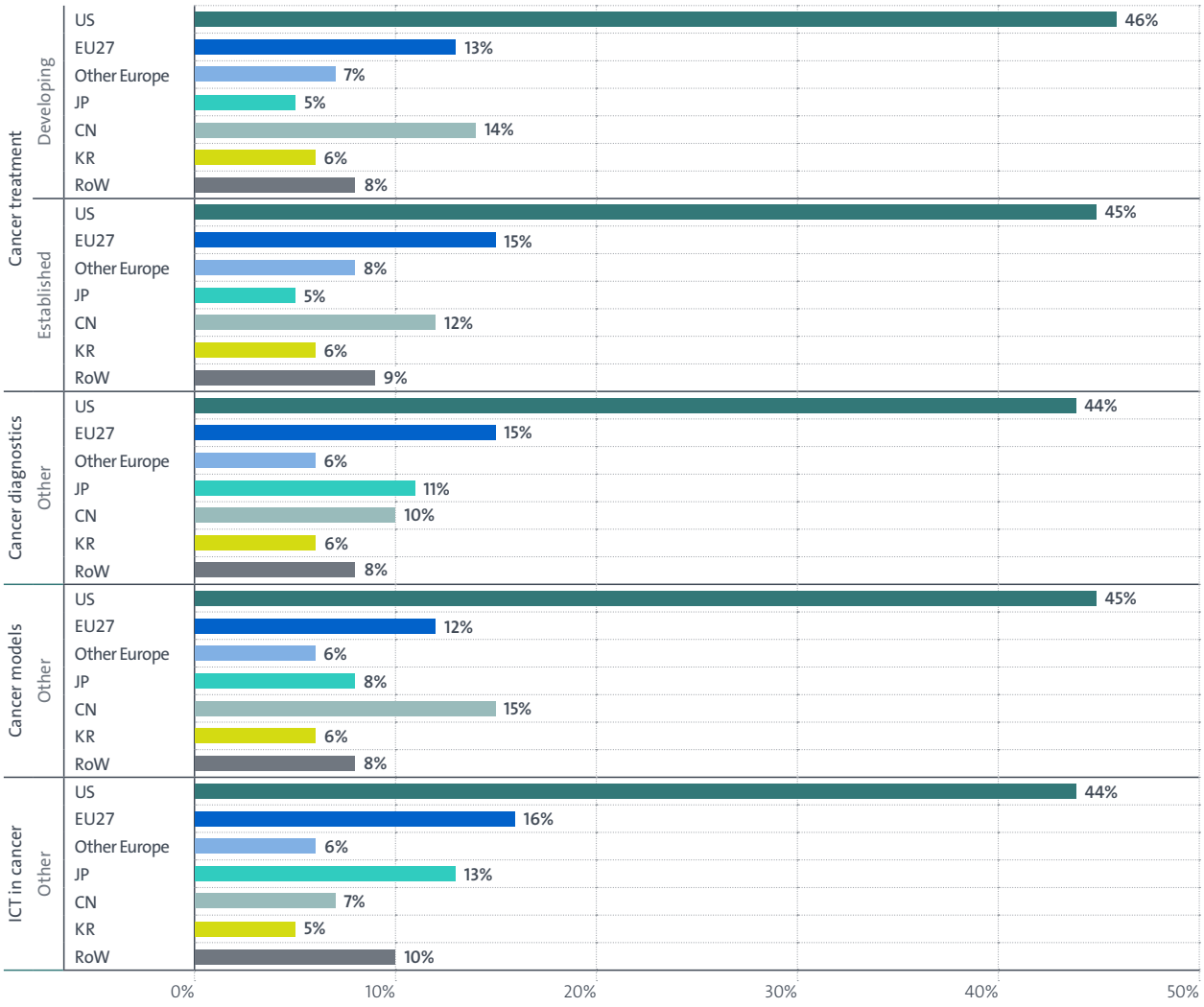
Overall, the US and P.R. China have been the main drivers of growth in cancer-related IPFs since 2015. The two countries contributed almost 70% to the growth in IPFs between 2015 and 2021. Although the US has been the dominant force in all four cancer-related technology areas, maintaining its shares of IPFs at around 45% in each of them, there are notable differences in growth patterns, even in the most recent five-year period (Figures 28 and 29). While the number of IPFs from US applicants increased significantly in developing cancer treatment technologies, cancer diagnostics and cancer-related ICT, growth in established cancer treatment and cancer modelling technologies was less pronounced. Growth in IPFs was driven by liquid biopsies (in cancer diagnostics) and by advancements in immunotherapy, gene therapy, and non-coding nucleic acids (in cancer therapies). IPFs in healthcare informatics from US applicants doubled between 2018 and 2021.

In recent years, growth in IPFs from Chinese applicants has primarily been driven by advances in immunotherapy and targeted cancer therapies, but also in liquid biopsies and cancer imaging technologies. Their annual contribution to cancer models grew almost seven-fold between 2015 and 2021, placing them second in this sector behind the US.

The EU's contributions remained high over the latest five-year period, with shares ranging from 12% in cancer models to 16% in cancer-related ICT. The main growth drivers of IPFs from EU-based applicants were immunotherapy among the cancer treatment technologies, liquid biopsies in cancer diagnostics, and healthcare informatics. Japanese applicants' main contributions to innovation against cancer are in diagnostics, especially liquid biopsies, with 11% of IPFs between 2017 and 2021, and in cancer-related ICT technologies (13%), mainly healthcare informatics.

Figure 28

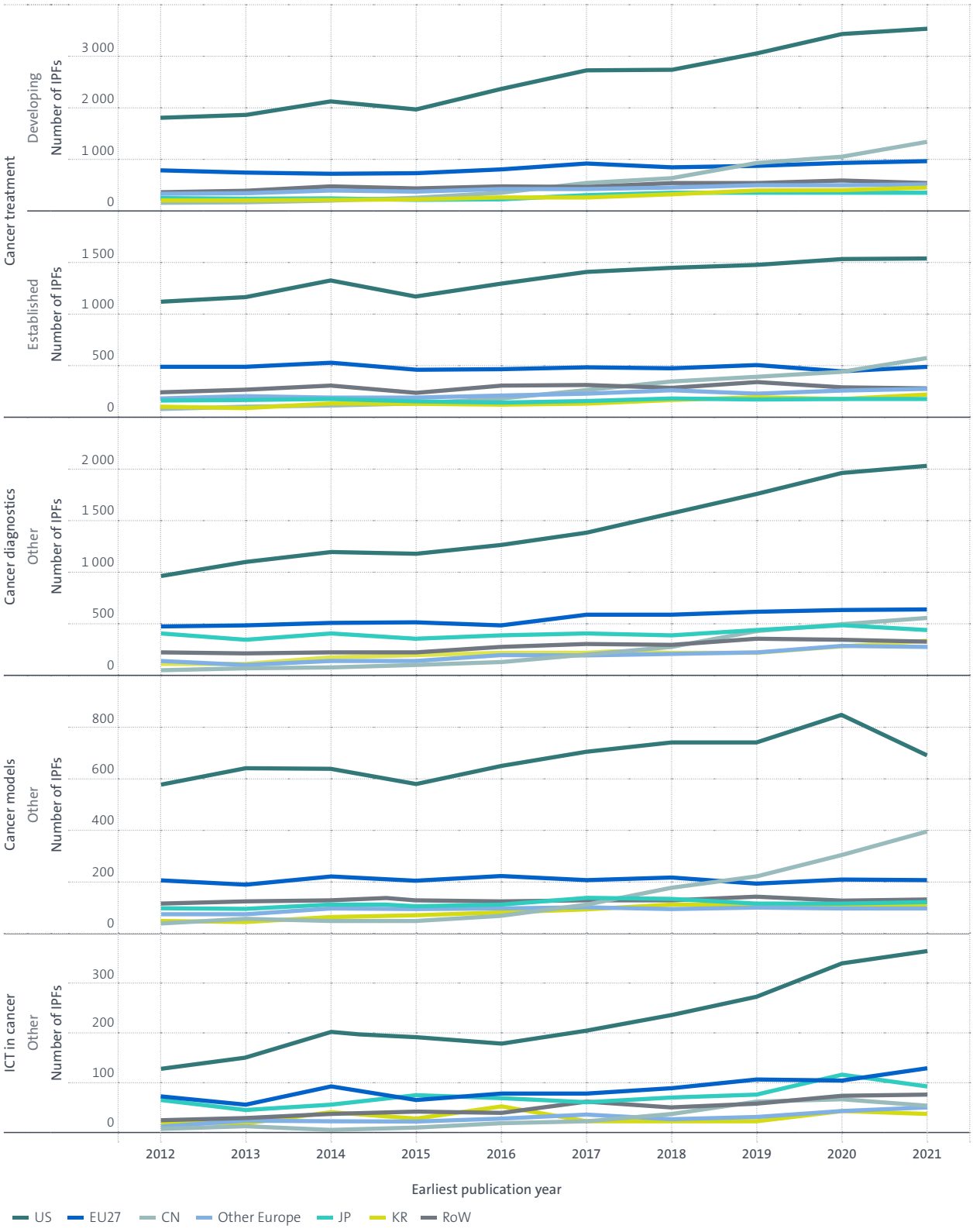
Shares in IPFs in cancer-related technologies, by country and technology sector, 2017–2021



Source: EPO

Figure 29

Trends in IPFs in cancer-related technologies, by country and technology sector, 2012–2021



