

Personalised medicine

The right treatment for the right person at the right time

SUMMARY

'Personalised medicine' refers to a medical approach that uses molecular insights into health and disease to guide decisions with regard to the prediction, prevention, diagnosis and treatment of illnesses. Genetic factors play a role in most human diseases, with gene variations contributing to their incidence or course.

New tools harnessed by personalised medicine include '-omics' technologies, which seek to define and explain the molecular mechanisms of the human body, and biomarkers, allowing us to subdivide patients into groups according to their likely response to a specific treatment, and so decide on the best-suited medication.

Integrating advances in molecular technology into clinical practice comes with challenges, namely the translational gap, data protection, regulatory clarity and cost. Moreover, it is considered essential to educate patients (to acquire health literacy) as well as healthcare professionals (both in terms of providing them with undergraduate education and with continuous opportunities to advance their skills).

EU initiatives in the field of personalised medicine include the Innovative Medicines Initiative (IMI), financial support to major research projects, and participation in international consortia. The Luxembourg Council Presidency has made personalised medicine one of its health priorities.



In this briefing:

- What is personalised medicine?
- Applying molecular understanding
- New tools for detection, diagnosis and treatment
- Educating patients and healthcare professionals
- EU projects and initiatives
- Main references

Glossary¹

DNA: deoxyribonucleic acid, a complex molecule constructed of a double helix of nucleotides held together by hydrogen bonds between their nitrogenous bases. It is the chemical code of instructions that direct the building and actions of cells (genetic information).

Genome: the entire genetic material of an individual.

Genome-wide association study (GWAS): a method to rapidly identify genes associated with complex common diseases such as diabetes and cancer, or traits such as height and obesity. It involves searching the genomes of a large number of people for small genetic variations (SNPs) that occur more frequently in individuals with the disease or trait of interest.

Germ cells: precursors to reproductive cells (eggs and sperm).

Mutation: a rare, random change in the genetic material that can be inherited.

Nucleotide: the basic element of DNA strands, each nucleotide is formed by one or more phosphate groups, a five-carbon sugar (deoxyribose) and a nitrogenous base (adenine, guanine, thymine or cytosine).

Research platform: a research network focused on a well-defined theme.

Sequencing: analytical methodology aimed at determining the precise order of the nucleotides in a strand of DNA.

Single-nucleotide polymorphism (SNP): the most frequent known genetic variation among humans. Each SNP represents a difference in a single nucleotide of the same segment of DNA. SNPs normally occur throughout a person's DNA, and most SNPs have no effect on health.

'-omics': technologies aimed at exploring the roles, relationships and actions of the various types of molecules that make up the cells of an organism.

Somatic cells: any cells of the body that are not reproductive cells.

What is personalised medicine?

'Personalised medicine' is a multi-faceted term without a clear-cut definition. It refers to an emerging approach to medicine that uses scientific insights into the genetic and molecular basis of health and disease brought on by the sequencing of the human genome,² to guide decisions in regard to the prediction, prevention, diagnosis and treatment of disease. The [aim](#) of personalised medicine is generally perceived to be the 'right treatment for the right person at the right time'.

Applying molecular understanding

With a better understanding of the molecular basis of diseases and of how environmental factors interact with a person's genetic make-up, it will become easier to characterise illnesses and select better-adapted treatments.

Personalised medicine is considered to be an evolution away from the 'one-size-fits-all' medical model. It implies a shift from the current organ-, system- or disease-oriented understanding of disease to a molecular concept: for instance, some diseases that have so far been seen as one disease have been shown in fact to be [several diseases](#), with different pathologic mechanisms requiring different treatment. Conversely, other diseases that are considered different today have been shown to share common aetiological factors at molecular level.

