Healthy Plants. Healthy People. Healthy Planet.

Securing a safer, healthier and more sustainable future through the power of plant and microbial science

John Innes Centre
Unlocking Nature's Diversity

The Sainsbury Laboratory
TSL

***The John Innes Centre** is an independent, international research centre specialising in plant science and microbiology. It is a registered charity funded by UKRI-BBSRC, the European Research Council and other charitable sources including the John Innes Foundation. The John Innes Centre uses genetic approaches to answer fundamental questions of bioscience, and to translate the answers into environmental and societal benefits.*

***The Sainsbury Laboratory** is a world-leading independent research institute that specialises in plant-microbe interactions, funded by The Gatsby Charitable Foundation, The University of East Anglia and UKRI-BBSRC. Its work is focused on leading global efforts to reduce crop losses to disease.*

The Healthy Plants, Healthy People, Healthy Planet (HP³) project is our vision for achieving a safer, healthier and more sustainable future through the power of plant and microbial science.

The John Innes Centre and The Sainsbury Laboratory are at the forefront of efforts to bring this vision to life, but getting there requires a step change in capability that is only achievable through new ways of working.

We are working with UKRI's Biotechnology and Biological Sciences Research Council (BBSRC) to develop the case for investment in our new infrastructure, and are seeking private capital investment alongside public funding to enable us to realise our exciting and ambitious vision.

Here, we lay out the near and very real threats facing humankind and the planet more widely, the potential for plant and microbial science to overcome them, and why a UK hub for plant and microbial science would provide pivotal resource for developing solutions.

For more information, please contact Felicity Perry, Head of Communications and Engagement at the John Innes Centre:

Email: **felicity.perry@jic.ac.uk**
Telephone: **+44 (0) 1603 450 269**
Mail: **John Innes Centre,
Norwich,
NR4 7UH**

The current COVID-19 pandemic is a stark demonstration of our collective vulnerability and a reminder that our world is more interconnected than we had ever realised. Damaging pathogens could just as easily emerge in the form of crop diseases or human infections by bacteria with antimicrobial resistance, putting our food security and health at enormous risk.

Our response to the pandemic has also shown us that transformational collaboration at pace is possible. The John Innes Centre and The Sainsbury Laboratory are uniquely positioned to lead the scientific advances needed to solve these era-defining threats. Our exciting discoveries in plant science, genetics, microbiology and plant-microbe interactions have had a huge impact, but advances in technology, scientific practice and computing mean there is even greater potential to be realised.

Working together in a new, collaborative, interdisciplinary and technology-driven way, we aim to tackle and overcome the biggest threats facing the world, making the scientific potential of today meet the global challenges of tomorrow.

With the required attention, collaboration and support, we believe that a revolution in plant and microbial research can be achieved that will help us deal with these era-defining challenges in a sustainable way that protects food security, enhances biodiversity and reduces the risk of future viral threats to humans or plants.

We want to establish the very best plant and microbial science laboratory infrastructure anywhere in the world. Capital investment in cutting edge, future-proofed facilities will create a UK hub for world-leading plant and microbial research that will supercharge our national ability to translate scientific knowledge into practical solutions.

Professor Dale Sanders FRS
Director, JIC

Professor Nick Talbot FRS
Executive Director, TSL

Contents

01 ***Global risks: why we need to act now*** 08

Feeding the world: food security and sustainable agriculture 10

Human health risks: antimicrobial resistance and viral pandemics 11

Climate change and disruptions to food supply 12

02 ***Healthy Plants; Healthy People; Healthy Planet: plant and microbial science as a solution*** 14

Healthy Plants: protecting and improving food sources sustainably 16

Healthy People: protecting humanity from disease and unlocking the health benefits of plants and microbes 18

Healthy Planet: harnessing the power of plants and microbes to combat climate change 20

03 ***HP^3 in action:*** 22

Delivering the key levers of change 24

How we're bringing our vision to life 26

04 ***The step-change needed to meet these challenges:*** 28

A national plant and microbial science hub to address global issues 30

Enable a new kind of scientific research 32

Support government policy and strategy 34

1 Global risks: why we need to act now

We have a rapidly closing window of time in which to address three critical challenges facing society and the planet that sustains us.