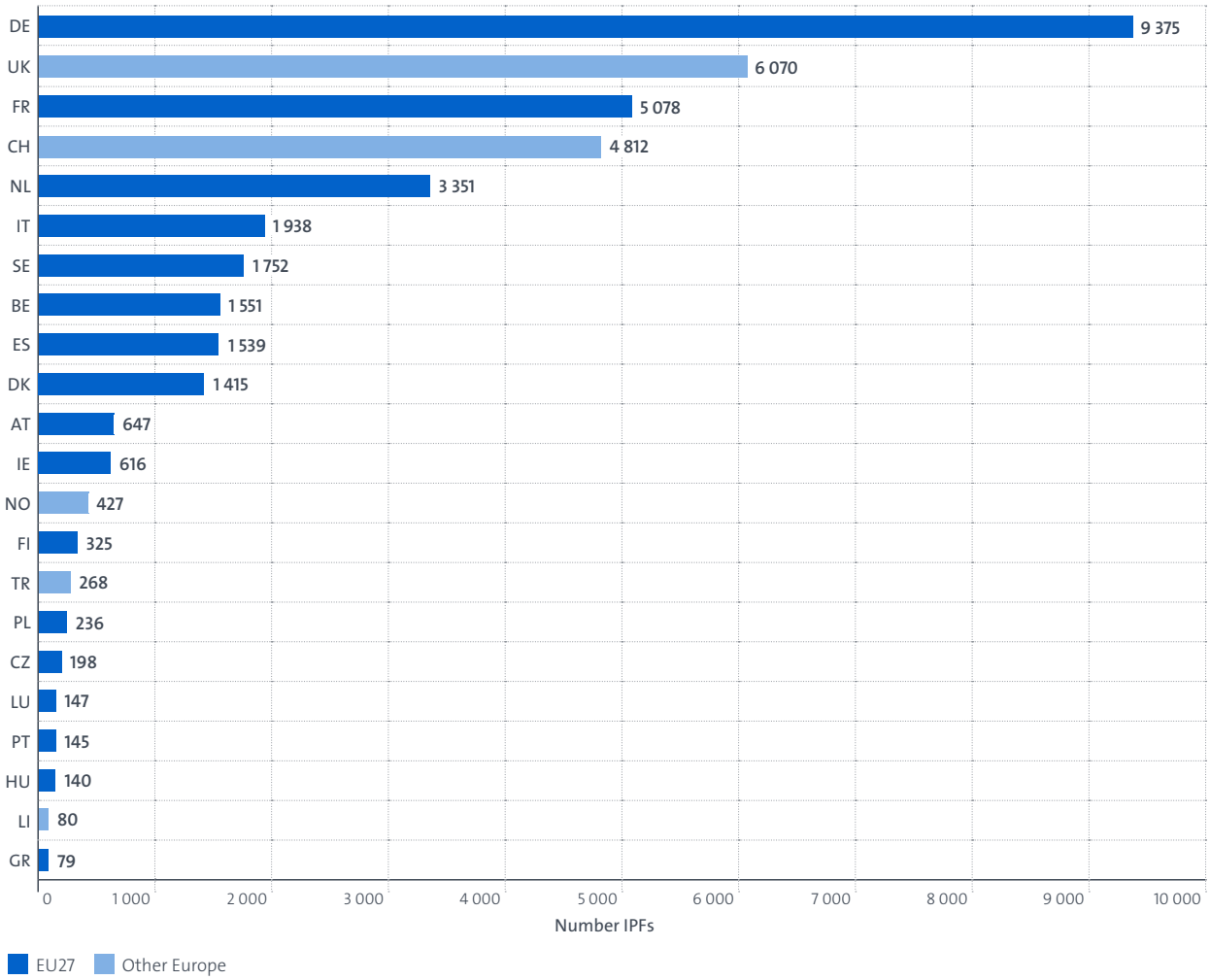
Source: EPO

4.2 Cancer-related innovation in Europe

Among European countries, German applicants have been the clear leaders for the last two decades, with over 9 000 cancer-related IPFs between 2002 and 2021 and a share of 23% among European applicants (Figures 30 and 32). However, its annual number of IPFs has stagnated somewhat over the last two decades, with its share declining to less than 19% in the most recent five-year period (Figure 32). In the most recent period, UK applicants successfully doubled their yearly number of IPFs between 2013 and 2021. As a result, they closed the gap with Germany and secured their position as the second-largest contributor with a 15% share of all European IPFs between 2002 and 2021. Contributions from French and Swiss applicants, each with a share of around 12%, also gradually increased over the past decade (Figure 31). Dutch applicants ranked fifth among European nations, contributing over 8% of all IPFs. Interestingly, a single firm, Philips, was responsible for more than 55% of Dutch IPFs.

Figure 30

Distribution of IPFs in all cancer-related technologies by European country, 2002–2021

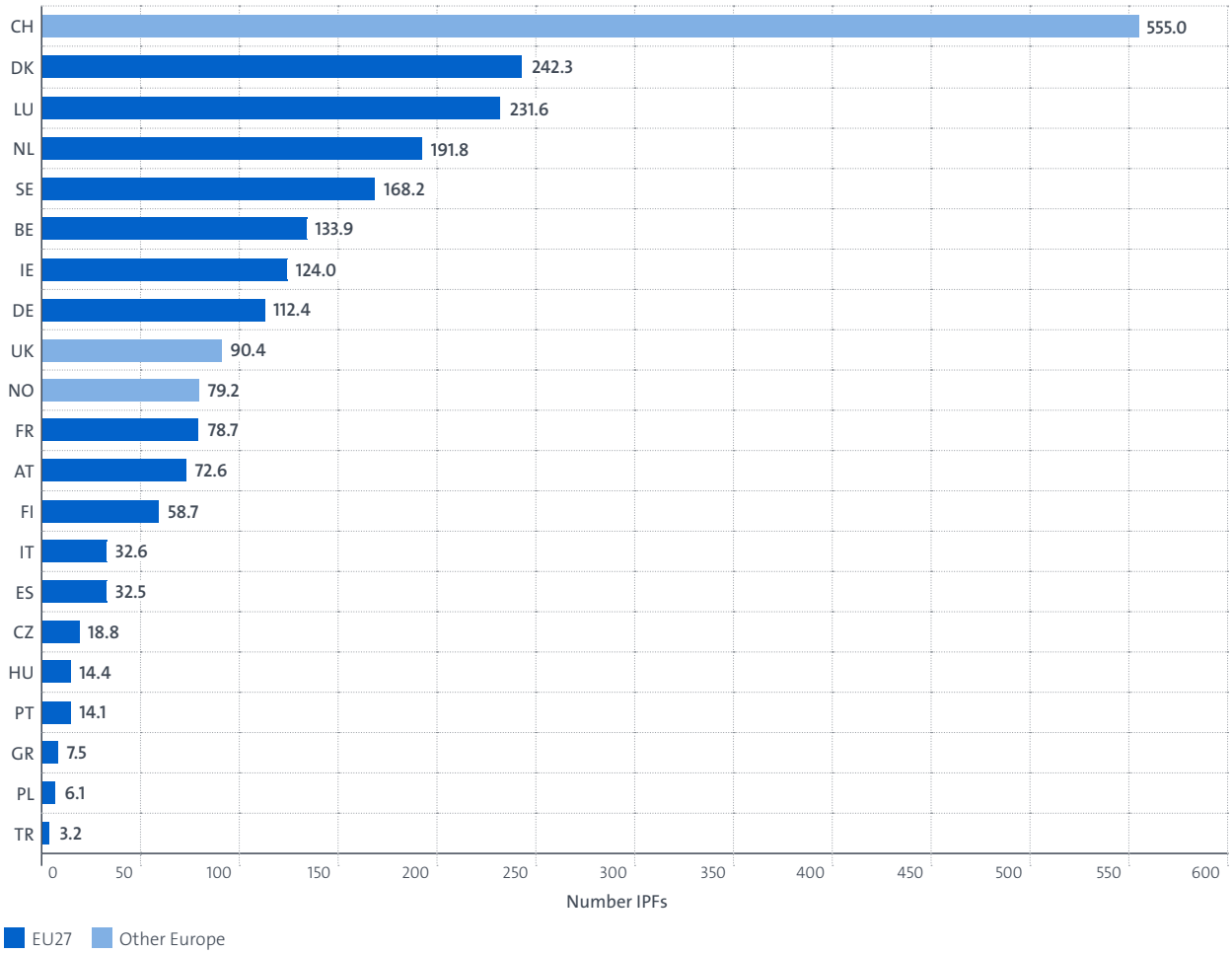


Source: EPO

Figure 31 shows the ranking of European countries based on the number of cancer-related IPFs per million inhabitants, for countries with a population of at least half a million inhabitants. With over 500 IPFs per million inhabitants, Switzerland is clearly ahead of all other countries. Denmark and Luxembourg follow with figures above 200. Germany is eighth, followed by the United Kingdom.

Figure 31

IPFs in all cancer-related technologies per million inhabitants (European countries), 2002–2021

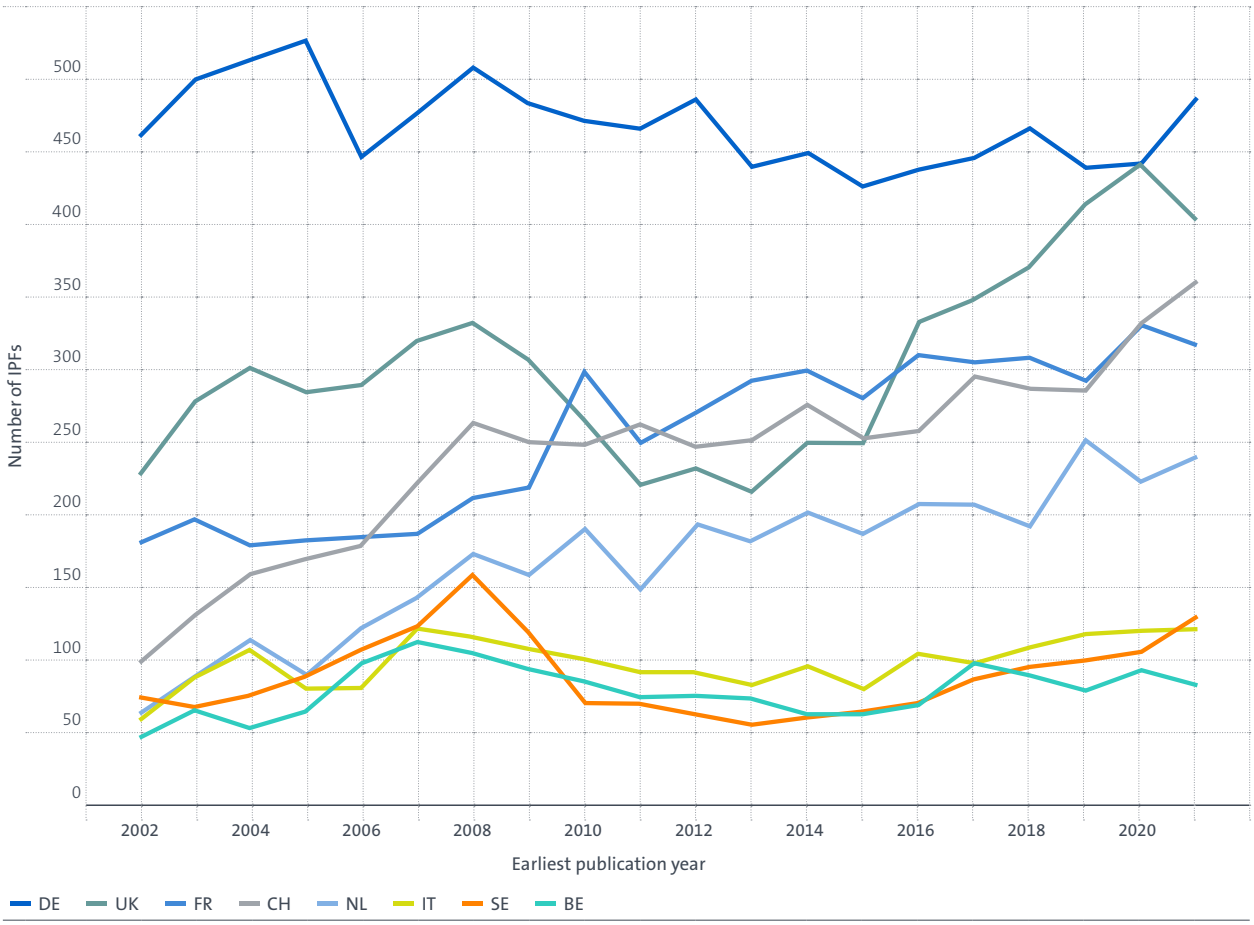


Note: Source of population figures is the United Nations Department of Economic and Social Affairs, Population Division.

