

Generation Scotland: Facts and Figures

In 2006, the first Scottish Family Health Study participants attended a clinic in Glasgow. 2016 marks the tenth anniversary of this milestone, and we are celebrating it by looking back at the past and forward to the future of Generation Scotland at the GS Symposium in May, on our new website, and in this report.

What is Generation Scotland?



It is a bioresource of human biological samples available for medical research...



...created thanks to funding from the Scottish Government and maintained through collaborative research.

Generation Scotland is a partnership between four Scottish universities, the NHS, and the people of Scotland. GS received core support from the Chief Scientist Office of the Scottish Government Health Directorates¹ and the Scottish Funding Council². Currently, Generation Scotland does not receive core funding. Instead, the resource is maintained through collaborative research: researchers who wish to access the data and materials that GS holds are charged an access fee in order to maintain the resource.

¹ CSO grant CZD/16/6

² SFC grant HR03006

Three Research Tissue Banks

The Generation Scotland: Scottish Family Health Study (SFHS)³ is the largest of the three tissue banks, and holds samples and extensive phenotype and genotype data on around 24,000 participants. Genetic Health in the 21st Century (21CGH) and the Donor DNA Databank (3D)⁴ hold samples and data on a smaller number of participants, but are valuable resources for researchers looking for control samples.

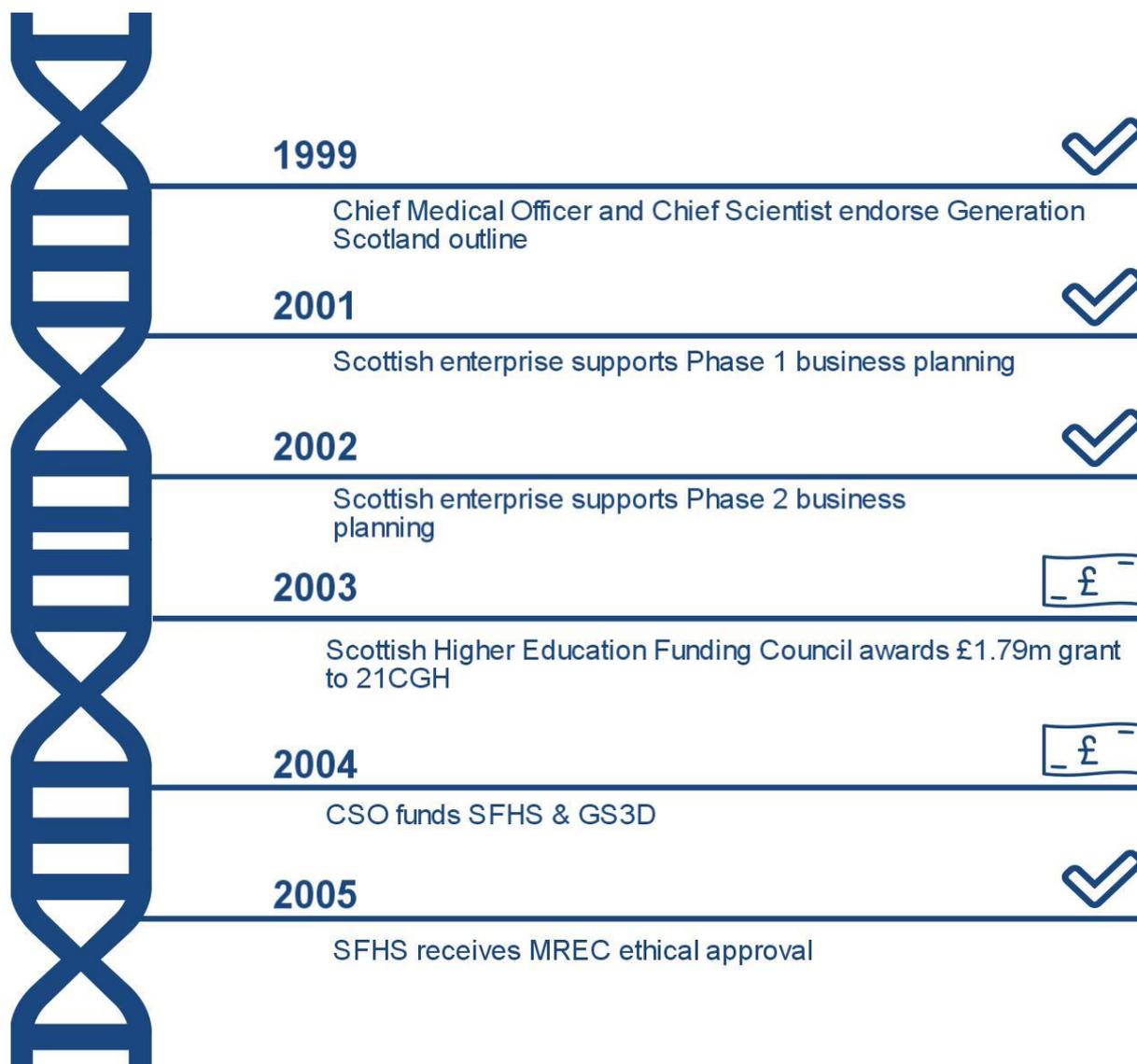
Scottish Family Health Study (SFHS)	Genetic Health in the 21st Century (21CGH)	Donor DNA Databank (GS3D)
 ~24,000	~2,000	~5,000
 Blood, serum, DNA, urine, cryo-preserved blood, biochemical data	Blood, plasma, DNA, cells	DNA, plasma
 Intensive phenotype, clinical measures, mental health, cognition	Moderate phenotype, clinical measures, personality, cognition	Minimal phenotype
 Identify genetic variants, enhanced power for linkage & association studies, CNV inheritance testing	Control dataset	Control samples for replication