Feeding the world

Every minute the world loses 23 hectares of arable land, yet every day there are 160,000 more mouths to feed. We take for granted an abundance of affordable produce year-round, but it comes at high cost to wildlife and soil due to high-intensity agricultural practices. We must secure and increase yields in a sustainable way if we are to supply enough food to feed the world.

Combating global health threats

The death toll associated with antimicrobial resistance could reach 10 million a year by 2050: more than cancer and diabetes combined. Antibiotics - once highly effective at treating infections caused by bacteria, parasites, and fungi increasingly fail to kill these microbes due to over-use. New and deadly viral infections are emerging that require rapid responses to develop cures. The recent COVID-19 pandemic demonstrates this vulnerability.

Climate change

Environmental degradation allows new pests and diseases to appear and old ones to re-emerge in food-growing regions, putting 40% of global crop yields at risk. We must fight this threat while dramatically decreasing the shocking carbon footprint of food production, which is responsible for 26% of global greenhouse gas emissions. We must transform our entire agricultural system to increase resilience to this threat.

Feeding the world: food security and sustainable agriculture

A growing world population requires an ever-increasing volume of food to sustain it. Every day, there are over 160,000 additional mouths to feed, with a decreasing area of arable land available for growing the food required to do so.

Population increases lead to a higher demand for food, while consumer demand forces commercial crop and food growers to yield a greater variety of produce at affordable prices. The result is high-intensity agricultural practices, which degrade soil health and jeopardise the success of future growth.

A changing environment is also bringing new types of pests and diseases. When left unchecked, these can result in decreases of crop yields of up to 40%. Current projections suggest that there will be 2.1 billion more mouths to feed by 2050, and developing disease-resistant crops will be a key part of sustainably feeding them.

Simply put, we are not currently able to produce food with a sufficiently high level of nutrients, or with a sufficient yield to fulfil future needs. Urgent action is required to improve the sustainability of agriculture, and to protect plants from a growing threat of pests and diseases.

Plants are just as susceptible to pathogens as humans are, and recent events have shown we lack resilience in the face of emerging diseases. A global pandemic affecting one major food crop would be no less devastating than COVID-19 in terms of its humanitarian consequences.

> Food requirements in sub-Saharan Africa are expected to triple by 2050 as a result of population growth

Human health risks: antimicrobial resistance and viral pandemics

Many bacterial pathogens have developed resistance to antibiotics, while the current pandemic demonstrates a virus that resists existing anti-viral drugs.

Antibiotics that were once highly effective at treating infections caused by bacteria, parasites and fungi are increasingly failing to kill the microbes they were designed to combat. The over-use of antibiotics has led to a widespread risk of ill-health or death that was previously preventable.

Globally, it is predicted that deaths arising from antimicrobial resistance will reach 10 million a year by 2050. This would represent a higher death toll than cancer and diabetes combined.

The financial incentive for the private sector to develop new antibiotics is limited given the high costs of research and development and the likely limited lifetime of efficacy of any product.

> Deaths arising from antimicrobial resistance will reach 10 million a year by 2050