Source: EPO

Figure 32

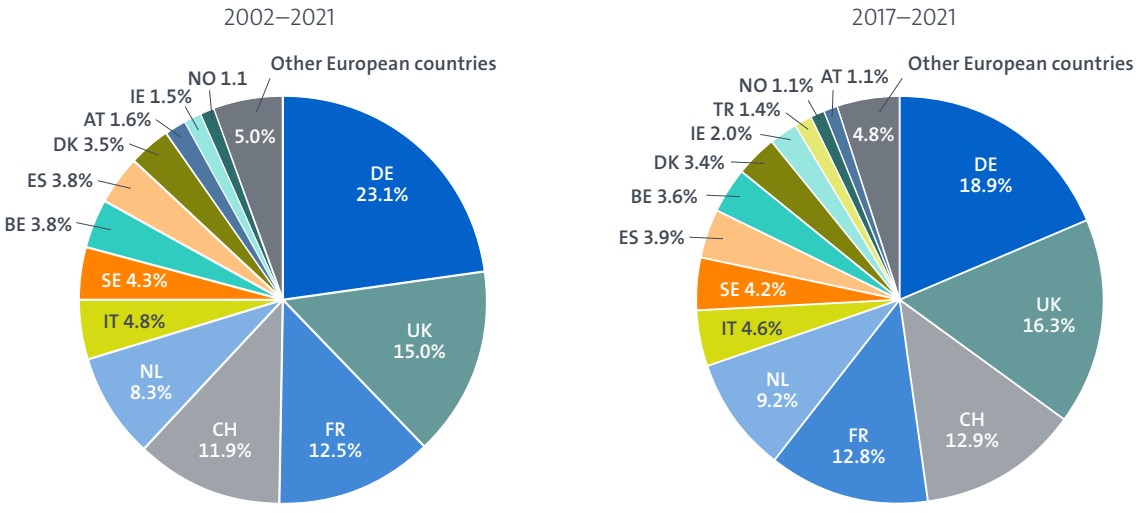
Trends in IPFs in cancer-related technologies among the top European countries, 2002–2021



Source: EPO

Figure 33

Shares in IPFs in all cancer-related technologies by European country



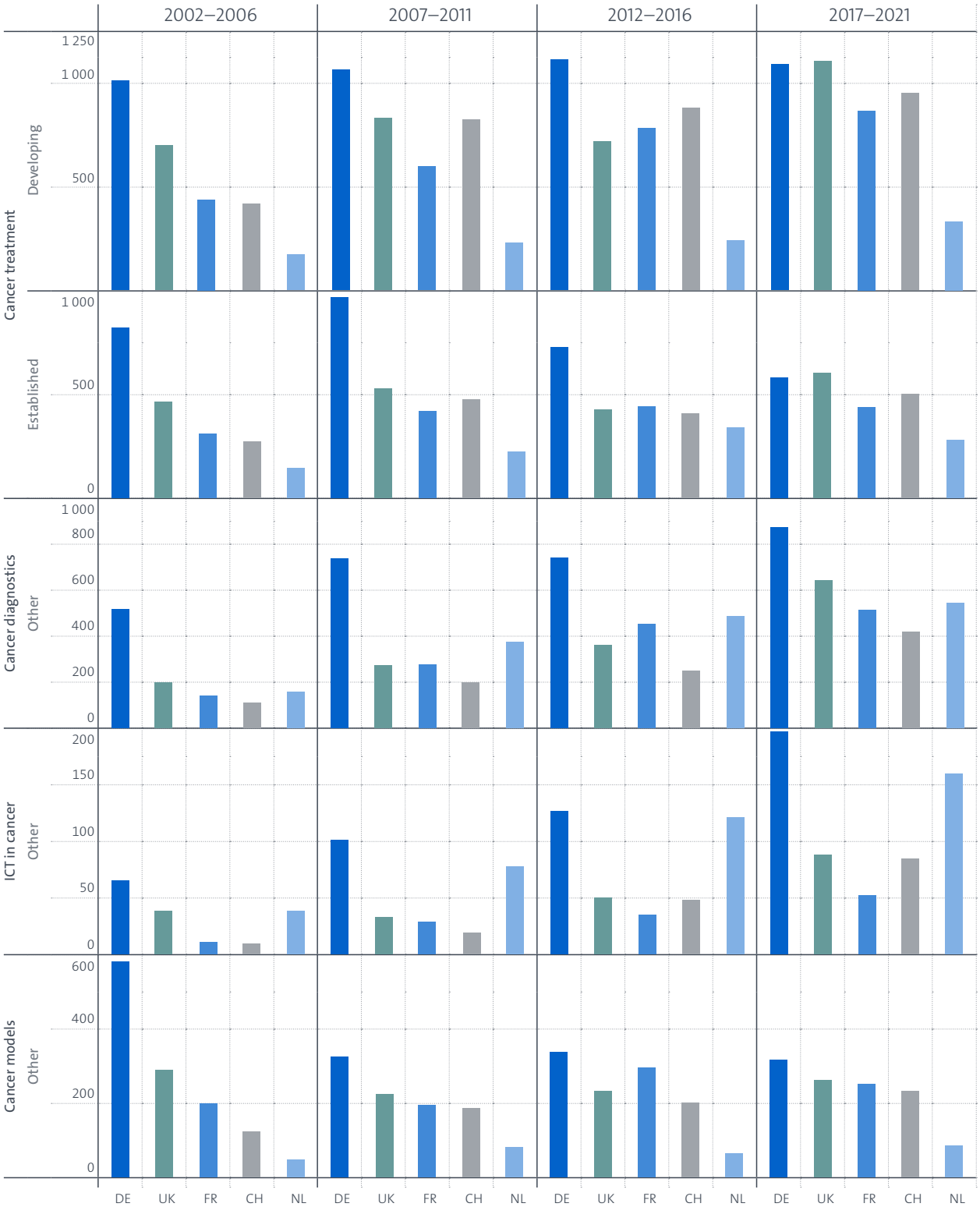
Source: EPO

This section examines the performance of European applicants in various cancer-related technologies (Figure 34). The contributions of German applicants decreased most in established cancer treatments over this period, particularly in hormonal therapies and classical chemotherapies. However, they were able to maintain their annual contribution of IPFs in developing cancer therapies. The decrease in IPFs for targeted therapies in recent years was counterbalanced by an increase in IPFs related to immunotherapy. In the field of cancer diagnostics, German applicants showed an upsurge in IPFs for liquid biopsies, whereas their contribution to tumour biopsies has declined since 2018. The recent progress in cancer-related ICT resulted solely from IPFs in healthcare informatics.

UK applicants showed significant growth in patenting activity for liquid biopsies, increasing from 15 IPFs in 2013 to nearly 110 in 2021. The rise in cancer therapies was influenced by immunotherapy, which led to a doubling in the number of IPFs between 2014 and 2019. IPFs related to targeted therapy experienced a resurgence after a marked decline from 2007 to 2011. The growth in patent applications from French applicants over the past decade was similarly boosted by developments in immunotherapy and targeted therapy. The quantity of IPFs related to personalised medicine, biopsies, and cancer models experienced a sharp rise from 2007 until approximately 2016, although growth then slowed or declined. In 2021, Switzerland exceeded France in the number of IPFs due to the impressive performance of Swiss applicants in healthcare informatics, liquid biopsies, and imaging, but also in emerging cancer treatment technologies, including immunotherapy, gene therapy, and non-coding nucleic acids, as well as conventional radiotherapy.

Figure 34

Trends in IPFs in cancer-related technologies, by European country and technology sector



Source: EPO

Line-field Confocal Optical Coherence Tomography (LC-OCT) device – deepLive

Case study: DAMAE MEDICAL

Company:	Damae Medical
Headquarters:	Paris, France
Founded:	2015
No. of employees:	30
Products:	Non-invasive, advanced medical imaging in the dermatology field

"Damae's growth and success will depend in part on its ability to protect its products and inventions, in particular by obtaining and maintaining patents in the territories targeted by its business activities, mainly in Europe, the United States and Australia."
David Siret, Chief Technical Officer, Damae Medical

Damae Medical is a spin-out from the French Institut d'Optique Graduate School. Founded in 2014, the company used a patented imaging technology to create a new medical device for the real-time diagnosis of melanoma. Their non-invasive solution can detect malignant tumours early on and is currently used in over 40 centres around the world. The company is built around a robust IP portfolio and has a well-defined strategy to give it a competitive edge.

More than meets the eye

Globally, skin cancer is one of the most common cancers and early detection is not always possible. A dermatologist typically first examines skin abnormalities with the naked eye and then a dermoscope. If there is any uncertainty, the dermatologist may take a biopsy, which is sent to a laboratory for examination. However, if the skin shows no obvious signs of disease, the dermatologist might not request a biopsy.

Taking the initiative

Professor Arnaud Dubois had spent several years at the cutting edge of research into optical coherence tomography (OCT). In 2013, biophotonics graduate students Anaïs Barut and David Siret were tasked with creating a business proposition for a startup as part of their final-year project. Their research led them to Dubois, and together they began exploring various technologies in the biomedical field. They soon became convinced that Dubois' OCT technology had market potential. The professor initiated a patent application at the end of 2013, and the following year the trio established Damae Medical.

