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Systems Thinkers

Second Edition

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About the Authors

Magnus Ramage is a senior lecturer in information systems at The Open University, where he has worked since 2000, teaching systems thinking and sociotechnical IT systems. As well as researching the history of systems thinking, he conducts research on critical approaches to the concept of information and on the organisational and social impact of collaborative technologies. He holds a PhD in Information Systems from the University of Lancaster.

Karen Shipp is an educator and facilitator who created interactive and transformative learning experiences at The Open University from 1987 to 2011, the last ten of these as a lecturer in the Systems Group.

Introduction to the First Edition

This is a book about the people who shaped an idea – that to make sense of the complexity of the world, we need to look at it in terms of wholes and relationships rather than splitting it down into its parts and looking at each in isolation. In this book we call that idea systems thinking, although others have called it by other names (such as systems theory or systems sciences). Within this idea we include a number of areas which have independent origins but have tended over time to become interlinked while retaining their distinctiveness – general systems theory, cybernetics, complexity theory and system dynamics among others.

Our focus in the book is on people and how their personalities, lives and links with each other shaped these ideas. Other books have been written on the ideas as such, describing and classifying them in various ways, presenting a history of the ideas or arguing for the importance of one perspective or another. By focusing on the creators of the ideas, and by taking a broad look at a range of areas, we aim to shed a different light on systems thinking.

The people we write about are all fascinating, although in quite different ways. Some are widely known as the originators of one or another systems approach; some are very well known within the systems community but less so outside it; while others are well known figures who are less widely acknowledged as systems thinkers. Some are associated with a particular academic discipline, such as management, sociology or environmental studies, while others ranged widely across disciplines.

Each of the 30 authors in this book is discussed in a separate chapter, comprising two parts: first, a discussion of their life and work, and second, an extract from their writing. The extract, necessarily short (just a few pages) is intended to be a 'taster' to show the author's style of writing, their concerns and interests, and to encourage you to read more of their work. In many cases, we have edited it to bring out the author's main argument, while preserving their unique voice. It is not intended as a comprehensive guide to their key ideas – it is unlikely that by reading the extract in this book, you will be able to apply the author's ideas, but we hope it will give you a sense of why the ideas are so significant, and which of the authors you might want to find out more about.

Defining Boundaries

One of the key concepts in many approaches to systems thinking is the *boundary*: how do you define what is within the system and what is outside of it? So it is perhaps no surprise that we have spent a considerable amount of time defining our own boundaries for this book.

Our goal in the book is to describe a set of thinkers whose work has been profoundly influential, and who collectively shaped the field of systems thinking. Our choice of thinkers is personal and partial, but it has been taken with great care and consideration. Inevitably you will find some exclusions that you may find puzzling or annoying, but we believe you will find that the thinkers we have included to be interesting and thought-provoking.

We are not seeking here to produce some sort of definitive canon of 'great systems thinkers'. Any such list would be flawed and necessarily incomplete, and would have to arise from a widespread effort rather than the work of a small group.

Two constraints affecting our choice were that we limited ourselves to 30 thinkers (for reasons of space) and that we made a deliberate choice to focus on individual authors rather than specific articles, schools of thought, or approaches. Our basic criteria for inclusion were that an author:

1. Explicitly identified themselves with one or more of the major traditions in systems thinking, by citing the works of previous authors within those traditions and/or working directly with earlier thinkers
2. Advanced systems concepts through their work and/or advanced another field through their application of systems concepts
3. Expressed their ideas in print

The first criterion is the most important. It required us to be explicit about our definition of 'systems traditions'. Initially, we took two major schools of thought as our starting point – general systems theory (GST) and cybernetics. Each has a single figure who can be identified as its founder (Ludwig von Bertalanffy and Norbert Wiener, respectively), as well as a number of others who made significant contributions to the field; each also has a clear historical point of creation as an explicit movement (the founding of the Society for General Systems Research in 1956 and the Macy Conferences on Cybernetics, 1946–1953).

There are few bodies of thought within systems thinking that cannot be explicitly traced back to one or both of these traditions. There are two exceptions to this, however. First, systems engineering, which essentially arose independently of general systems theory; however it later took on much of GST's language. Second, system dynamics, which despite its intellectual similarity to cybernetics (with its focus on feedback loops), does not pay any direct homage to that field in its official histories (e.g. Forrester 2007) – however it too has gradually taken on much of the concerns and language of both cybernetics and GST.

We see complexity theory as falling within our first criterion, with its strong links both to cybernetics and GST (as well as other sources); but operational research, with its somewhat different intellectual tradition, as falling outside of it.

The second criterion is intended to be relatively loose, simply stating our intention that the author should have developed the field of systems thinking, or applied systems thinking to another field in such an innovative way that that field has been significantly advanced. We take ‘advance’ to imply a significant contribution to the body of knowledge. With this criterion, we are explicitly excluding those who have used systems concepts in their work, often excellently and in very interesting ways, but have not fed back into the academic field. It is fair to say that the majority of those who have made significant contributions to systems thinking have simultaneously applied their contributions to other fields, although in a small number of cases the authors were sufficiently strongly self-identified with systems thinking (or one of its parts) that their main contribution has largely been within systems thinking.