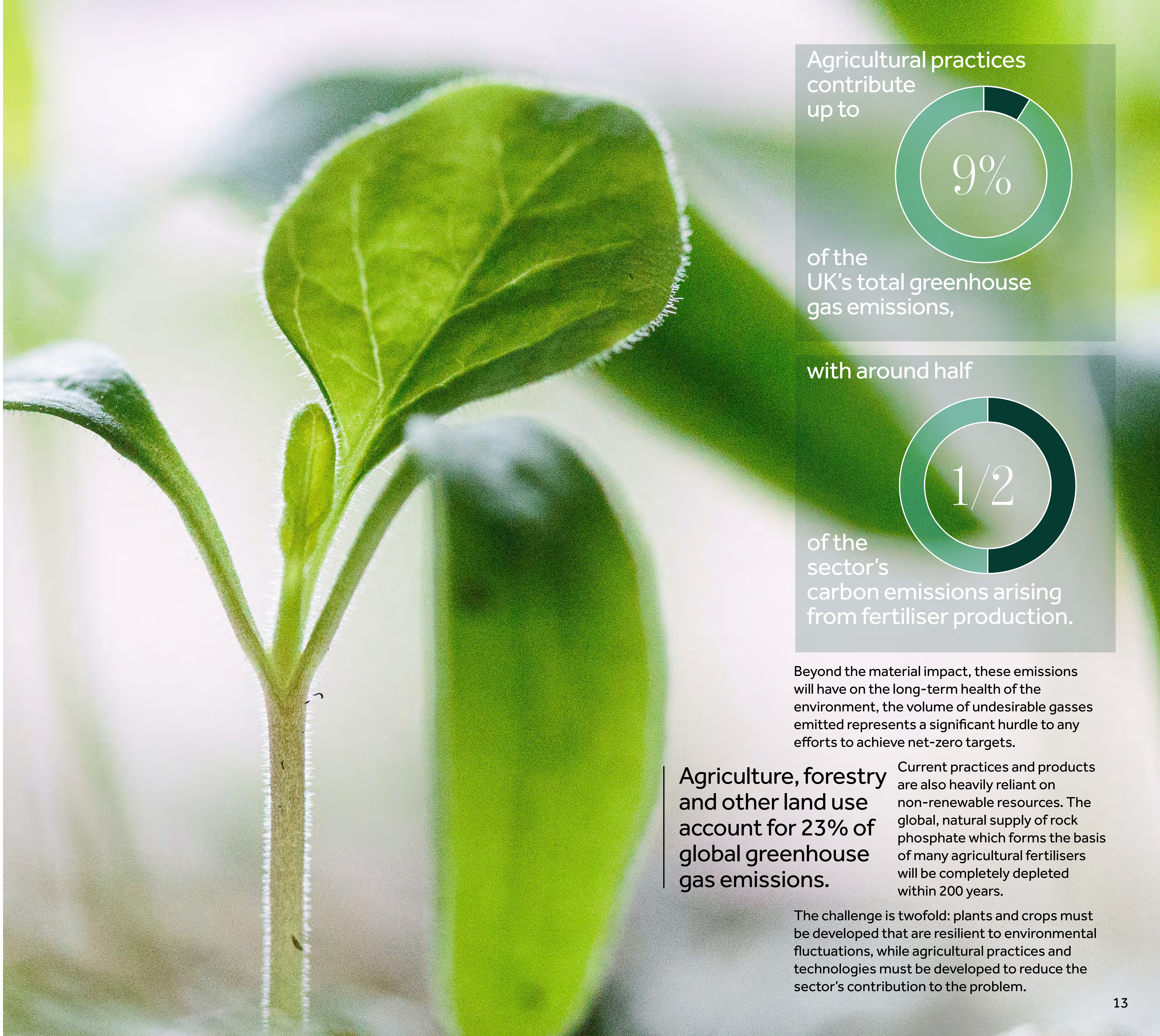
The wider economic and health costs of antimicrobial resistance represent a public threat that is too large to ignore and cannot be considered the sole responsibility of the private sector. We must put in place a public sector delivery pipeline that takes account of these risks.

There is a significant gap between the level of research going into discovering new and effective antibiotics and the inputs required to discover and synthesise new solutions. We must close the gap between urgent public health needs and private sector constraints.

Climate change and disruptions to food supply

The climate emergency has the capacity to cause widespread disruption to global food supplies. Flooding is as high a risk as drought when climate cycles change, and this volatility is having an increasingly damaging impact on our ability to create a sustainable supply of food for a growing global population. This risk of flooding is coupled with the additional threat of higher temperatures and the impact they have on the fertility and therefore yields of the world's major crops.

It is an irony that industrialised agriculture itself is a significant cause of the climate crisis that is putting food availability at risk. Huge quantities of fossil fuels used in the production of fertilisers, coupled with environmental degradation through deforestation, are some of the biggest and most avoidable contributors to climate change.



Agricultural practices contribute up to

9%

of the UK's total greenhouse gas emissions,

with around half

1/2

of the sector's carbon emissions arising from fertiliser production.

Beyond the material impact, these emissions will have on the long-term health of the environment, the volume of undesirable gasses emitted represents a significant hurdle to any efforts to achieve net-zero targets.