Three partner institutions supported research and commercialisation: Institut d'Optique Graduate School, Paris-Saclay University and Centre National de la Recherche Scientifique (CNRS). Initially, they were joint owners in the patent application. Damae first obtained an exclusive licence to the core patent family in return for royalties on sales but later acquired outright ownership in return for equity. This decision was pivotal, since outright ownership would later be a drawcard for investors.

Securing funding

To date, Damae has raised over EUR 20 million through seed and Series A funding rounds, with a mix of venture capital and private investors. It has also relied on European Union grants, receiving EUR 2.4 million through the Horizon 2020 programme.

Technology and IP proved crucial in securing investment. During both seed and Series A rounds, investors audited Damae's IP portfolio, looking at its patents, trade marks, know-how, domain names and copyright in software and databases. The thorough audit and subsequent favourable audit report showed investors that Damae's technology and business plan were worth backing.

Managing IP

The company's proprietary deepLive medical device produces cellular-level 3D images of the skin, with diagnoses supported by software and artificial intelligence. Damae employs a complementary mix of IP rights to cover these solutions. In addition to patents in key territories, the company has filed for design right protection for its handheld probe and owns several trade marks. Selected process designs, specifications and manufacturing methods are maintained as trade secrets.

Damae has developed a system for categorising its inventions as high-impact or low-impact patents. Essentially, high-impact patents feature broad claims, cover the core technology and are maintained in international markets where the most competition exists. Low-impact patents cover improvements to the core technology and are maintained only in selected markets.

While their IP strategy is ever evolving, Damae currently files French national applications to gain patent priority, followed by an international (PCT) application within 12 months. This buys the company time to gather research data and test prototypes while delaying patent prosecution costs. Their strategy also includes patent database monitoring, allowing them to keep an eye on competitors and avoid infringement.

5. Developments in selected cancer technologies

5.1 Cancer biopsies

Cancer biopsies are medical procedures in which a small sample of tissue or cells is extracted from the body to diagnose or monitor cancer. The term "biopsy" was introduced into medical terminology in 1879 by Ernest Besnier, and the method has been widely adopted in oncology as well as in practically all clinical specialties. Biopsies are crucial in the fight against cancer for diagnosis, tumour characterisation, staging, treatment planning, monitoring, and research purposes. There are two main types of biopsies: tumour biopsies and liquid biopsies.

Tumour biopsies, also known as tissue biopsies, involve extracting a tissue sample from a suspected malignancy using methods such as a needle, endoscopy, or surgery. Then, a pathologist examines the specimen under a microscope to diagnose whether the tissue is cancerous. Although the sample can provide valuable insight into the type and stage of a tumour, it is an invasive procedure that can cause pain and bleeding and carries infectious risks. Furthermore, tissue biopsies can be limited in terms of their application, and possibly fail to fully encompass the genetic diversity of the cancer (Huang C., et al., 2019).

Liquid biopsies are minimally invasive screenings that involve analysing a blood sample or other bodily fluids for cancer cells or tumour DNA fragments. They offer a non-invasive, repeatable, and ongoing overview of a patient's cancer, providing valuable information on effective treatment options. They entail the analysis of biomarkers including circulating tumour cells (CTCs), circulating tumour DNA (ctDNA), and circulating proteins in bodily fluids such as blood, urine and cerebrospinal fluid (Shegekar T. et al., 2023). These biomarkers can yield valuable information about cancer biology. This includes information about tumour heterogeneity, real-time tumour evolution and response to therapy, which are the underlying principles of personalised medicine, as well as about the mechanisms of cancer metastasis.

While liquid biopsies have great potential for transforming cancer care, they are not without limitations. For example, they may not detect all genetic alterations in early disease states, and their accuracy may vary among tumour types and disease stages. In addition, there is still a need to standardise sample collection, processing, and analytical processes, and a need for more molecular profiling methods (Shegekar T. et al., 2023).

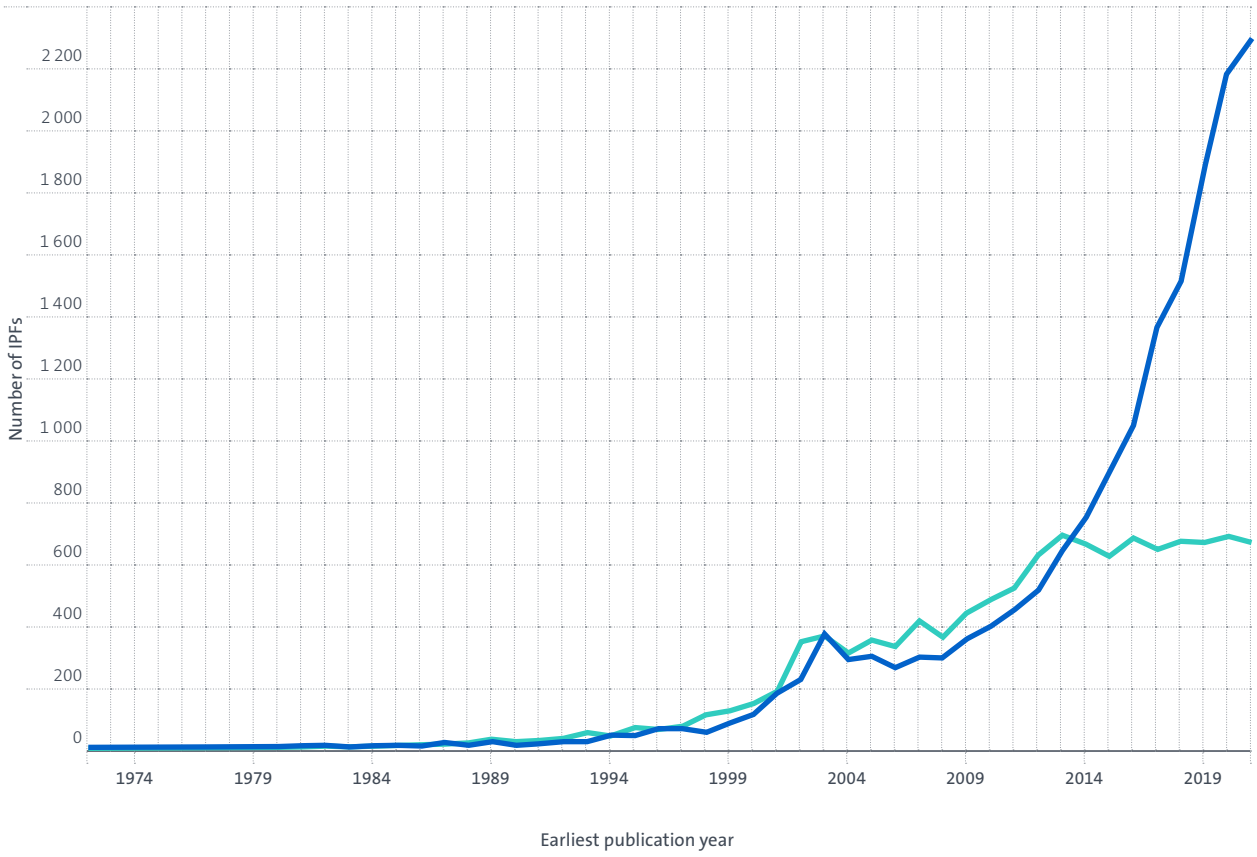
For a long time, conventional tissue biopsies have been accepted as the norm for diagnosing cancer.

Patent trends (Figure 35) indicate that prior to 2013, almost every year a greater number of IPFs were published in tumour biopsies than in liquid biopsies. This changed significantly in subsequent years. Whereas the number of IPFs associated with tumour biopsies remained stable at approximately 600–700 yearly, the number related to liquid biopsies surged from slightly over 500 in 2012 to over 2 300, or 4.6 times more, in 2021.

The surge in the technical advancement of liquid biopsies throughout the past decade has been catalysed by the rapid progress in molecular biology, genomics and next-generation sequencing technologies (Noor J. et al., 2023). Developments in bioinformatics have played a significant role in these advancements because the unbiased analysis, i.e. sequencing, of materials such as CTCs and ctDNA is computationally challenging.

Figure 35

Trends in IPFs in liquid and tumour biopsies, 1972–2021



Source: EPO

— ctDNA is released by tumour cells into body fluids, such as blood, and carries the genetic mutations of the original tumour. It is by far the area with the highest patenting activity, with over 2 000 IPFs in 2021 (Figure 36). It is more abundant in body fluids than other biomarkers and can be analysed using next-generation sequencing technologies to provide a comprehensive picture of the genomic landscape of a tumour.

