A systems approach to public health

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Abstract

The modern burden of chronic diseases such as obesity, diabetes, cardiovascular disease and related conditions is the result of a complex web of interacting factors, with the individual sitting at the nexus of a network of biological, social, societal and environmental forces that together impact their risk of disease. Our biological predispositions to chronic diseases have origins deep in evolutionary history. There is no simple solution or medical intervention that will solve these problems. The Charles Perkins Centre at the University of Sydney was designed as a new model for addressing the burden of chronic disease based on principles from evolutionary biology and ecology. It brings together multidisciplinary teams spanning philosophers to clinicians in a complex adaptive research ecosystem, from which are emerging unexpected linkages and new solutions.

Introduction

In Australia 63% of adults and 25% of children are now classified as overweight or obese (ABS, 2013). These numbers show no real sign of abating and there are major impacts on health, particularly through associated comorbidities (O'Rahilly, 2016). Overweight and obesity have not yielded to public health campaigns urging us to eat less and move more. If the rise in chronic disease burden was simply the result of individuals not taking personal responsibility for their lifestyles, then it would represent a failure of willpower of monumental proportions. Rather, the explanation is more complex. In essence, we have designed our world in every respect to make it difficult to live a healthy lifestyle.

Like all animals, humans have evolved to minimize energy expenditure and maximize accessibility to safe and palatable food. These are powerfully adaptive traits, but because of our most notable adaptation – the human brain - we have designed a world in which we have achieved our ancestral hearts' desires. We have bred our food plants and animals and designed our food production and supply systems to maximize the qualities missing in our ancestral environments – energy dense, fat and sugar-rich foods; our towns, homes and workplaces are designed to allow minimal energy expenditure; our economic systems are designed to value wealth over health. In the Darwinian market place of the modern economy, companies that sell what we want prosper, even if that means selling us foods that degrade health. Political solutions are not easy – prevention is better than cure, yet makes little profit and wins few votes in the short term. As a consequence, although in the developed world we benefit from the longest average lifespans in human history and enjoy unprecedented food security and wealth (albeit increasingly unequally distributed), we are nonetheless suffering an epidemic of non-communicable diseases.

Building a complex adaptive system to tackle a complex societal problem

Complex adaptive systems have been the greatest solvers of hyper-complex problems in the history of the known universe. Evolution by natural selection has given rise to the wonders and diversity of life-forms that populate our planet; modifiable interactions between nerve cells give rise to the complex computing powers of brains and to the emergence of consciousness, and interactions between genes, signalling molecules and cells in the embryo ultimately give rise to the fully formed organism through the processes of development. How better, then, to tackle the complex issues of chronic disease than by building a complex adaptive research and education ecosystem?

Universities are pre-adapted to undertake such a task. They are populated by a continuing stream of young clever people full of energy, at the peak of their creativity and ready to learn. Universities possess expertise across a diversity of disciplines, giving the potential for both depth and breadth. But this potential has been hard to realise because, traditionally, universities have been built as a collection of separate disciplinary entities – Faculties, School and Departments. At the Charles Perkins Centre we have set out to design a system that brings disciplines together and augments rather than dilutes specialist expertise.

The Charles Perkins Centre (CPC) was set up to bring the University together across its disciplines and locations by establishing new collaborative, multi-disciplinary research and education that has impact on peoples' lives. The centre's namesake is Dr Charles Perkins, an alumnus of the University of Sydney and the first Aboriginal man to gain a University degree. Charles exemplified many of the characteristics we wished for the Centre: he worked across sectors of society, he challenged prevailing ways of thinking, and he made an impact (Read, 2001).

The Charles Perkins Centre research and education hub

To serve both as a physical manifestation of the ethos of the centre and act as its headquarters, a new building was designed, built and populated on central campus adjacent to the Royal Prince Alfred Hospital – the CPC research and education hub. The $385 million building was completed ahead of schedule and under budget and was formally opened in June 2014. The hub comprises nearly 50,000 m^2 of wet laboratories, dry laboratory areas, advanced teaching spaces, high-end core facilities and a pathology museum. It has its own clinic, The Charles Perkins Centre Royal Prince Alfred Clinic, run under the clinical governance of the hospital to the CPC academic strategy, admitting patients, delivering new forms of care and research, and linking the patients back into the basic research within the building. The building is home to more than 850 researchers, educators and practitioners, spanning engineers to philosophers, economists to clinicians, metabolic scientists, computer scientists and mathematicians, public health and policy researchers, and many more.

The building is not the entirety of the centre, however. Across all locations there is now a network of more than 1,200 CPC members engaged in the research and educational activities of the centre (membership is defined by initiating or joining such an activity). Regional hubs have been established at Broken Hill, Nepean and Westmead, and CPC members are found across all faculties, and beyond the University.