Personalised medicine can provide [healthcare professionals](#) with an additional basis to categorise some diseases and enable them to:

- determine if a person has a higher risk of developing a disease and consequently apply suitable prevention strategies;
- diagnose a disease earlier after onset, thereby allowing more effective treatment options;
- enhance therapeutic efficacy by ensuring that the most appropriate medicine is used and that the dosage regimen takes into account any genetic variations, which may influence how the medicine is metabolised; and to
- avoid 'trial and error' and reduce the probability of medicine-related side effects and complications by matching the treatment to a patient's genomic profile.

Background

Genetic variations, single-gene and complex common diseases

Humans vary in their inherited DNA sequences in a number of ways. It is now believed that genetic factors play a role in most human diseases, with gene variations contributing to their incidence or course. Variations can be broadly [categorised](#) as (i) single-gene and (ii) complex.

(i) Variations of a single gene may lead to rare diseases with predictable inheritance such as cystic fibrosis and [Marfan syndrome](#). The identification of the specific DNA variations linked to them has now opened up [possibilities](#) for new [treatments](#).

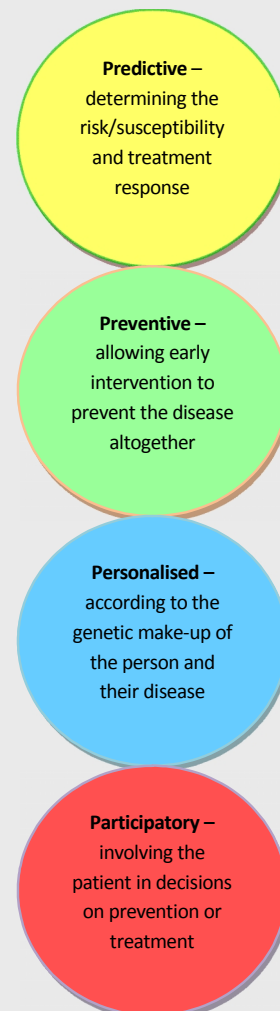
(ii) Variations involving multiple genes interacting with each other and with environmental factors (e.g. smoking, poor diet, lack of exercise) have been associated with '[complex common diseases](#)'. These include a wide variety of conditions such as stroke, high blood pressure, high cholesterol level, heart disease, cancer, diabetes and Parkinson's disease.

Genetic/genomic testing

The genetic information required for targeting a treatment in personalised medicine is obtained through genetic testing. The testing can be differentiated into somatic (for mutations acquired in the DNA of somatic cells after conception; these are not heritable) and germ-line (for mutations in the DNA of the germ cells, which are heritable). So far, genetic testing has focused on one or a few genes, rather than on sequencing the entire genome (roughly 3 billion DNA base pairs). However, with sequencing technology becoming much more efficient, its speed has increased dramatically, facilitating the analysis of full chromosomes or entire genomes. Consequently, the cost for a whole human genome sequence has dropped enormously (initially it was US\$[2.7 billion](#)) and is expected to reach the US\$[1 000](#) benchmark in the near future.

The '4 Ps'

Personalised medicine is sometimes conceptualised as a '4 P' model:



Source: adapted from [Future of Cancer Care](#), BCRF.

New tools for detection, diagnosis and treatment of disease

'-omics' technologies

-omics technologies seek to define and explain the molecular mechanisms of the human body. Examples include genomics (the study of genes and their function), glycomics (the study of cellular carbohydrates), lipidomics (the study of cellular lipids), metabolomics (the study of molecules involved in cellular metabolism), pharmacogenomics (the study of how genetic variations influence an individual's response to medicines) and proteomics (the study of proteins). -omics platforms are capable of analysing the functions of different classes of molecules in a high-throughput manner. These analyses can provide information on the molecular and cellular processes that have an impact on disease. So far, these technologies have mostly been used as research tools. Translating -omics into clinical applications is thought to play a crucial role not only in diagnosis and treatment, but also in prevention of illness, and enable a better understanding of human health and disease in general.