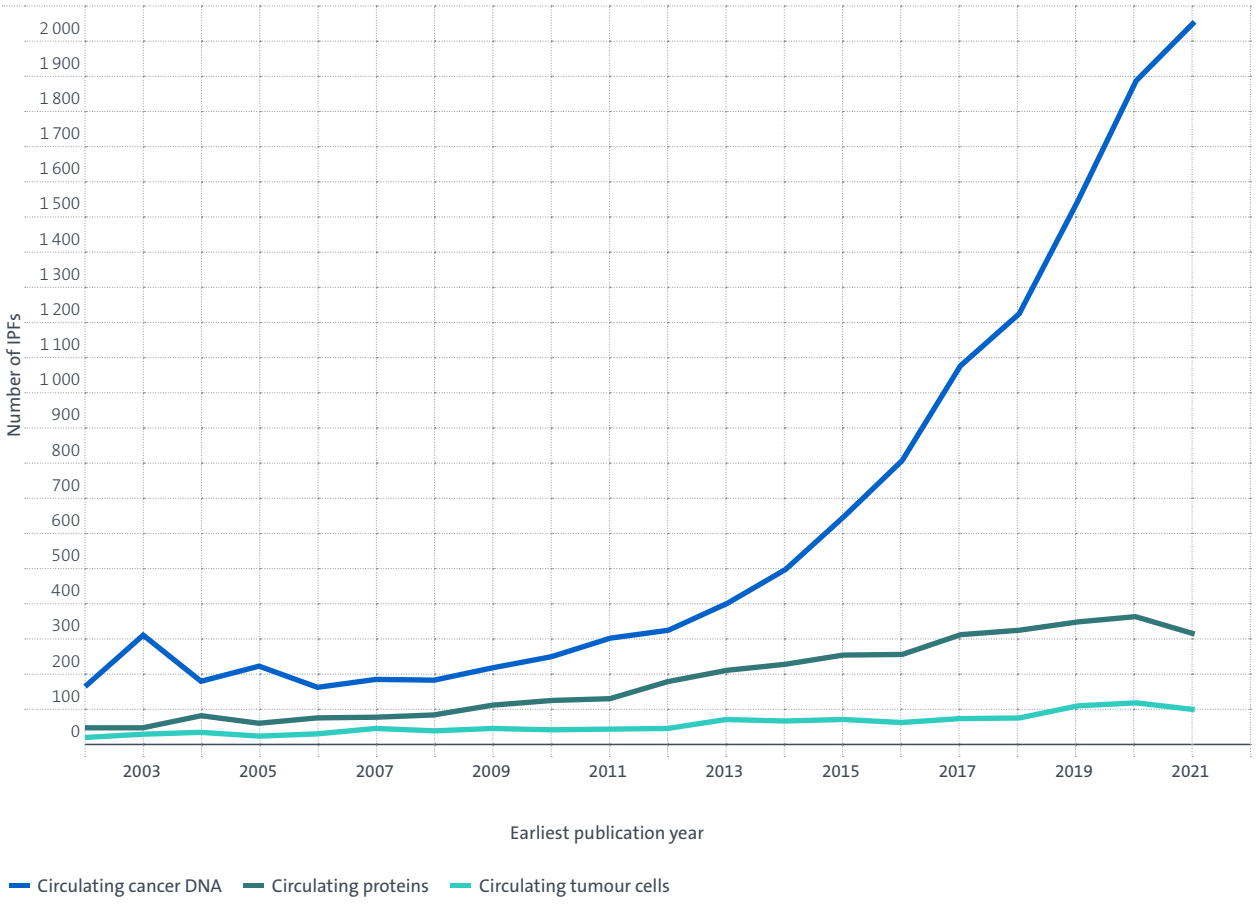
— CTCs are tumour cells that have detached from the primary tumour and entered the bloodstream or lymphatic system (Tan CR. et al., 2016). They can provide information about the tumour's molecular characteristics and help monitor disease progression and response to therapy. Despite a noticeable increase in the number of IPFs over the last 15 years, from only 76 IPFs in 2007 to over 300 IPFs in recent years, the field is still significantly smaller than ctDNA.

— Circulating proteins is the smallest liquid biopsy technology with around 100 IPFs per year during the most recent period. Circulating proteins are proteins released by tumours into the bloodstream and can serve as potential biomarkers for cancer diagnosis and prognosis. However, the sensitivity and specificity of these biomarkers remain suboptimal, limiting their widespread clinical application (Duffy and Crown, 2022).

With 53%, US applicants were responsible for more than one in two IPFs related to liquid biopsies between 2017 and 2021 (Figure 37). European applicants, with 12% from EU27 and 7% from other European countries, provided the second largest contribution, followed by Chinese (8%) and Japanese applicants (7%).

Figure 36

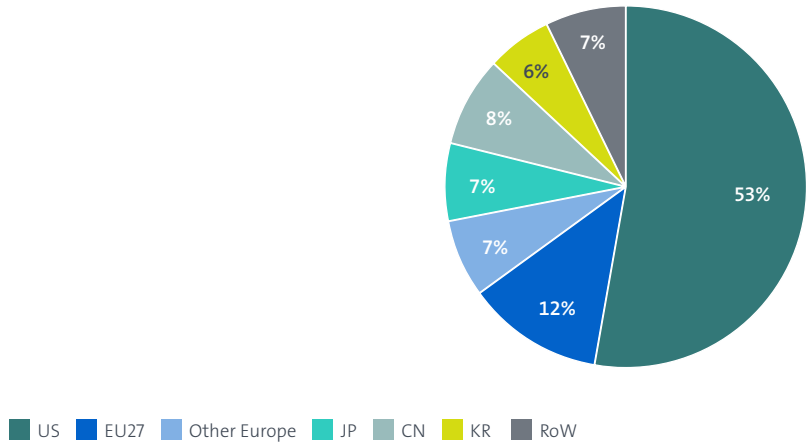
Trends in IPFs in different liquid biopsy technologies, 2002–2021



Source: EPO

Figure 37

IPF shares in liquid biopsy technologies by country of origin, 2017–2021



Source: EPO

Table 1 indicates that the University of California is the primary applicant with respect to liquid biopsies, having submitted 191 IPFs between 2017 and 2021. They also concentrate heavily on ctDNA and CTCs. Among the top five, two companies, Roche and Illumina, concentrate on ctDNA. US institutions, for example the Massachusetts Institute of Technology (MIT) and the Broad Institute, a research organisation affiliated with MIT and Harvard University that unites researchers from various disciplines, largely dominate the field, although the French institute INSERM is also among the top ten applicants with almost 100 IPFs. Liquid biopsy is a developing area, and there remains a lot to be discovered about its potential uses and limitations. The considerable number of universities and research institutes among the leading applicants indicates that technological advances are mainly derived from fundamental research, rather than from commercial product development.

Table 1

Top five applicants in liquid biopsy technologies, 2017–2021

	Circulating cancer DNA	Circulating tumour cells	Circulating proteins	Grand total
University of California (US)	176	33	2	191
MIT (US)	147	9	3	153
Roche (CH)	139	15	6	146
Broad Institute (US)	142	5	2	142
Illumina (US)	120	8		120

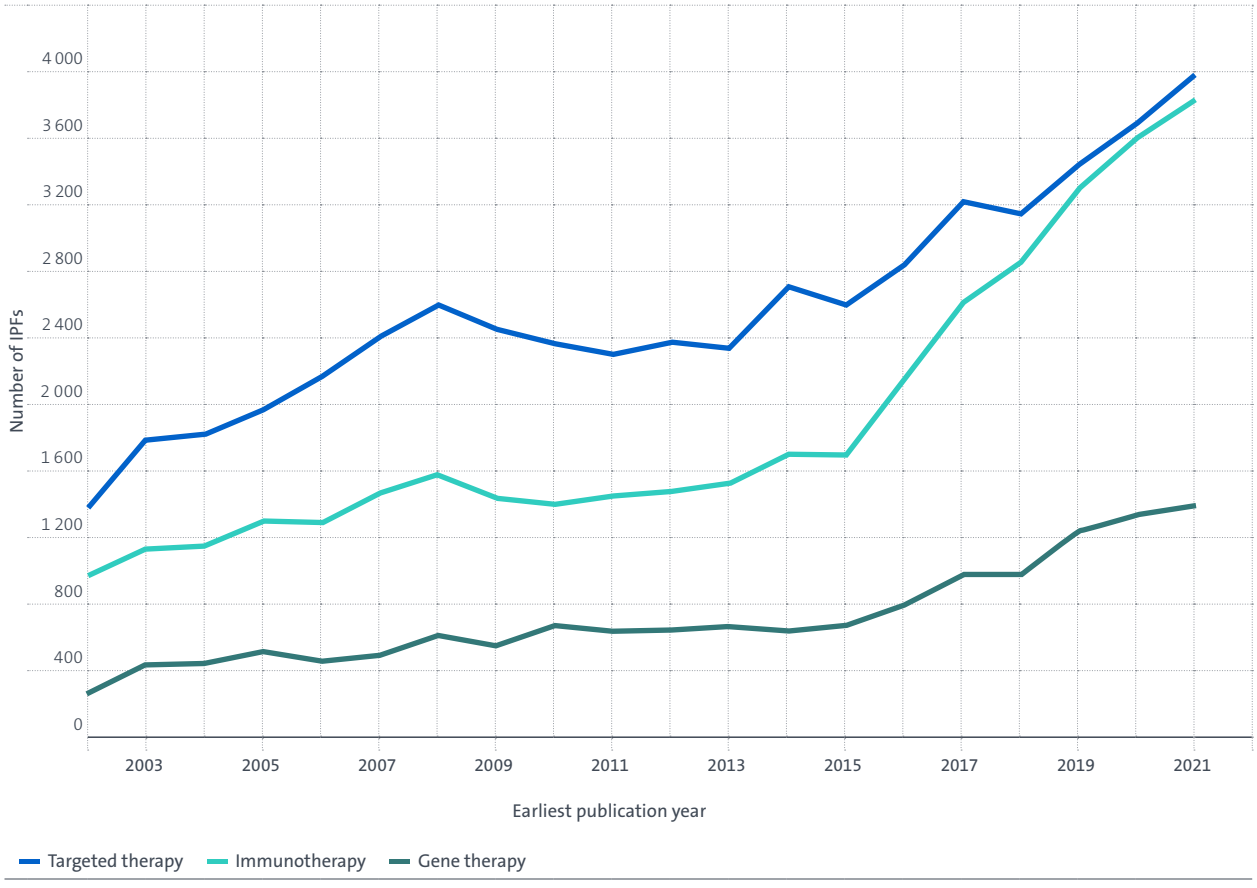
5.2 Novel treatment approaches

Traditional cancer treatments, including surgery, chemotherapy, and radiotherapy, aim to eliminate or damage swiftly dividing cells to either terminate their growth or slow it down. Nevertheless, these methods possess various inherent limitations. First and foremost, they may also damage healthy cells that proliferate quickly, such as those in the intestines, leading to significant side effects. Secondly, the efficacy of these therapies may vary depending on the type of cancer. Not all kinds of cancer respond to all forms of treatment, and the response may rely on the precise features of the cancer. Additionally, cancer cells do not all proliferate concurrently – instead, certain cancer cells can remain inactive or dormant and might not respond to chemotherapy or radiotherapy. These inactive cells could later awaken after treatment, resulting in the disease returning.

Over the last decades, new approaches have been developed that could overcome the limitations of the traditional therapies. They can either be used instead of the existing methods or in combination with them to achieve optimum results for the patients. The primary catalysts of cancer-related innovation growth were immunotherapy, which employs the body's immune system to combat cancer, targeted therapy, which targets particular genes and proteins that aid in the proliferation, division, and metastasis of cancer cells, and additional biological approaches, most notably gene therapy, a treatment strategy that modifies or replaces cellular genetic material to facilitate a cure.