The academic strategy of the Charles Perkins Centre as a complex adaptive system

The main novelty of the CPC lies in its academic strategy, which was explicitly designed as a complex adaptive system. In any such system there are interacting entities or agents, interactions among which lead to higher order 'emergent' phenomena. Importantly, such self-organised emergent outcomes cannot simply be predicted from the individual activities of each of the interacting agents. Similarly, the agents themselves cannot make those predictions, or even necessarily understand the entirety of what they are involved in.

The core principles in setting up the Centre as a complex adaptive system were to:

- Make it attractive and easy for individual researchers to engage, and make it worthwhile for their home Faculties to let them;
- Set the rules of engagement to value ambition, collaboration, sharing and partnership;
- Make it easy to find compatible expertise, thereby keeping disciplinary depth and gaining breadth;
- Set a single overarching mission, but not prefigure routes to that end, constrain what is done based on presumptions of what is relevant, or insist on everything being directly translatable (useful);
- Construct the system around specific projects, which provide the basic nodes from which to build the collaborative network. Such 'project nodes' will yield new knowledge, but also inevitably interconnect to share knowledge and insights and ultimately yield larger outcomes;
- Allow projects nodes and collaborations to seek resources, grow, morph and die organically, such that the CPC system as a whole evolves;
- Capture and communicate these outcomes for public good;
- Foster entrepreneurship and commercialisation.

Any complex system needs boundary conditions and a framework. The Charles Perkins Centre academic strategy is not structured around diseases - for example by having domains of activity for obesity, diabetes or cardiovascular disease, as would perhaps be more conventional. There are, instead, four domains that define disciplinary areas. These are: population health; the biology of disease processes; society and environment, and a domain called 'solutions', to which all pathways directly or indirectly lead, providing the translational flow for the centre. There are in addition six cross-cutting themes that intersect all four domains. These are: nutrition; physical activity, exercise and energy expenditure; sleep; Aboriginal and Torres Strait Islander health; ethics, politics, and governance of chronic disease, and complex systems and modelling. The last of these themes involves mathematicians and computer scientists spanning areas of activity from metabolic networks, to the communities of micro-organisms that inhabit the gut and impact health, to human social networks.

These four domains and six themes form the basic framework for the strategy. The framework has been populated by newly established project nodes, which now total 67 in number. These have each been established around particular multidisciplinary research projects under the direction of the CPC Executive Committee and engage CPC

members in a dynamic and exponentially growing collaborative network (Table 1).

Since inception of the academic strategy in June 2012, this network has not only grown in number of members and nodes, but it has also yielded an exponential increase in productivity and impact. One measure of this can be seen in numbers of co-authored, peer-reviewed publications among members (Figure 1). Other measures that have shown strong growth include public engagement (as indicated by media impact of the work of the centre and events held under the auspices of CPC), industry and government engagement, competitive grant funding (e.g. CPC members have secured more than 40% of the University of Sydney's income from the National Health and Medical Research Council for the past two years), changes to models of care in clinical practice, contributions to national and global policy debates and health reports, and philanthropic support (which now stands at $92 million). There has also been growing interest in emulating the CPC model at other institutions in Australia and abroad.

Emphasising common causes rather than disease-specific processes

The major chronic diseases share common underpinnings both at the mechanistic level and in their social and environmental determinants. It is through understanding these commonalities that the greatest dividends will arise for both prevention and cure. This is nowhere better demonstrated than in the case of the diseases of ageing.

The greatest risk factor for all chronic diseases is increasing age, with commensurate impacts on the costs of healthcare (de Cabo and Le Couteur, 2015). Rather than taking the traditional view, which is to research each disease condition separately and to seek specific medical interventions, our aim is to understand the basic processes of ageing biology and to seek common features that underpin all metabolically related diseases. The logic is that by understanding those common processes we can better mitigate multiple conditions, for example through diet, exercise, changes in sleep regime, and use of better targeted pharmacological interventions, and do so in a more targeted way that takes account of the particular needs and circumstances of different populations.

This is just one of the philosophies that the CPC has started to deploy in its research, integrating new advances in nutritional biology (Raubenheimer and Simpson, 2016), work in animal models (Solon-Biet et al., 2014), clinical trials and human cohorts (Le Couteur et al., 2016), and emphasizing metabolic systems as the nexus between genes and environment (Humphrey et al., 2015). Such an approach has provided the basis for a new program in precision medicine, which will provide a focus for the work of the CPC over coming years.