Agriculture, forestry and other land use account for 23% of global greenhouse gas emissions.

Current practices and products are also heavily reliant on non-renewable resources. The global, natural supply of rock phosphate which forms the basis of many agricultural fertilisers will be completely depleted within 200 years.

The challenge is twofold: plants and crops must be developed that are resilient to environmental fluctuations, while agricultural practices and technologies must be developed to reduce the sector's contribution to the problem.

2

HP³: science-based solutions to the world's most pressing challenges

The importance of plants to life on Earth is staggering. Plants are the source of all humankind's food and produce 98% of the oxygen we breathe. Along with the microbes they interact with, plants contain vast amounts of information that we study and translate into practical solutions. This is the foundation of our Healthy Plants, Healthy People, Healthy Planet (HP³) vision.

Key to unlocking these benefits is a deeper understanding of the genetic variation of plants and how to deploy that variation for the benefit of sustainable agriculture.

> We can generate new crops that are disease resistant, drought-proof, less reliant on chemicals and also more nutritious

Advancements in genomics, bioinformatics and interpretation of large data sets in the last two decades have unlocked opportunities to harness the power of plants to shape and to help combat the challenges of climate change, human health threats and food security.

By understanding plant genomes, we can generate new crops that are disease resistant, drought-proof, less reliant on chemicals and also more nutritious. Where previously we examined single genomes to uncover reactive solutions, technological advances mean that – with the correct infrastructure – we begin to breed plants predictively to create pre-emptive solutions before emerging threats have a chance to occur.

Extending these genomic analyses to soil microbes will generate biologically based solutions to key issues including the degradation of soil health, the protection of plant health and the discovery of new antibiotics to protect human health.

Healthy Plants: protecting and improving food sources

The challenge that must be overcome in order to solve the food security crisis is complex. We must find a way to increase the yield and nutritional value of crops, while reducing the area of land, volume of water and number of chemicals required to achieve this.

Two approaches are central to meeting this challenge: improving disease resistance and increasing yields.

REDUCING CROP LOSS TO DISEASE

Improving disease resistance in plants has a direct positive impact on yields, as fewer crops are destroyed by damaging pathogens.

In 2016 global trade saw the wheat blast fungus, typically isolated to South America, arrive in Bangladesh, where it destroyed 15,000 hectares of wheat, resulting in yield losses of 25-30% and threatening wheat production across South Asia. As climate change enables pathogens to spread across the world to regions where major food crops are grown, the need for effective disease resistance will only increase.

Advances in genomic sequencing allow us to map not only the genetic make-up of plants, but also that of pathogens. This allows us to identify ways to harness strategic genetic advantages of the plants we aim to protect, boosting immunity to these pathogens.

only 10% of the genetic potential within wheat has been exploited to date

USING GENETICS TO IMPROVE CROP YIELDS

It has been estimated that only 10% of the genetic potential within wheat has been exploited to date because of the complex nature of the wheat genome. Advances in genomics will enable a closer understanding of plants and a greater ability to develop revolutionary new varieties of crops that feed more people with fewer inputs.

With improved connectivity, enhanced scientific capabilities and closer coordination, we are seeing greater numbers of global collaborations to improve the yields, resilience and nutritional value of wheat, which is second only to rice as a source of calories consumed worldwide.

For example, the CEPAMS partnership between the John Innes Centre and the Chinese Academy of Sciences is one of the most advanced Sino-UK collaborations in the life sciences and is exploring how plant-microbe interactions can boost yields and how plants' molecular reactions to environmental stresses such as drought or heat can be harnessed to improve crop resilience.

Healthy People: Protecting humanity from disease and unlocking the health benefits of plants and microbes

The ways in which plants interact with microbes in their natural environments provide valuable information that can be harnessed to develop antibiotics, vaccines, and other clinical products to combat existing and emerging threats to human health.

Advanced imaging and genomic sequencing techniques allow us to mine plants for substances that inhibit damaging microbes – such as plant pathogens or even human disease-causing agents. This field has already delivered information and solutions contributing to responses to diseases such as zika virus and polio. The potential to deploy this to other viral threats to human health is vast.