Biomarkers

Biomarkers, i.e. measurable indicators of healthy and pathological processes in the body, can belong to different types of biochemical molecules such as proteins, DNA, RNA or lipids; novel genetic biomarkers are continually being discovered. They may be used to [identify](#) and diagnose a disease as early as possible (diagnostic biomarkers), detect a person's [risk](#) of developing a disease (risk biomarkers), make out the evolution or [progression](#) of a disease, i.e. if it is indolent or aggressive (prognostic biomarkers), and assess the [response](#) to and toxicity of a treatment (predictive biomarkers). In developing medicines, sub-dividing ('stratifying') patients into groups according to their biomarker profile allows decisions on which medicines are best suited for a particular patient group. Single-nucleotide polymorphisms (SNPs) can act as biomarkers to help locate genes that confer an increased or decreased susceptibility to complex common diseases. To identify SNPs, researchers conduct genome-wide association studies. The large sets of information gained from such studies are entered into dedicated repositories – 'biobanks' – and made available to researchers worldwide.

BRCA1 celebrity case report

In 2013, US actress Angelina Jolie underwent [preventive](#) double mastectomy, and two years later, had her ovaries and fallopian tubes prophylactically [removed](#) as well. A test had revealed that she had inherited a 'faulty' gene, BRCA1, that strongly increased her risk of developing breast and ovarian cancer. Harmful mutations in the BRCA genes cause cancer down generations, and research has shown that a female BRCA1 carrier has a 60–90 % chance of developing breast cancer and a 40–60 % chance of ovarian cancer. Surgery – although not the only option – may significantly reduce the cancer risk such women face.

Biobanking

A [biobank](#) collects and stores biological material and associated medical and epidemiological information from a large number of people (donors). It organises samples and data in a systematic way so they can be used for the purpose of medical-scientific research and diagnosis. Biobanks typically apply some sort of anonymisation to assure the privacy of donors, and include governance structures (e.g. ethics committees) and procedures (e.g. consent) to protect participants' rights and interests.

Challenges in implementation of personalised medicine

- **Translational gap:** observers point out that progress in translating molecular-biology breakthroughs into clinical practice ('from bench to bedside') is [slow](#). It is considered essential to encourage healthcare professionals in primary care to embrace new

tools, and to foster partnerships between specialists of various disciplines in cross-cutting collaborations.

- **Data protection, confidentiality and right to information:** both the identification of biomarkers and next-generation sequencing rely heavily on the collection and analysis of very large sets of data ('big data'). This points to the requirement to ensure the confidentiality of sensitive personal information, for instance in the cross-border transfer of data in large research projects, but also in the context of biobanks: although donors are generally anonymised, many biobanks have provisions that participants remain identifiable for research purposes. As donated samples may be used for further research, questions arise as regards ownership of these samples, the issues of informed consent and the right to information, including the right not to know.³
- **Regulatory clarity:** stakeholders have stressed the [need](#) for a clear regulatory framework for personalised medicine – to ensure it respects the principle of universal and equal access to healthcare, to avoid discrimination of patients on the basis of genetic data (e.g. by insurance companies or employers), and to regulate genetic/genomic information for commercial purposes.
- **Cost:** molecularly targeted treatments tend to be [expensive](#) since, by definition, they are suitable for only a limited number of patients. From the perspective of payers (public health systems, private insurers), this may raise the question of affordability in a context of strained public health budgets, and of the degree to which these costs could be compensated by efficiency gains.

Educating patients and healthcare professionals

Patients

Personalised medicine starts with, and is centred on, the patient and their involvement. It is, however, a [complex](#) discipline, and if patients are to make informed decisions about health-related issues, it will be vital for them to have the necessary knowledge. In other words, they need to be 'empowered' to become participants in their own healthcare. Health literacy – the ability to access, understand, appraise and apply health information to make sound health decisions – can be a [catalyst](#) for patient empowerment. The [EU Health Strategy](#) expressly recognises the importance of health literacy. While a new [report](#) by the European Commission on the topic finds that health literacy has received growing attention in most of the EU Member States in recent years, a workshop organised by the European Parliament's Scientific Foresight Unit (STOA) in July 2015 highlighted that health literacy levels across the EU are still rather low, and that there are persistent inequalities across Member States.