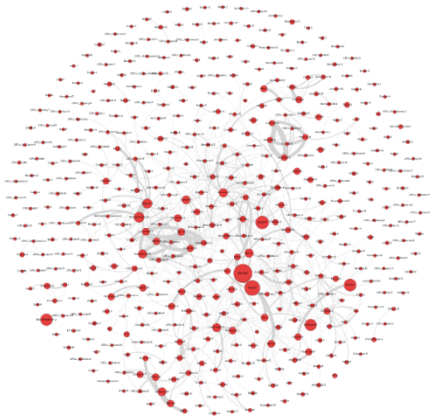
Table 1. List of CPC project nodes as at December 2016.

Cardiovascular clinical project node
Dog ownership and human health
Cardiac translational imaging
Community Academic Partnerships (CAP) in health, wellbeing, and health workforce development: building an evidence base regarding impact
BABY1000
Businesses, markets and the social context of health
CPCNet - Measuring the value add of CPC collaborative networks
Chronic disease management clinical project node
Climate adaptation and health
Child and adolescent mental health
Brain and body
Aboriginal nutrition, physical activity and wellbeing
Bias in research

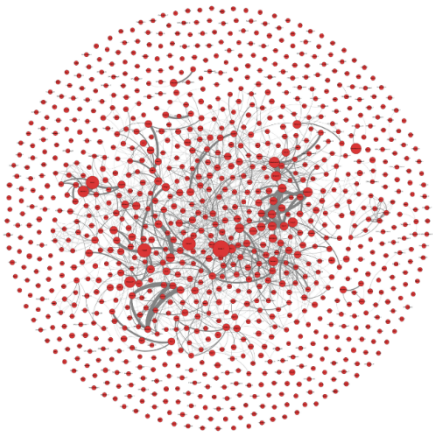
Developmental Origin of Health and Disease (DOHaD)
Building system wide capacity for complex and big data analysis and storage in T2D
Gut microbiome
Endocrinology and diabetes clinical project node
Health and creativity
Health literacy chronic disease network
E-health in gaming and avatars
Health informatics and health analytics
Healthy Food Systems: Nutrition diversity safety (formerly Global Food and Nutrition Security)
Early prevention of obesity in childhood
Health humanities
Health and economics: cross portfolio impacts of health on individuals and families
Evidence synthesis
Fibrosis and wound healing
Implementation science
Integrative Systems Lab (ISL)
Economics of human development
Human food chain
Integrated care clinical project node
Incidental physical activity and sedentary behaviour
Human-animal interactions
Life Lab
Lifestyle management clinical project node
Obesity services in the Nepean region
Nutrition, ageing and health
PLANET Sydney network
Nutrition, human health and natural resources
Preventative cardiology
One welfare
Living healthier lives under the Australian sun
Population analysis of human diet and nutrition
Science of learning science
Schizophrenia: cardiometabolic and other medical comorbidity
Politics of obesity
Remote / Indigenous communities – responding to community led innovation.

Positive computing in health systems
Regional governance and leadership in addressing rural and remote health outcomes: A far west NSW initiative
Smart food production systems
Women's health clinical project node
Translational gerontology
Wireless wellbeing and personalised health
Work and health
Virtual reality
Twin project node
Tissue Engineering and Regenerative Medicine (TERM)
Theory and method in biosciences
Healthier workplaces
Food governance
Nutrition and cardiovascular health
Writer in Residence
Oral and systemic health
Immune therapies
Developing cell-based therapies for Type 1 diabetes
Nutritional Immunometabolism

2014



2015



2016

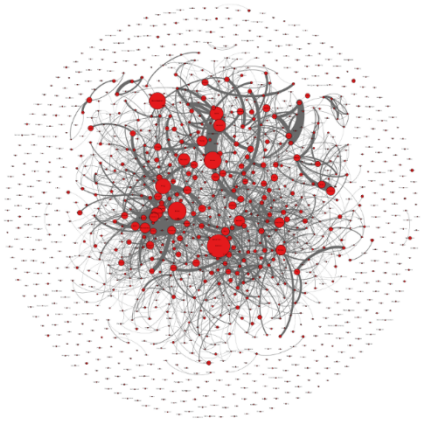


Figure 1. The publication 'connectome' of CPC members for 2014 (18 months after inauguration of the CPC strategy in June 2012), 2015 and 2016. Individual members are shown as red dots, the diameters of which reflect numbers of publications per member and the connecting lines between dots indicate co-authored publications in peer-reviewed journals. Note both the growth in number of members (ca. 500, 1000 and 1200 over successive years, from zero in June 2012) and the number of publications, but more than this, the growth in connectivity of the network, indicating establishment of new, productive collaborations among members, many of whom joined the CPC with no previous history of collaboration with other members. The connectome for 2016 has had to be rescaled (hence the smaller size of peripheral dots).

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