Figure 38

Trends in IPFs in selected developing treatment technologies, 2002–2021



Source: EPO

As depicted in Figure 38, the number of IPFs in targeted therapies, currently the largest field for cancer therapy, rose from slightly over 2 600 in 2015 to nearly 4 000 IPFs. Of the targeted therapies, protein kinase inhibitors (PKIs) constitute the most dynamic and significant category of cancer therapeutic agents. PKIs act by inhibiting the activity of protein kinases, which are enzymes that play a vital function in different cellular processes, such as cell growth and division. Dysregulation of kinases may result in cancer, rendering them beneficial targets for therapy. These inhibitors disturb the signalling pathways that manage tumour cell functions, hindering cancer cell proliferation and metastasis. Several types of kinase inhibitors have been approved for cancer treatment, including tyrosine kinase inhibitors used for various types of tumours.[23]

The most noteworthy development in recent years has been observed in immunotherapy, where the annual number of IPFs has more than doubled between 2015 and 2021, from slightly over 1 700 to over 3 800. On the other hand, cancer vaccines have demonstrated a lack of growth, with only about 150 IPFs in recent years.

Antibodies have demonstrated a substantial increase, with almost 1 800 IPFs in 2021, whereas cellular immunotherapies recorded over 800 IPFs in the same year. Monoclonal antibodies (mAbs), commonly known as antibodies, are laboratory-created immune system proteins utilised in cancer treatment. Similar to the body's own antibodies, monoclonal antibodies have specific target recognition properties, assisting the immune system in identifying and eliminating cancerous cells. Presently, over 160 antibody therapies have been approved worldwide, with 42.6% of them treating cancers (Lyu X. et al., 2022). Cellular immunotherapy, also referred to as adoptive cell therapy, is a cancer treatment that utilises the immune system's cells to eradicate cancer. The therapy entails obtaining the patient's immune cells, modifying them genetically to target cancer cells, and reintroducing them into the patient. Chimeric antigen receptor T-cell (CAR T) therapies, tumour infiltrating lymphocyte (TIL) therapies, and T-cell receptor (TCR) therapies are a few examples of cellular immunotherapies. Although significant advancements have been achieved, particularly with CAR T therapies, current research and clinical trials are focused on developing and optimising these treatments to enhance their effectiveness and expand their range of applicability across various types of cancers.

Genetic therapy is another very quickly growing field, although smaller than the other two (Figure 38). However, the number of IPFs has increased from less than 700 in 2015 to almost 1 400 IPFs in 2021. Genetic therapies are medical approaches that treat genetic disorders and can be broadly classified into gene transfer (or gene addition) and genome editing. Gene transfer aims to restore the function of a faulty or missing gene by providing the affected cell with a new gene. The new gene may be a normal version of the faulty gene or a different gene that bypasses the issue and enhances the cell's function. Genome editing offers greater precision by enabling targeted modifications to the cell's DNA to correct errors and restore functionality. Currently, only a limited number of genetic therapies for specific types of cancer have been approved, but numerous others are in the developmental stage.

According to Table 2, gene therapy has the greatest proportion of IPFs among applicants from universities, hospitals or PROs, at nearly 50%. This is evident from the list of top candidates, which includes three American universities, as well as the Broad Institute. The French research institute INSERM ranks third, with over 100 IPFs between 2017 and 2021. This dominance of US institutions is also reflected in the share of US applicants in all IPFs related to gene therapy, which was 55% between 2017 and 2021.

In targeted therapy and immunotherapy, roughly one-third of IPFs originate from universities, hospitals and PROs, a significantly lower proportion compared to gene therapy. Multiple companies feature among the leading applicants in both fields. Roche holds top position in both immunotherapy and targeted therapy, with Novartis ranking third in targeted therapy. Bristol-Myers Squibb ranks as the second top applicant in immunotherapy, while Johnson & Johnson comes in fifth. The University of California and INSERM rank highly among the leading contenders in both treatment technologies. The overall contribution of European applicants is least in gene therapy, with a combined share of 17% during 2017–2022, whilst achieving the highest share in immunotherapy, at 22%. Chinese applicants are strongest in targeted therapies, with a 15% share.

23 LiverTox: Clinical and Research Information on Drug-Induced Liver Injury [Internet]. Bethesda (MD): National Institute of Diabetes and Digestive and Kidney Diseases; 2012-. Protein Kinase Inhibitors. [Updated 2023 Nov 20]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK548591/

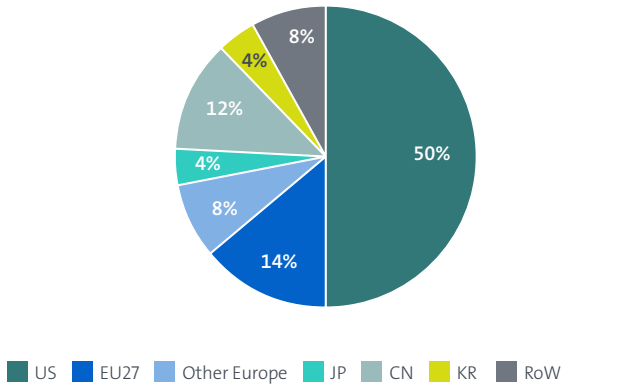
Table 2

Top applicants and geographical distribution in selected developing treatment technologies, 2017–2021

Immunotherapy – top applicants

Roche (CH)	382
Bristol-Myers Squibb (US)	293
University of California (US)	227
INSERM (FR)	212
Johnson&Johnson (US)	202

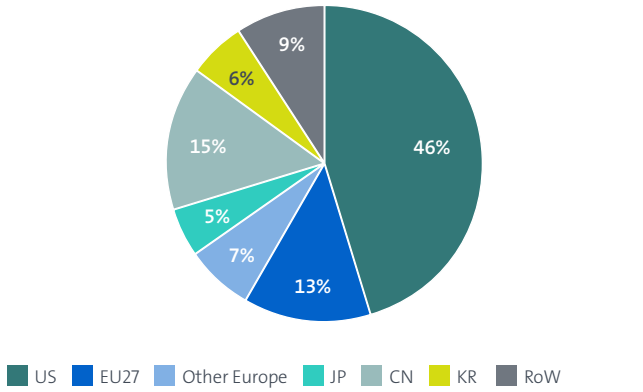
Immunotherapy - by origin



Targeted therapy – top applicants

Roche (CH)	266
University of California (US)	258
Novartis (CH)	229
Dana-Farber Cancer Institute (US)	219
INSERM (FR)	211

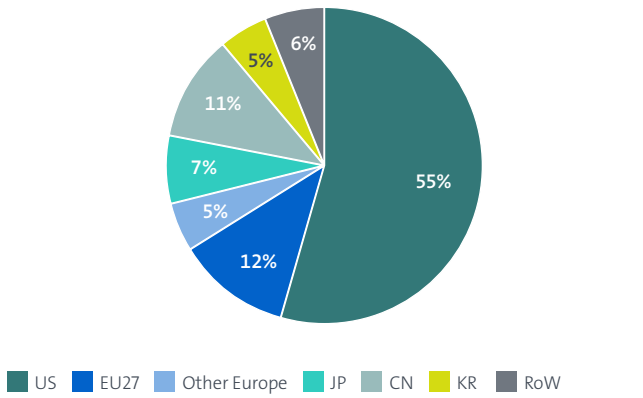
Targeted therapy – by origin



Gene therapy – top applicants

University of California (US)	179
MIT (US)	123
INSERM (FR)	110
Broad Institute (US)	106
Harvard University (US)	103

Gene therapy – by origin



Source: EPO

Case study: OncoQR

Company:	OncoQR ML GmbH
Headquarters:	Vienna, Austria
Founded:	2013
No. of employees:	1-10
Products:	Novel therapeutic cancer vaccines based on a technology platform

"The robust patent portfolio allowed us to attract funding and create opportunities for collaboration."
Geert C. Mudde, co-founder OncoQR and S-TARget therapeutics

OncoQR is a biotechnology startup that develops therapeutic cancer vaccines. Based in Vienna, the company's proprietary platform enables the production of targeted vaccines that control the immune system's response to cancer. OncoQR is one of two startups founded to develop and commercialise the platform. With a robust patent portfolio and a clear IP strategy, the founders were able to generate revenue early on. This would become vital in view of the lengthy timeframes required for biotechnology products to reach the market.

Leveraging the power of the immune system

Cancers circumvent the immune system's defences, making them difficult diseases to treat. Radiation and chemotherapy can be effective, but not all types of cancer respond, and healthy cells may even be damaged. While immunotherapies offer targeted treatments capable of eliciting, amplifying or suppressing the immune reaction, they produce harsh side effects in some patients.

Geert Mudde had focussed his cancer research on developing vaccines to overcome the drawbacks in immunotherapeutic approaches. His team had a breakthrough in 2009 when they developed Active Checkpoint Control Immunotherapy (ACCI), which aims to selectively and specifically trigger tumour-killing mechanisms naturally available in the immune system. This led to the development of the Specific Total Immune Remodulation (S-TIR) platform, a new basis for cancer vaccines and the treatment of allergies.

A targeted approach

Mudde founded F-star Therapeutics to advance his work on S-TIR, filing for a patent in 2006. When he left F-star Therapeutics, Mudde negotiated an exit deal in which he retained rights to the patent and secured a commitment from F-star to contribute financially if he started a new biotech venture.

He met bioengineer and entrepreneur Christof Langer and together they founded S-TARget therapeutics in 2010 to bring the S-TIR technology to the market. In 2013, they tested an anti-allergy vaccine to treat a type of asthma in captive-bred monkeys. The results were promising: the vast majority of monkeys were cured of a disease they had carried throughout their lives. This success inspired Mudde and Langer to begin testing their oncology vaccine. Again, their treatment induced amounts of antibodies against the cancer antigen that far exceeded expectations.

Realising their platform worked in two fields – allergy treatments and oncology – Mudde and Langer split their business interests, aiming to build two separate companies. They founded OncoQR in 2013 and the new spin-off was granted a worldwide exclusive licence to the S-TIR platform for use in oncology.

The platform advantage

For biotech startups, having a base technology reduces costs associated with product development and IP because protecting one platform is cheaper than patenting multiple elements of various products. The approach also enables a fast scale-up following regulatory approval.

For both S-TARget and OncoQR, patents have been vital to growth. Three basic patents protect the platform, with additional patents to cover various oncology products. Their IP cover helped S-TARget attract private investment and obtain pre-seed grants early on. In the years that followed, both companies received investment from national funding programmes and generated revenues from out-licensing. Today, the co-founders employ a three-pronged strategy: a collaborative model that involves partially licensing S-TIR, advancing their in-house R&D via OncoQR, and an out-licensing deal with an undisclosed company.

In addition to a robust patent portfolio, OncoQR retains trade secrets that cover certain production-related aspects. These are not covered by claims in the patents and are protected by non-disclosure agreements with relevant personnel. This lowers patenting costs because the company protects only the most important elements of the technology. As a result, potential infringers do not possess sufficient information to manufacture OncoQR's products efficiently.