New technologies are now allowing us to move from the prescriptive to the predictive – enabling preventative work to neutralise emerging threats before they can become a real danger. The need for these interventions will only grow as climate-induced epidemiological unpredictability increases.

Healthy Planet: harnessing the power of plants and microbes to combat climate change

In recent decades, a near-inverse relationship has developed between the health of the environment and crop outputs. As the latter has improved, the former has declined. Plant and microbial science offer a route to decoupling these trends.

UNDERSTANDING PLANT GENES AND THEIR ENVIRONMENTAL INTERACTIONS

Key to reducing the level of inputs required in agriculture is finding ways to improve the amount of nutrients that plants absorb from their surroundings. If plants can absorb greater amounts of crucial materials from their natural environment and effectively resist pathogens, then chemical inputs will decrease. Protecting soil health is a core part of these efforts, as is the genetic improvement of plants.

By sequencing multiple plant genomes, we are able to alter the effectiveness with which plants assimilate key nutrients such as nitrogen from their surrounding environment. Understanding the relationship between genes inside plants and how they respond to their surroundings will be a pivotal step towards reducing the amount of fossil fuel-based fertilisers, pesticides and fungicides required to grow crops.

REDUCING GREENHOUSE GAS EMISSIONS THROUGH GREATER BIODIVERSITY AND SOIL HEALTH

A promotion of plant health beyond the sphere of agriculture is vital in any effort to reduce the volume of carbon emitted into the atmosphere. Through greater biodiversity the amount of carbon captured by plants through photosynthesis or absorbed by soil will increase, with a reciprocal reduction in the levels released into the atmosphere.

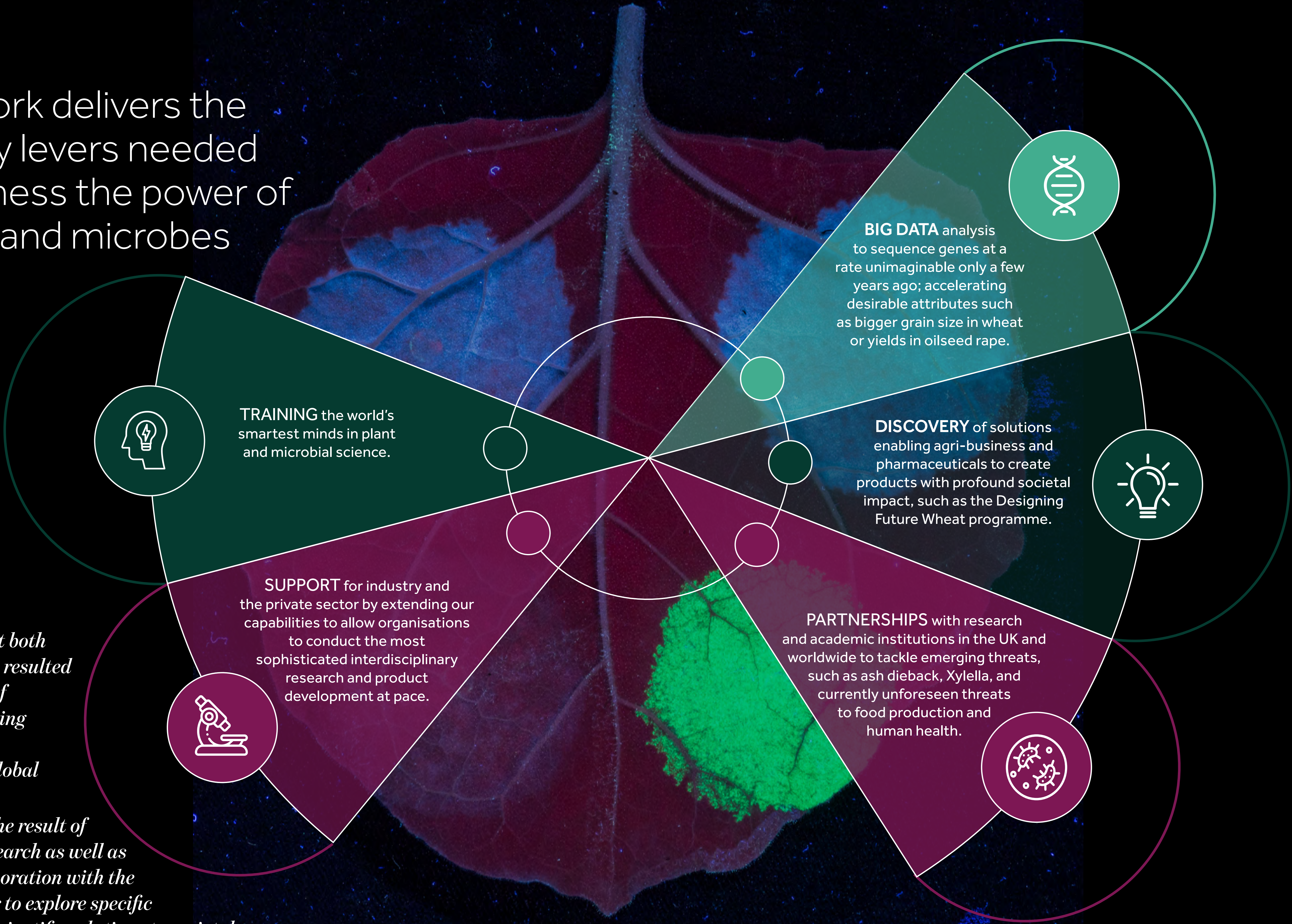
An improvement in biodiversity will be a natural consequence of a lower reliance on chemical inputs and more sustainable agriculture. As more efficient land use due to greater crop yields increases, and soil damage caused by chemicals decreases, biodiversity and soil health will improve, enabling a greater volume of carbon to be sequestered.