The third criterion is intended to allow us only to include those who have explicitly described their contribution in a printed form. This does not necessarily include only academics – there are a number of practitioners on our list who participated in the various intellectual communities around systems thinking but wrote their ideas in a form others could use. It certainly does not include only academic-style writing: many of the authors we found most helpful are those who have written for a more popular audience. However, it does exclude those practitioners who have not published their work.

Inclusions and Exclusions

Some issues in boundary setting arise from the choices discussed above and are worth exploring in further detail. First, our identified starting point of systems thinking as the explicit statements of GST and cybernetics by von Bertalanffy and Wiener, inevitably excludes those who preceded those authors. There are a number of important thinkers from the first half of the twentieth century who take an explicitly holistic line, in some cases explicitly discussing their work in terms of systems, such as Alexander Bogdanov and Jan Smuts; and philosophers who have influenced a number of major systems thinkers, such as John Dewey and Alfred North Whitehead. The same is true of thinkers from an earlier age, such as Aristotle (who first said that “the whole is greater than the sum of the parts”) and Heraclitus. While all might be considered relevant, none of these thinkers are part of the tradition that is explicitly self-identified as systems thinking.

A trickier issue arises with Gestalt psychology with its emphasis on the relationship between wholes and parts; and indeed key people within the Gestalt movement, such as Wolfgang Köhler, were present at some of the Macy conferences. Nonetheless, given that Gestalt psychology arose prior to the founding of systems thinking, it is best thought of as a strongly-related precursor rather than explicitly part of the systems ‘movement’. However, we have made a different choice in the case of the Gestalt-influenced thinker Kurt Lewin who was the originator of a number of ideas of great relevance to systems thinking including action research, the popular use of the term 'feedback', the founding of the field of organisational development, and (via Kolb) the concept of learning as a cyclical process.

A gap in this book is the absence of practitioners who have not chosen to describe their methods, ideas or applications in written form. This is not to say that such practitioners do not advance the discipline, given that much work within systems thinking is grounded in the cyclical relationship between theory and practice, but our focus in this book is on systems *thinking*, as expressed in writing.

Two other under-represented groups in our list of thinkers are women and those from outside of the Anglo-American tradition. We regret the lack of many women in this book (only three of our 30 thinkers are female), but this sadly reflects the history of systems thinking as a discipline, which as with many scientific disciplines has been male-dominated. We made a decision not to hide this fact by skewing our criteria to include more female writers. There are many women currently doing highly important work in systems thinking, so it is to be hoped that this balance may be different in future work.

Most of our thinkers are either from North America or Europe, and indeed most of the mainland European thinkers have worked in North America (many as part of the large migration by academics from central Europe in the 1930s and 1940s due to Nazi persecution and post-war hardship). Our stance partly reflects our need (due to our own limitations) for authors to have written or been translated into English, but also reflects the intellectual tradition we have considered, which largely arose in the USA with a significant British connection. There are many interesting systemic thinkers from outside this group, and the systems thinking traditions we discuss would be richer for hearing their voices, but this is not something we have been able to do in this work.

It is striking to compare our choices to those of others who have attempted a similar task, such as the three collections of papers edited by Emery (1969), Beishon and Peters (1972) and Midgley (2003). From their statements and lists of authors, we can see a fairly similar set of choices to those we have made. The historical points at which they start their collections are similar to ours and to each other – Emery includes a paper by Köhler (on open and closed systems) and Midgley includes an extract from Bogdanov's work on 'tektology' (and argues strongly in his introduction that it has as much right to appear there as von Bertalanffy's work, despite Bogdanov's weaker influence on the later systems thinking tradition); but otherwise the earliest major authors in each are von Bertalanffy and Wiener. Midgley (2003, p. xix) makes the useful point that "I do not believe it is possible to present a 'neutral' account of either systems thinking or its history … interpretation is inevitable, and what appears central or peripheral depends on the purposes and assumptions of the person or people constructing the historical narrative".

An important distinction in our approach from the collections of papers mentioned above is that we have focused on people rather than ideas or papers. This has led to some significant choices. We have included those with especially interesting lives, and in a few cases have not included influential authors whose lives we have found less interesting. This has led us to omit certain areas important to the history of systems thinking which were not developed by clearly identifiable individuals, such as systems engineering. In a number of cases authors produced some of their most well-known works in collaboration with another author but we have chosen to focus on one of the authors – thus we write about Humberto Maturana but not Francisco Varela, about Howard Odum but not Eugene Odum, and about Eric Trist but not Fred Emery. A different book would include all of these authors.

There are many other authors we could have included in this book as well as those already mentioned, and have not, sometimes for the reasons discussed above but also simply for lack of space. These include Bela Banathy, Fritjof Capra, Bob Flood, Adam Kahane, David Kolb, Joanna Macy, James G. Miller, John Mingers, Ian Mitroff, Talcott Parsons, Gordon Pask, Anatol Rapoport and Ralph Stacey.