³ Smith et al. (2013). Cohort Profile: Generation Scotland: Scottish Family Health Study (GS:SFHS). The study, its participants and their potential for genetic research on health and illness. *International Journal of Epidemiology*, 42(3), 689-700. <http://doi.org/10.1093/ije/dys084>

⁴ Kerr et al. (2010). Generation Scotland: Donor DNA Databank; A control DNA resource. *BMC Medical Genetics*, 11, 166. <http://doi.org/10.1186/1471-2350-11-166>

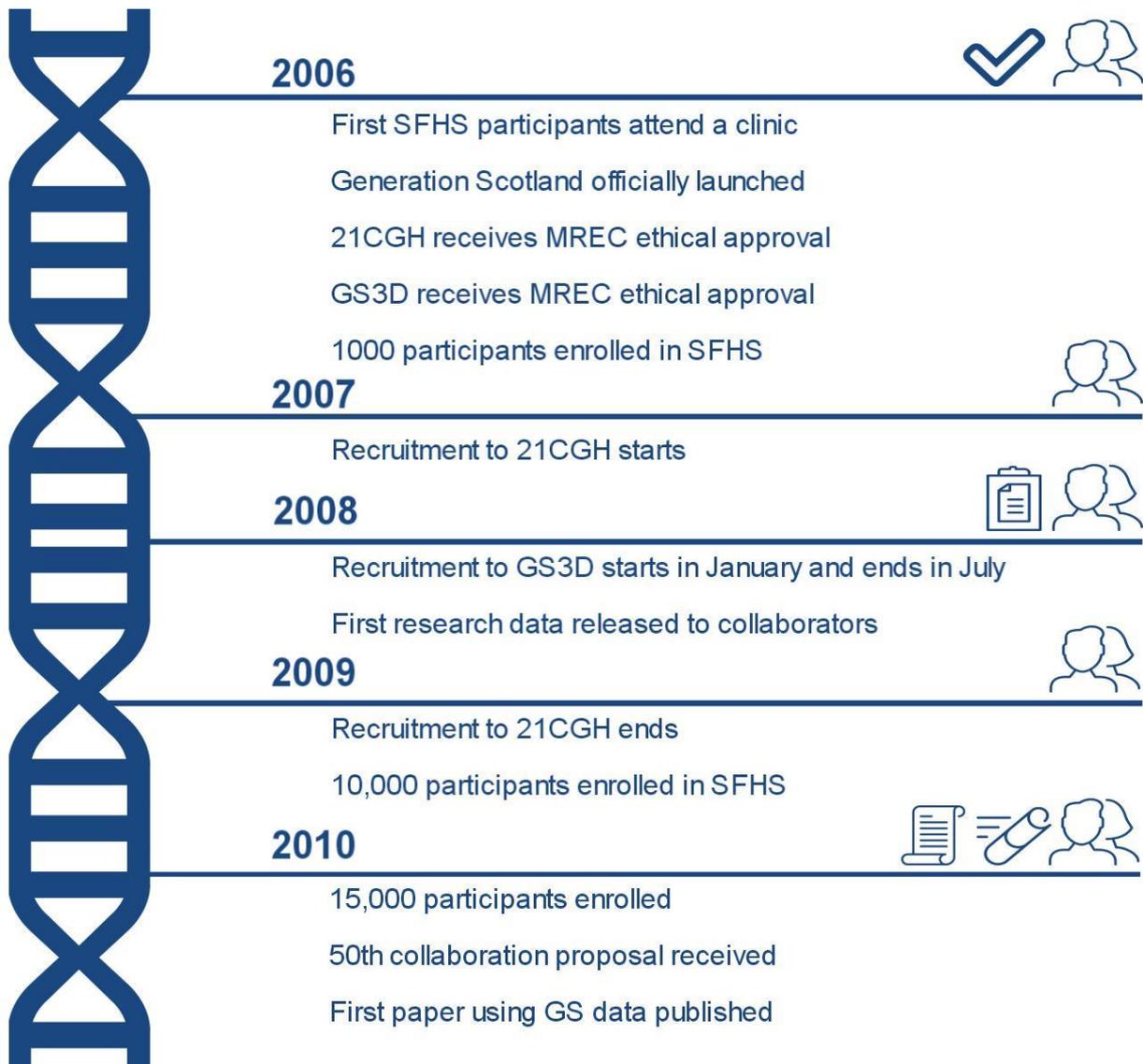
Back to the beginning

In 1999, the Chief Medical Officer and Chief Scientist endorsed the Generation Scotland outline. Over the next six years, business planning was carried out, funding secured and ethical approval⁵ received.



⁵ Ethical approval for the GS:SFHS and GS:3D studies was obtained from the Tayside Committee on Medical Research Ethics (on behalf of the National Health Service). Ethical approval for the GS:21CGH study was obtained from the Scotland A Research Ethics Committee.