> A promotion of plant health beyond the sphere of agriculture is vital in any effort to reduce the volume of carbon emitted into the atmosphere.

HP^3 in action:

The John Innes Centre and The Sainsbury Laboratory are uniquely positioned to drive scientific advances that will solve many of the world's biggest environmental and health challenges.

Our work delivers the five key levers needed to harness the power of plants and microbes



To date, work undertaken at both institutes has resulted in a number of ground-breaking and practical solutions to global challenges.

Our work is the result of academic research as well as intense collaboration with the private sector to explore specific and applied scientific solutions to societal problems and economic development.

How we're bringing our vision to life

UNLOCKING A £4.3 BILLION OPPORTUNITY IN THE WHEAT GENOME

> The value of historic John Innes Centre discoveries in wheat are worth £4.9 billion globally.

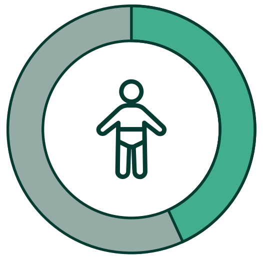
Using multiple state-of-the-art genetic approaches, John Innes Centre scientists have unlocked some of the hidden potential for increased yield within the wheat genome. By controlling the genetic mechanism that determines seed size, increases in grain weight of up to 13% are now possible.

The value of historic John Innes Centre discoveries in wheat are worth £4.9 billion globally. The centre's current wheat programme will generate an additional £4.3 billion in global gross value-added over the next 25 years through improved productivity.

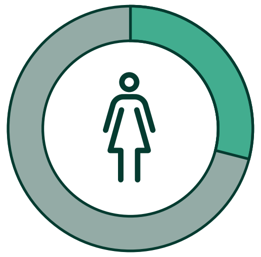
BIOFORTIFYING GRAINS TO COMBAT MALNOURISHMENT

It has been estimated that globally

43%
of children



29%
of women



of reproductive age have anaemia, and about half of these cases result from iron deficiency.

Zinc deficiency is associated with stunted growth in children under the age of 5 years and reported to affect approximately 155 million children globally.

Recent research by the John Innes Centre into the wheat genome has produced a variant that contains twice the typical amount of iron, something that cannot be achieved by normal breeding and is made possible only by the latest developments in scientific practices.

FINDING SOLUTIONS TO INDUSTRIAL CHALLENGES

The John Innes Centre and The Sainsbury Laboratory's expertise in the practical application of plant- and microbial-based discoveries is the basis for expansive collaboration with industry.

Private sector collaboration is a core function of the John Innes Centre and The Sainsbury Laboratory, and our institutions play a vital role in extending our capabilities to industry, allowing organisations to conduct crucial product research and development that would not be possible in-house.