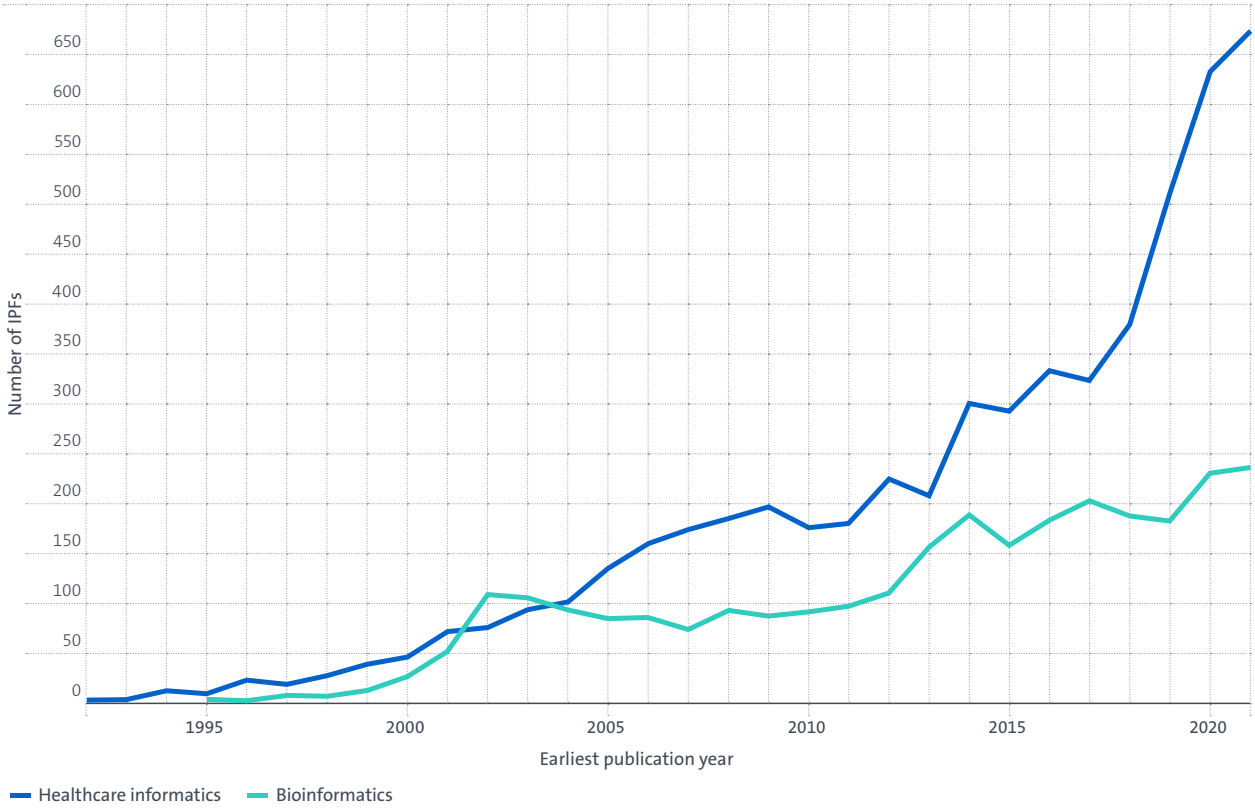
5.3 The role of ICT and AI

Bioinformatics is an interdisciplinary field that blends biology, computer science, information engineering, mathematics, and statistics to analyse and interpret substantial biological data sets. In the context of cancer diagnostics, bioinformatics plays a key role in identifying and authenticating biomarkers that are specific to clinical phenotypes related to early diagnoses. This facilitates monitoring of the patient's progress and response to therapy, and predicting enhancements in quality of life. Bioinformatics tools analyse large-scale gene expression data, significantly improving early cancer detection technology. Bioinformatics is also a crucial instrument in personalised medicine, supplying extensive knowledge about an individual's biology and facilitating the creation of tailored treatments for each patient. It plays an essential role in identifying targets for drug development and diagnostic classification of the pathways leading to the growth of each patient's tumour in cancer treatment technologies. The use of bioinformatics is pivotal in effectively exploiting genomic technologies for drug development while targeting the right patients.

In around 2000, there was an initial surge in patenting related to cancer bioinformatics, with the number of IPFs rising from almost zero to over 100 IPFs in a few years (see Figure 39). This growth appeared to coincide with progress in cancer models, as advances in bioinformatics facilitated the development of more sophisticated, human-like animal models. Following a period of decline and stagnation, akin to that observed in cancer models, the number of annual IPFs in bioinformatics once again started to increase, growing steadily over the course of the 2010s. As shown in Table 3, a total of 60% of all IPFs in cancer-related bioinformatics during the five-year period 2017–2021 were attributable solely to US applicants. European applicants, with a collective share of 18%, were ranked second. Hence, it is unsurprising that three American firms rank among the top five applicants, with Illumina emerging as the undisputed leader, and two European companies, Philips and Roche, also in the top five.

Figure 39

Trends in IPFs in bioinformatics and healthcare informatics, 1992–2021



Source: EPO

Table 3

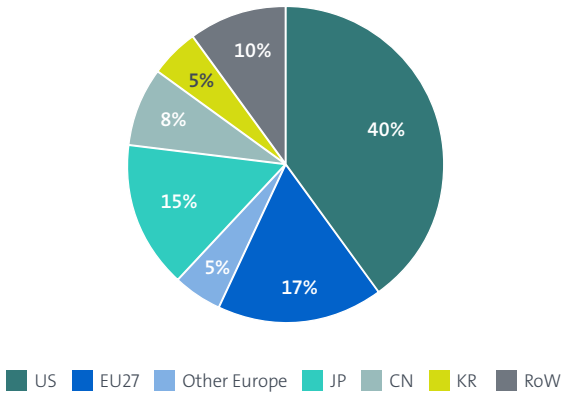
Top applicants and geographical distribution in bioinformatics and healthcare informatics, 2017–2021

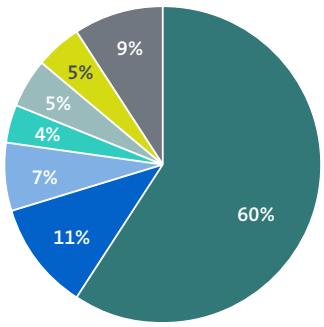
Healthcare informatics

Philips (NL)	128
Siemens (DE)	95
Fujifilm (JP)	87
Canon (JP)	61
Roche (CH)	50

Bioinformatics

Illumina (US)	76
Philips (NL)	27
NantWorks (US)	25
Guardant Health (US)	22
Roche (CH)	17





US EU27 Other Europe JP CN KR RoW

Source: EPO

Healthcare informatics is a multidisciplinary field that integrates medicine with computing fields such as computer engineering, software engineering, information engineering, data science, and information technology to enhance healthcare. The use of healthcare informatics in oncology has grown quickly since the 1990s and continued throughout the 2000s, ultimately reaching over 200 IPFs per year by 2012. In the context of biopsies, healthcare informatics can optimise the process of collecting, processing and analysing biopsy data, leading to meticulous and timely diagnoses. In radiotherapy, contemporary informatics platforms have contributed to considerable advancements in radiation treatment planning. Furthermore, healthcare informatics plays a vital role in robotic cancer surgery, augmenting the efficacy, accuracy, and efficiency of the procedures.

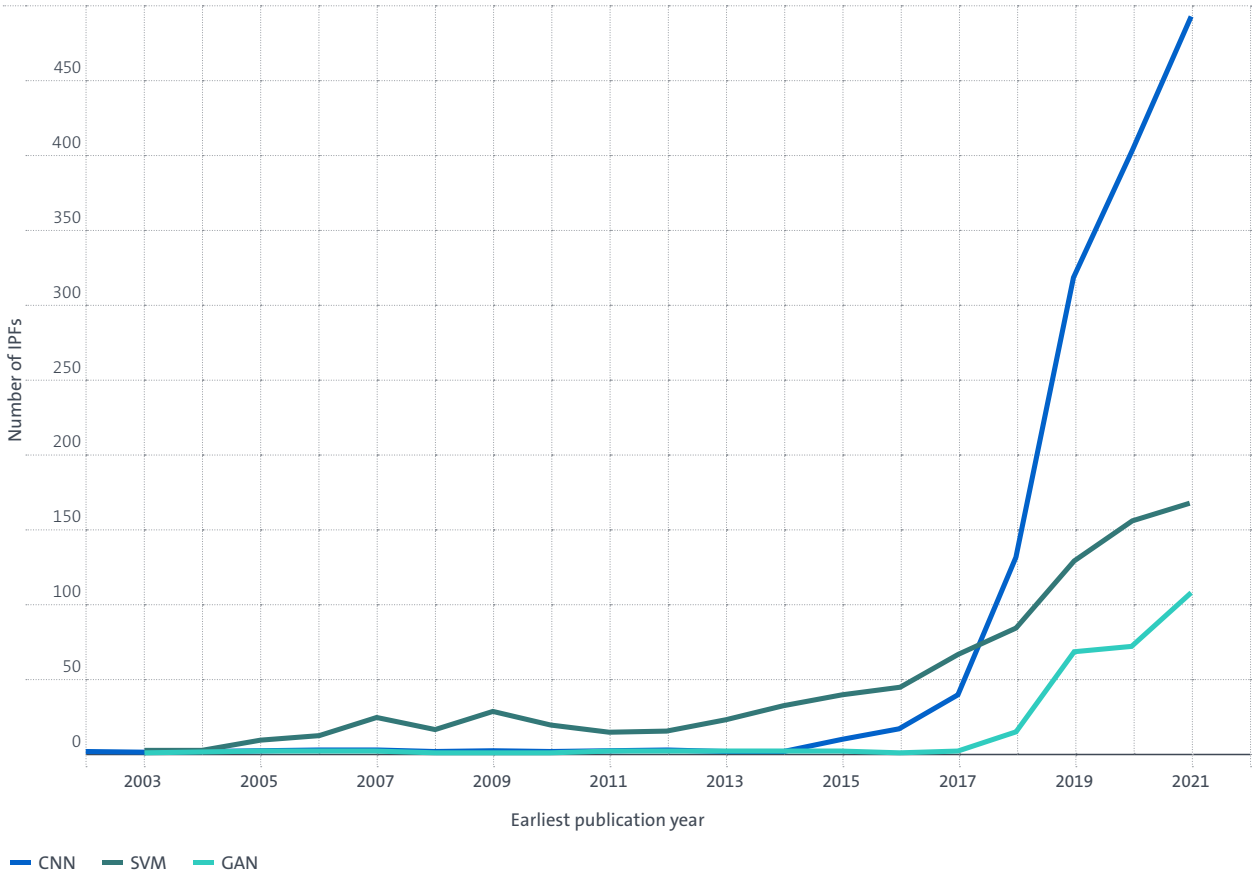
Since the mid-2010s, patenting activity in healthcare informatics has accelerated even more, with over three times as many IPFs being published in 2020 as in 2013. Interestingly, European and Japanese applicants, who hold a combined share of 37%, serve as a counterbalance to the US applicants (40%) in this technology domain.