Healthcare professionals

Appropriate education of healthcare professionals is considered key to the integration of personalised medicine into mainstream clinical care. A prerequisite is that healthcare professionals across disciplines (general practitioners, obstetricians, nurses, pharmacists, etc.) understand the role of -omics technologies and know how to use them in their day-to-day practice: they will need to be aware of the latest relevant diagnostic, prognostic and predictive tests, and how to interpret the data and use it as guidance for clinical decisions. Healthcare professionals may also have to develop communication skills – for new ways of engaging with patients (over genetic risk, personalised prevention, treatment and options, etc.) so as to allow for informed choice

and shared decision-making. Likewise, they may need to learn how to interact with the different professionals involved in the treatment of an illness (i.e. the treatment team). Such upskilling would ideally start with undergraduate medical or health education, and also be part of continuing education and training for the existing healthcare workforce.

EU projects and initiatives

Innovative Medicines Initiative (IMI)

Partnership between academia and industry is deemed essential to sustain the 'paradigm shift' in the era of personalised medicine. An example of this is the [Innovative Medicines Initiative \(IMI\)](#).

The IMI is one of five Joint Technology Initiatives (JTI), public-private partnerships (PPP), set up under the EU's Seventh Framework Programme for research and technological innovation (FP7). It was launched in 2008 as a PPP between the EU (represented by the European Commission) and the European pharmaceutical industry (represented by EFPIA, the European Federation of Pharmaceutical Industries and Associations). Its aim is to support collaborative projects between key healthcare players – universities, the pharmaceutical industry, small and medium-sized enterprises (SMEs), patient organisations and medicines regulators. The industrial participants do not receive any EU funding, but contribute to the projects 'in kind' (e.g. by donating researchers' time or providing access to research facilities).

The initiative's second phase, IMI 2, started in 2014 and will run for ten years. Its [goal](#) is to develop next-generation vaccines, medicines and treatment, in particular new and approved diagnostic markers for immunological, respiratory, neurological and neurodegenerative diseases. The total budget for IMI 2 is €3 276 billion. The EU will contribute up to €1 638 billion of this from [Horizon 2020](#), the European framework programme for research and innovation, which began in 2014. EFPIA will commit €1 425 billion in kind. Up to €213 million can be committed by other life-science industries or organisations as members or associated partners of individual projects. Ongoing IMI projects in the area of personalised medicine, and more specifically biomarkers, include [IMIDIA](#), [Onco Track](#), [PRECISEADS](#) and [U-BIOPRED](#).

Some universities and smaller research institutes have [criticised](#) the rules applying to IMI projects, notably the difficulty of obtaining sufficient funding, the question of how the results of a project will be dealt with, and the fact that the pharmaceutical industry still has a dominant position in setting the research agenda. Furthermore, Beatriz Becerra Basterrechea, MEP (ALDE, Spain) enquired in a written question ([E-009616/2015](#)) how the Commission was planning to improve its mechanisms for auditing companies' in-kind contributions to this partnership.

Research projects and collaborative initiatives

Through FP7, the EU has provided over €1 billion for research related to personalised medicine⁴ and covering topics such as large-scale gathering of data on proteins and the development of technology for stratifying patient groups. Funding has also been provided for specific disease areas (cardiovascular diseases, central nervous system diseases and rare diseases as well as cancer). Examples of ongoing projects include:

- [NEUROMICS](#) (Integrated European –omics research project for diagnosis and therapy in rare neuromuscular (NM) and neurodegenerative (ND) diseases) to develop treatment for ten major ND and NM diseases, with an EU contribution of €12 million;
- [NGS-PTL](#) (Next-generation sequencing platform for targeted personalised therapy of

leukaemia) to identify novel prognostic biomarkers for acute and chronic leukaemia, with an EU contribution of €5.87 million;

- [RISKYCAD](#) (Personalised diagnostics and treatment of high-risk coronary artery disease patients) to identify novel biomarkers for asymptomatic patients at high risk of major coronary events, and to develop new diagnostic tools and personalised therapeutic strategies for this selected patient group, with an EU contribution of €5.99 million.