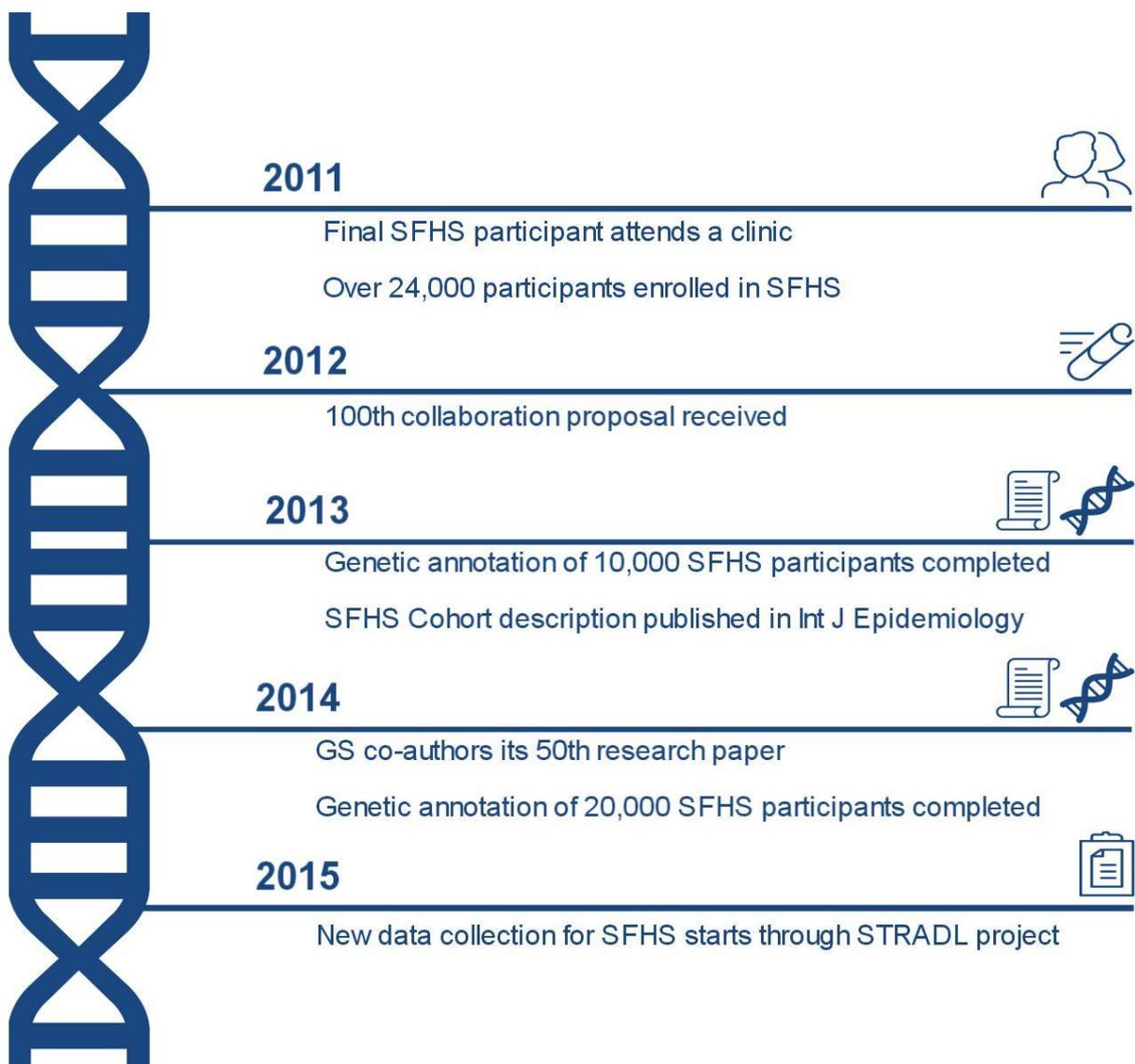
Participant recruitment through GP practices to the Generation Scotland: Scottish Family Health Study started in 2006. Participants came from all over Scotland, and attended a clinic in Glasgow, Dundee, Aberdeen, Perth, or Kilmarnock. The first set of research data was released to GS collaborators in 2008. By the end of 2010, Generation Scotland had received over 50 collaboration proposals, and the first journal paper arising from a GS collaborative project was published⁶.



⁶ Luciano et al. (2010). Shared Genetic Aetiology between Cognitive Ability and Cardiovascular Disease Risk Factors: Generation Scotland's Scottish Family Health Study. *Intelligence*, 38(3), 304-313. <http://doi.org/10.1016/j.intell.2010.03.002>

In 2011, the final Scottish Family Health Study participants attended a clinic, bringing the total number of SFHS participants to just over 24,000 and the total number of participants across the three biobanks to more than 30,000. There was considerable research interest in the Generation Scotland resources: by 2012, GS had received its 100th collaboration proposal. A great number of publications arose from collaborative projects, and by 2014, over 50 papers had been published in academic journals.

Over the past few years, the biobanks have continued to grow due to the addition of new data, such as the extensive genetic data on 20,000 SFHS participants⁷, collection of additional phenotype data through collaborative projects, and linkage to medical records.



⁷ GS has worked with a number of collaborators on generating genetic data on its resource, in particular with the Institute of Genetics and Molecular Medicine Quantitative Trait Locus (QTL) group with funding from the MRC and Wellcome Trust.