The top five applicants consist of two Japanese and three European companies, with Philips being the dominant player.

Most of the recent advancements have focused on utilising advanced image processing techniques and machine learning (ML) algorithms to enhance the precision and efficiency of detecting and diagnosing cancer. The three prominent ML techniques that have been used are convolutional neural networks (CNNs), generative adversarial networks (GANs), and support vector machines (SVMs), each with its distinct applications and features. As apparent form Figure 40, until 2017, SVM dominated cancer image analysis, but in recent years, CNN, a type of deep learning algorithm that has proven effective for image recognition and processing, has gained momentum. GAN is the least prevalent of the three techniques, with approximately 100 IPFs in 2021, and it is frequently used alongside CNN when managing image data. US applicants account for 30% of all IPFs related to AI techniques for advanced cancer image processing. Chinese, European, and Japanese applicants trail closely behind, each having an 18 - 19% share (Figure 39).

Figure 40

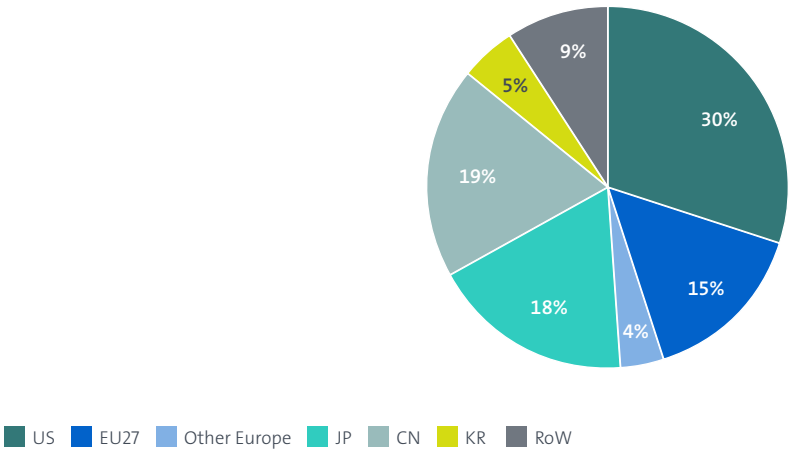
Trend in IPFs in AI for cancer image analysis, 2002–2021



Source: EPO

Figure 41

Shares in IPFs in AI for cancer image analysis by country of origin, 2017–2021



Source: EPO

References

Albrecht B., Alfane S., Keano H., Yang G. "Delivering innovation: 2020 oncology market outlook", 2020, McKinsey & Company: https://www.mckinsey.com/industries/life-sciences/our-insights/delivering-innovation-2020-oncology-market-utlook#/.

Analysis Group, 2021, "Innovation in the Biopharmaceutical Pipeline", Technical report, PhRMA: https://phrma.org/-/media/Project/PhRMA/PhRMA-Org/PhRMA-Org/PDF/G-I/Innovation_in_Biopharmaceuticals.pdf

American Cancer Society, "Cancer Facts and Figures, 2023": https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/annual-cancer-facts-and-figures/2023/2023-cancer-facts-and-figures.pdf.

American Cancer Society, "Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries", 2021: https://acsjournals.onlinelibrary.wiley.com/doi/full/10.3322/caac.21660.

Dalmartello M., La Vecchia C., Bertuccio P., Boffetta P., Levi F., Negri E., Malvezzi M., "European cancer mortality predictions for the year 2022 with focus on ovarian cancer", 2022, Annals of Oncology, 33, 3: https://www.sciencedirect.com/science/article/pii/S092375342104881X?via%3Dihub.

Cancer Tomorrow, IARC, "Estimated number of new cases from 2020 to 2040, Males and Females, age [0-85+]", 2020: https://gco.iarc.fr/tomorrow/en/d ataviz/trends?types=0&sexes=1_2&mode=population&group_populations=1&multiple_populations=1&multiple_cancers=0&cancers=39&populations=903_904_905_908_909_935

de Castro Figueiredo Bordon, K., et al., "From Animal Poisons and Venoms to Medicines: Achievements, Challenges and Perspectives in Drug Discovery", 2020, Frontiers in Pharmacology, Sec. Translational Pharmacology Volume 11 – 2020: https://www.frontiersin.org/articles/10.3389/fphar.2020.01132/full.

Dyba T., et al. "The European cancer burden in 2020: Incidence and mortality estimates for 40 countries and 25 major cancers", 2021, European Journal of Cancer, 157, 308-347: https://www.sciencedirect.com/science/article/pii/S0959804921004974?via%3Dihub.

EPO, "mRNA technologies", Insight report, 2023: epo.org/insight-mrna-technologies.

European Commission, "Europe's Beating Cancer Plan", 2022: https://health.ec.europa.eu/system/files/2022-02/eu_cancer-plan_en_0.pdf.

Duffy M., Crown J., "Circulating Tumor DNA as a Biomarker for Monitoring Patients with Solid Cancers: Comparison with Standard Protein Biomarkers", 2022, Clinical Chemistry, 68, 11, 1381–1390: https://doi.org/10.1093/clinchem/hvac121.

Farina E, Nabhen JJ, Dacoregio MI, Batalini F, Moraes FY, "An overview of artificial intelligence in oncology", Future Sci OA. 2022 Feb 10;8(4): https://www.future-science.com/doi/10.2144/fsoa-2021-0074.

Fred Hutch Cancer Center, "Cellular Immunotherapy": https://www.fredhutch.org/en/patient-care/treatments/immunotherapy/cellular-immunotherapy.html.

The Global Health Observatory, "Global health estimates: Leading causes of death", Geneva, WHO, 2020: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death.

Greenwell M., Rahman P.K.S.M., "Medicinal Plants: Their Use in Anticancer Treatment", Int J Pharm Sci Res. 2015; 6(10): 4103–4112. doi:10.13040/IJPSR.0975-8232.6(10).4103-12: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4650206/.

Huang C., et al., "Bioinformatics Analysis for Circulating Cell-Free DNA in Cancer", 2019, Cancers (Basel), 11(6): 805: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6627444/.

IQVIA Institute, "Global Oncology Trends 2023 Outlook to 2027", May 2023.

IQVIA Institute, "Global Trends in R&D 2023, Activity, Productivity, and enablers", February 2023.

Kwon, N.-Y.; Sung, S.-H.; Sung, H.-K.; Park, J.-K., "Anticancer Activity of Bee Venom Components against Breast Cancer", 2022, Toxins 2022, 14, 460: https://doi.org/10.3390/toxins14070460.

Le P., Romano G., Nana-Sinkam P., Acunzo M. "Non-Coding RNAs in Cancer Diagnosis and Therapy: Focus on Lung Cancer". Cancers 2021, 13, 1372: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8003033/pdf/cancers-13-01372.pdf.

LiverTox: Clinical and Research Information on Drug-Induced Liver Injury [Internet]. Bethesda (MD): National Institute of Diabetes and Digestive and Kidney Diseases; 2012-. Protein Kinase Inhibitors. [Updated 2023 Nov 20]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK548591/

Lyu X., Zhao Q.,, Hui J., Wang T., Lin M., Wang K., Zhang J., Shentu J., Dalby PA., Zhang H., Liu B., "The global landscape of approved antibody therapies", 2022, Antib Ther. 2022 Sep 6;5(4):233-257.

McIntosh, S., et al., "Global funding for cancer research between 2016 and 2020: a content analysis of public and philanthropic investments", Lancet Oncol 2023; 24: 636–45: https://www.thelancet.com/action/showPdf?pii=S1470-2045%2823%2900182-1.

Nevala-Plagemann C., Hidalgo M., Garrido-Laguna I., "From state-of-the-art treatments to novel therapies for advanced-stage pancreatic cancer", 2020, Nat Rev Clin Oncol 17, 108–123. https://doi.org/10.1038/s41571-019-0281-6.

Noor J., Chaudhry A., Noor R. et al., "Advancements and Applications of Liquid Biopsies in Oncology: A Narrative Review", 2023, Cureus 15(7): e42731. doi:10.7759/cureus.42731.

Precedence Research, 2023: https://www.precedenceresearch.com/oncology-market.

Schuhmacher A., et al., "Investigating the origins of recent pharmaceutical innovation", 2023, Nature Reviews Drug Discovery: https://www.nature.com/articles/d41573-023-00102-z.

Shegekar T., Vodithala S., Juganavar A., "The Emerging Role of Liquid Biopsies in Revolutionising Cancer Diagnosis and Therapy", 2023, Cureus 15(8).

Sindhu K., Adashi E., "The reignition of the Cancer Moonshot: An opportunity missed?", 2023, Cancer; 129 (23): https://acsjournals.onlinelibrary.wiley.com/doi/10.1002/cncr.35014.

Sgouros, G., Bodei L., McDevitt M.R. et al. "Radiopharmaceutical therapy in cancer: clinical advances and challenges", 2020, Nat Rev Drug Discov 19, 589–608: https://doi.org/10.1038/s41573-020-0073-9.

Sung H., et al., "Global health estimates: Leading causes of death", Geneva, WHO, 2020: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death.

Tan CR., Zhou L., El-Deiry WS., "Circulating Tumor Cells Versus Circulating Tumor DNA in Colorectal Cancer: Pros and Cons", 2016, Curr Colorectal Cancer Rep. 12(3):151-161: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4976692/

Xia, Changfa; Dong, Xuesi; Li, He; Cao, Maomao; Sun, Dianqin; He, Siyi; Yang, Fan; Yan, Xinxin; Zhang, Shaoli; Li, Ni; Chen, Wanqing "Cancer statistics in China and United States, 2022: profiles, trends, and determinants", 2022, Chinese Medical Journal 135(5); 584-590.

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