Other projects recently launched under Horizon 2020 include:

- [FORECEE](#) (Female cancer prediction using cervical -omics to individualise screening and prevention) to understand a woman's risk of developing a female-specific cancer, and to direct a personalised screening and prevention strategy, with an EU contribution of €7.99 million.
- [PoC-ID](#) (Platform for ultra-sensitive point-of-care diagnostics for infectious diseases) to develop new micro- and nanoelectronic-based sensing and integration concepts for advanced miniaturised in-vitro diagnostic devices, with an EU contribution of €5.96 million.

Furthermore, the EU has actively participated in [large-scale -omics research initiatives](#) in the form of international consortia such as the [International Cancer Genome Consortium \(ICGC\)](#) and the [International Rare Diseases Research Consortium \(IRDiRC\)](#).

High-level EU conference: 'Making access to personalised medicine a reality for patients'

Personalised medicine is one of the Luxembourg Presidency's health policy [priorities](#). On 8 July 2015, it organised a [conference](#) bringing together stakeholders from the Commission, the European Parliament, patient organisations and interest groups active in the field. In his [introduction](#), Health Commissioner Vytenis Andriukaitis cautioned that, while personalised medicine can provide highly specific diagnosis and treatment, it serves relatively small groups of patients. He stressed that 'new ways of dealing with this challenge' need to be found 'without discriminating [amongst] patients in accessing healthcare and ... undermining the cost-effectiveness, resilience and sustainability of Member States' health systems'. The conference's findings will feed into Council Conclusions to be adopted during the Council of Health Ministers (EPSCO) on 8 December 2015.

Main references

[European Perspectives in Personalised Medicine](#), European Commission, conference report, 12-13 May 2011.

[Use of '-omics' technologies in the development of personalised medicine](#), European Commission staff working document, SWD(2013) 436 final, 25 October 2013.

Boyd, S. D. et al., [A Balanced Look at the Implications of Genomic \(and Other 'Omics'\) Testing for Disease Diagnosis and Clinical Care](#), *Genes* 2014, 5(3), pp. 748-766.

Lewis, J. et al., [Ethics, Evidence and Economics in the Pursuit of 'Personalized Medicine](#), *J. Pers. Med.* 2014, 4(2), pp. 136-137.

Redekop, W. K. and Mladsi D., [The Faces of Personalized Medicine: A Framework for Understanding Its Meaning and Scope](#), *Value in Health* 16 (2013), pp. 4-9.

Endnotes

¹ Definitions mainly adapted from [Genetics Home Reference](#), [National Institutes of Health](#), [Use of '-omics' technologies in the development of personalised medicine](#), [Postnote on personalised medicine](#).

² The [Human Genome Project](#) was an international research effort to determine the sequence of the human genome and identify ('map') the genes it contains. The project began in 1990 and was completed in 2003.

³ As stipulated in the Council of Europe's [Additional Protocol to the Convention on Human Rights and Biomedicine, concerning Genetic Testing for Health Purposes](#).

⁴ Estimate for EU-funded projects launched during the period 2007-12.

Disclaimer and Copyright

The content of this document is the sole responsibility of the author and any opinions expressed therein do not necessarily represent the official position of the European Parliament. It is addressed to the Members and staff of the EP for their parliamentary work. Reproduction and translation for non-commercial purposes are authorised, provided the source is acknowledged and the European Parliament is given prior notice and sent a copy.

© European Union, 2015.

Photo credits: © bonumopus / Shutterstock.

eprs@ep.europa.eu

<http://www.eprs.ep.parl.union.eu> (intranet)

<http://www.europarl.europa.eu/thinktank> (internet)

<http://epthinktank.eu> (blog)