Our capabilities lead to the creation of products and technologies that enable businesses to thrive, creating significant economic value across multiple sectors. As a hub and focal point for research, we allow ideas to evolve into commercial realities for societal benefit.

> For every £1 invested in the John Innes Centre, £14 is generated for the wider UK economy. HP^3 will boost productivity and efficiency, increasing return on investment.

REACTIVE AND PRE-EMPTIVE STRIKES AGAINST PLANT DISEASES

In the recent case of ash-dieback – a devastating pathogen that affects ash trees and could cost the UK £7 billion over the next six years – The Sainsbury Laboratory, John Innes Centre and neighbouring Earlham Institute led through their own funding the sequencing of the pathogen to identify genetic strategies to combat it.

Our expertise in microbial science has also enabled partnerships between The Sainsbury Laboratory and the BecA-ILRI Hub in Kenya, and International Potato Centre in Uganda, for example, to develop new disease-resistant varieties of rice and potatoes for sub-Saharan Africa.

USING PLANT AND MICROBIAL SCIENCE AS A TEST BED FOR NEW VACCINES

Hypertrans, a John Innes Centre-developed platform for synthesising viral particles in plants, is now at the forefront of developing vaccines to COVID-19, zika, polio, and animal infections such as Bluetongue virus in sheep.

Practical applications will be crucial in the development in vaccines for other existing and emergent viral infections. An example can be seen in vaccine adjuvants originating from rare South American trees which are now being produced in standard laboratory plants to address biodiversity and health Issues.

In addition, a key discovery made at the Sainsbury Laboratory, RNA interference, has led to a completely new class of drug for human healthcare, recently approved by both the Food and Drug Administration in the United States, and the NHS in the UK.

4

The step-change needed to meet these challenges

Our expertise in plant genetics and disease, cell biology and plant interactions with the environment have for a century made major scientific breakthroughs shaping the world we live in. Ensuring the benefits of these breakthroughs are realised for the next century will require a step change in the way we work, utilising cutting-edge technologies, the latest ways of working, and access to the world's best scientific thinkers.

The core of the current John Innes Centre and Sainsbury Laboratory buildings were established in the 1960s. That core facility on this world-leading centre is requiring extensive, day-to-day maintenance for buildings that – for the most part – will have to be demolished within the next decade. We already have commitments from the private and charity sector to fund a new, state-of-the-art estate, but we require further investment to make our vision a reality.

Investment will enable a step change in the way our science is carried out, enabling interdisciplinary research that embraces artificial intelligence, machine learning and robotics, bio-imaging, and genomic, proteomic and metabolomic platform technologies. We need to decompartmentalise our working practices to fuel closer collaboration, allowing us to throw everything at our projects from the world of biology, physics, genomics, computing, and data science.

It is through these approaches that new and transformative insights will be made, producing an unprecedented understanding of crop science, nutrition, disease response and food security. Through this investment the UK will emerge as the global leader in the innovations necessary to feed the world sustainably and protect human health for the next century.

Through this investment the UK will emerge as the global leader in the innovations necessary to feed the world sustainably and protect human health for the next century.

Transforming the UK into an international hub for plant and microbial science

By creating the world's foremost hub of plant and microbial science – open for business to a global audience – private sector organisations will have access to a one-stop shop housing the field's greatest scientific minds. Access to this kind of creativity and expertise will accelerate the discovery and creation of new products and technologies, with far-reaching impacts and commercial value.

Upgraded facilities will also mean that the John Innes Centre and The Sainsbury Laboratory will be accessible to other research and academic institutions. By extending facilities and field research capabilities to other organisations, the UK's entire capacity for making critical discoveries in plant and microbial science will be elevated.

Investment will translate into a step change not only for the John Innes Centre and The Sainsbury Laboratory, but also into a fundamental shift in the UK scientific community's ability to turn its innovation and creativity into solutions that will underpin the way the world eats and protects human health for the next century and beyond. This vision is closely aligned with the objectives of UKRI as set out in their Strategic Prospectus and Infrastructure Roadmap.