Collaboration with researchers

Research interest in the Generation Scotland resources has steadily increased. Since 2007, academic and commercial researchers have submitted over 240 collaboration proposals. Although most of the proposals come from within the UK, there is a growing interest in Generation Scotland resources from researchers further afield, such as the Netherlands, Canada, and the United States.

Since 2007, more than
240 collaboration proposals
have been submitted

Research interests are diverse



Bone and joint disease



Diabetes



Cancer



Mental Health



Cardiovascular disease



Pain



Cognition



Other

The 'other' category of research interests shown in the graphic above encompasses a great variety of interests, such as obesity, virology, population genetics, epigenetics, and reproductive health. In addition, Generation Scotland resources have been used to develop and test new protocols and technologies. Many collaborative projects focus on more than one area of interest.

The Generation Scotland Access Committee reviews all proposals to ensure that they are scientifically sound, can be supported by the resource and comply with the aims of GS and the original consent given by participants. Expert working groups have been established to co-ordinate research in the fields of cognition, mental health, pain and genomic annotation.

In addition to collaborative projects with individual researchers, Generation Scotland contributes to various national and international consortia. Currently, over 15 consortia are using Generation Scotland data. These consortia focus on a variety of research areas, such as ageing, mental health, and cardiovascular disease.

Generation Scotland is part of various consortia



**Dementias
Platform^{UK}**
Medical Research Council



**UK
10K**

RARE GENETIC VARIANTS IN HEALTH AND DISEASE



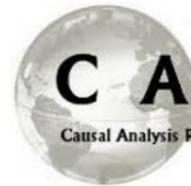
EU-MASCARA



DOLORisk

EPAD

European Prevention of
Alzheimer's Dementia Consortium



C A R T A

Causal Analysis Research in Tobacco and Alcohol



**Genetic Investigation of
ANthropometric Traits**



COHORTS FOR HEART AND AGING RESEARCH
IN GENOMIC EPIDEMIOLOGY

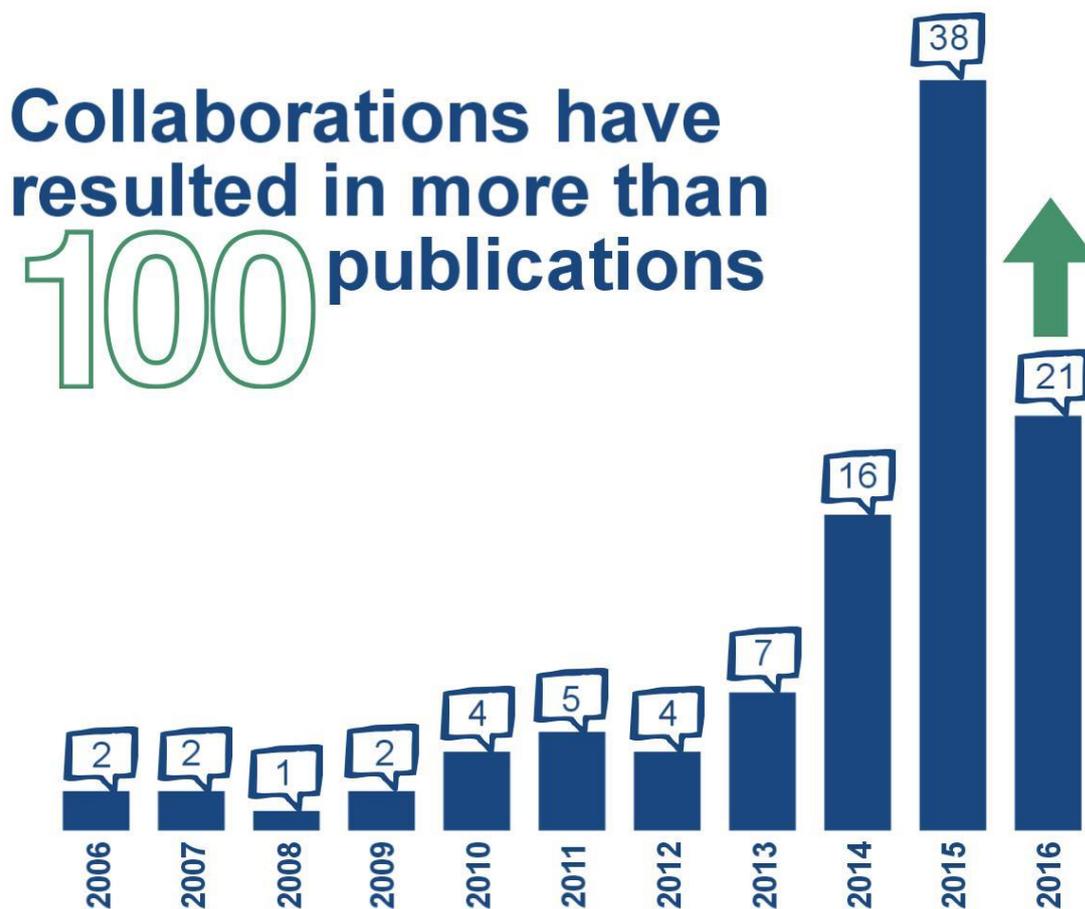
By contributing data to consortia, Generation Scotland supports important meta-analyses and large-scale research projects. Several publications in high-impact journals such as Nature and Molecular Psychiatry have arisen from these projects^{8,9}, with many more expected to follow.