Investment will translate into a step change not only for the John Innes Centre and The Sainsbury Laboratory, but also into a fundamental shift in the UK scientific community's ability to turn its innovation and creativity into solutions that will underpin the way the world eats and protects human health for the next century and beyond.

Enabling a new kind of scientific research

ADVANCED TECHNOLOGY: ENHANCED OUTPUTS

The latest technologies will enable us to examine the information housed within plants and microbes with a level of accuracy that will transform our understanding of them. Our current facilities cannot house this equipment.

THE GREATEST MINDS, COMBINED: ENCOURAGING INTERDISCIPLINARY WORK

The complexity of current global challenges requires solutions created through not only biology and microbiology, but also data science, physics and chemistry and many other disciplines.

New facilities will literally break down barriers between these capabilities, allowing us to take a holistic and richer view of scientific challenges and questions, and to analyse and problem-solve at a system level, rather than in isolated contexts.

FROM REACTIVE TO PREDICTIVE: HARNESSING AI AND MACHINE LEARNING

Combined with more advanced imaging capabilities, facilities designed to house the most powerful computational infrastructure will allow us to model interactions between genes and potential environmental factors.

We will be able to ‘war game’ many more environmental scenarios to help us create crops that we know will not only survive, but thrive within them, just as we will be able to ensure we are prepared for the next global health threat.

OPEN FOR BUSINESS: ENABLING EXTERNAL COLLABORATION

An expanded physical capacity for research will allow us to be truly open for business, extending our research and field trial capabilities to national and global research institutions and private sector organisations.

An international hub of this kind will catapult the innovation and discovery potential of institutions and organisations across the world, generating huge economic value and even greater agricultural, environmental and social benefits.

Meeting the world’s biggest challenges requires state-of-the-art facilities, designed in a completely new way to support the innovative science of the next century.

Supporting government policy

SUPPORTING THE UK'S AGRICULTURAL AND CROP STRATEGIES

The Agriculture Bill currently being examined by Parliament is an opportunity to secure a resilient, sustainable and biodiverse future for UK agriculture. The bill acknowledges that our agricultural system must go beyond crop production and also prioritise the promotion of clean air, clean water, and biodiversity, and to reduce the risk of environmental hazards.

The establishment of a state-of-the-art, national plant and microbial science hub in Norwich will see our ability to fulfil the ambition of the bill increase dramatically by providing the best innovators in the country with a platform to produce solutions to our biggest agricultural and environmental challenges. In doing so, the capabilities and outputs of the Norwich Research Park will accelerate while the broader East of England economy will thrive.

> The gross value-added impacts of our work will be worth over £300 million to the UK across the next decade, and a further £5.7 billion internationally.

The agriculture, food and drink sector in the East of England already employs nearly 80,000 people, and a new hub would not only boost the sector's efficiency and innovation, but also attract inward investment, new talent and create further commercial opportunities within it.

SUPPORTING THE UK'S INDUSTRIAL STRATEGY

Investment in a new estate will revolutionise the John Innes Centre and The Sainsbury Laboratory's capabilities, and therefore the potential benefits of research and private sector partners. The resultant uplift in collaboration and partnerships will drive greater inward investment into plant and microbial science work while contributing significantly to the fulfilment of the UK Government's commitment to increasing R&D spending to 2.4% of GDP by 2027.

The boost to inward investment that this will enable will be dramatic, positioning us and the broader Norwich Research Park as the world's foremost hub for the application of genomics to agriculture and human health.

SUPPORTING THE UK'S CLEAN GROWTH GOALS

With the latest technologies and ways of working, we can create even more crops requiring even less inputs, driving the clean growth effort laid out in the Grand Challenges of the Government's Industrial Strategy by contributing to the UK's clean growth efforts.

Success in this area will see the agricultural sector's use of and reliance on fossil fuel-derived chemicals decrease significantly. By exporting these advances internationally, we will see UK-based outputs contributing to global reductions in GHG emissions, with far-reaching environmental and health benefits.

John Innes Centre
Unlocking Nature's Diversity

The Sainsbury Laboratory
TSL

www.jic.ac.uk

www.tsl.ac.uk

Email: felicity.perry@jic.ac.uk
Telephone: +44 (0) 1603 450 269