⁸ Walker et al. (2015). The UK10K project identifies rare variants in health and disease. *Nature*, 526(7571), 82-90. <http://doi.org/10.1038/nature14962>

⁹ Davies et al. (2015). Genetic contributions to variation in general cognitive function: a meta-analysis of genome-wide association studies in the CHARGE consortium (N=53 949). *Molecular Psychiatry*, 20(2), 183-192. <http://doi.org/10.1038/mp.2014.188>

Research output

Over the past decade, Generation Scotland has contributed to more than 100 publications in academic journals. Before the first paper using GS data was published in 2010, several papers were published on methodology and ethical, legal, and social issues (ELSI) in biobanking.



In 2016, 21 papers were published up until June. With many more manuscripts in preparation, this number will certainly increase.

Papers arising from projects using Generation Scotland data have been published in a variety of high-ranking academic journals. These include journals such as Nature, Nature Genetics, Nature Neuroscience, Molecular Psychiatry, International Journal of Epidemiology, PLoS Medicine and PLoS Genetics.

In all publications arising from projects using Generation Scotland resources, GS requires appropriate acknowledgement of the resource, which includes a statement about the funding and ethical approval of Generation Scotland.

**GS research has been published
in more than 40 different journals**

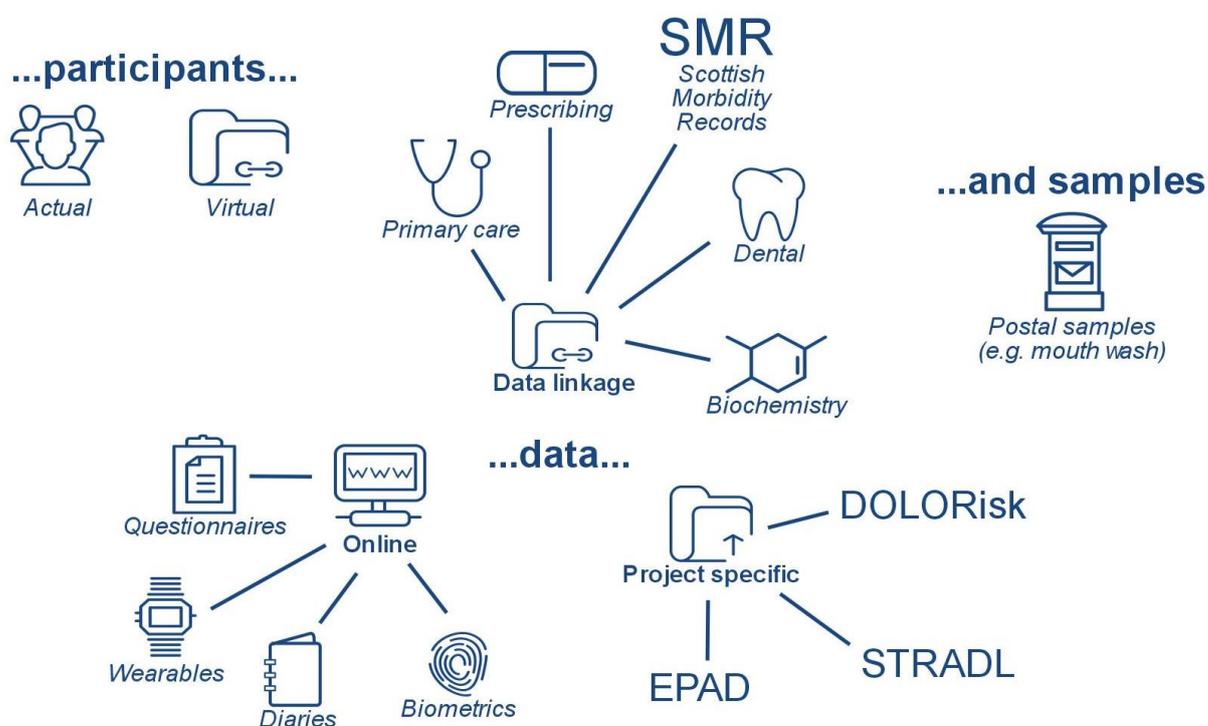
The logo for the journal Nature, featuring the word "nature" in a black, lowercase, serif font.The logo for Molecular Psychiatry, consisting of the words "Molecular Psychiatry" in white, serif font on a red rectangular background.The logo for the International Journal of Epidemiology, with "International Journal of" in blue and "Epidemiology" in bold blue on a yellow rectangular background.The logo for PLOS GENETICS, featuring a stylized globe icon, the word "PLOS" in bold, and "GENETICS" in a smaller font.The logo for Nature Genetics, with "nature" in a smaller font above "genetics" in a larger, white, lowercase, serif font on a dark green background.The logo for Nature Neuroscience, with "nature" in a smaller font above "neuroscience" in a larger, white, lowercase, serif font on a dark teal background.The logo for Nature Communications, featuring a stylized orange and yellow wave graphic above the words "nature COMMUNICATIONS" in a white, lowercase, sans-serif font on a light grey background.The logo for BMC Medical Genetics, with a teal circular graphic to the left of the text "BMC Medical Genetics" in a white, sans-serif font.The logo for the Journal of Human Hypertension, with "Journal of" in a smaller font above "Human Hypertension" in a larger, white, serif font on a dark blue background.

The future of Generation Scotland

After conducting a successful study, many of our collaborators and consortia come back with another proposal. This demonstrates the high quality of the data collected and its long term value. Collaboration with additional Scottish, UK and international researchers and cohorts as well as stronger links with industry will add further value to the resource. Expanding the Generation Scotland cohorts by recruiting new families would be costly, but adding more members to participating families might be more practical and affordable. It may also be possible to link GS to other independent studies in Scotland. The larger the cohort, the more powerful it becomes to ask and answer health related questions. Clinic visits, face-to-face interviews and sample collection are particularly costly elements of the study, but there is a lot that can be done remotely and therefore more cheaply, e.g. by posting saliva specimens, completing on-line questionnaires and linking to routine health care data. This may be the most practical way forward.

Linkage to routinely collected NHS data, such as prescribing data, dental data, and Scottish Morbidity Record data (e.g. hospital referrals, stroke and cancer incidence etc) can add a wealth of existing data to the resource. New data could be collected online, for example through questionnaires and diaries. Additionally, collaborative projects with researchers (e.g. STRADL, EPAD¹⁰, DOLORisk¹¹) are generating new data that will be added to GS.

Future plans: to expand the resource by adding...



¹⁰ <http://ep-ad.org>

¹¹ <http://dolorisk.eu>