Groupings

We have grouped the thirty authors into seven categories (see Fig. 0.1). To some extent these groups exist simply as a device to make the book more manageable to read and understand. However they also reflect what to us are coherent groupings of authors. Some of them might be considered explicit schools of thought (such as system dynamics), while others group authors with connected ideas (such as learning systems).

The choices we have made are intended to show clear connections between authors, and a few are deliberately unusual to provoke thought. The groupings were

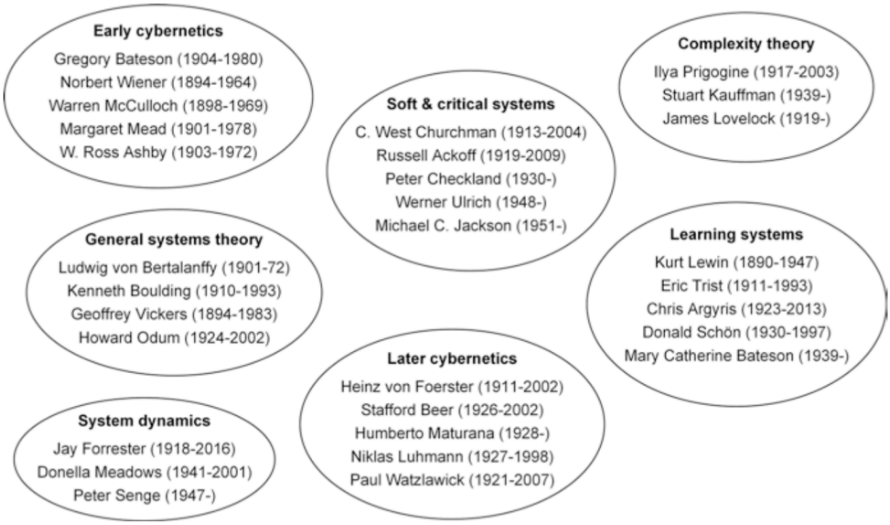

Fig. 0.1 The authors and groupings in this book (updated for 2nd edition)

created from the starting point of our chosen authors, rather than schools of thought, and thus they do not represent a comprehensive guide to a particular school of thought (for example, there are many more thinkers who have contributed to general systems theory than the four we cover). The seven groupings are: early cybernetics, general systems theory, system dynamics, soft & critical systems, later cybernetics, complexity theory, and learning systems, and we will briefly introduce each in turn.

Early cybernetics is a highly influential approach based on the concepts of feedback and information, and the parallels between human and machine behaviour, applying these ideas to a wide range of disciplines. This grouping contains some of the pioneers who shaped the field of cybernetics (Gregory Bateson, Norbert Wiener, Warren McCulloch, Margaret Mead and Ross Ashby). Most of them were core participants in the Macy Conferences on Cybernetics (Ashby was not at most of these conferences, but his publication of the first textbook in the field had a deep influence). While Norbert Wiener coined the term 'cybernetics', and in many ways founded the field, we have chosen to write first about Gregory Bateson, as he represents the first flowering of cybernetics at its richest and broadest.

General systems theory is concerned with issues of open systems, emergence, boundary and hierarchy. The general systems movement championed interdisciplinarity long before it was widespread, with its goal of 'science in the service of humanity'. Our grouping contains four thinkers, two of whom can rightly be said to be the founders of general systems (Ludwig von Bertalanffy and Kenneth Boulding) and two slightly later thinkers who explicitly identified their work as being within general systems (Geoffrey Vickers and Howard Odum).

System dynamics focuses on computer modelling of systems with a high degree of feedback and circularity. It has its origins largely in the work of one man, Jay Forrester, and our grouping includes Forrester along with two of his students who have had enormous influence, Donella Meadows and Peter Senge. System dynamics is hugely important and interesting, but has been historically slightly isolated from other systems approaches; this section of the book shows some of the similarities and differences between system dynamics and other approaches.

Soft and critical systems is a highly applied approach that arises from the use of techniques from systems engineering and operational research to human systems, especially in management and public policy, and a sense of dissatisfaction with the capacity of those techniques to take account of the reality of human systems. These experiences led the thinkers in this section (C. West Churchman, Russell Ackoff, Peter Checkland, Werner Ulrich and Mike Jackson) to create a new set of methodologies that explicitly considered issues such as multiple perspectives, power and intractable problems with no simple solutions.

Later cybernetics is a grouping of several different authors who all have their roots in the work discussed in the 'early cybernetics' grouping, and thus form a second generation of cyberneticians, but who have each taken that work in somewhat different directions. The thinkers in this group are Heinz von Foerster, Stafford Beer, Humberto Maturana, Niklas Luhmann and Paul Watzlawick. There is a considerable overlap with the 'second-order cybernetics' approach described by Heinz von Foerster – which takes into account the observer as well as the observed – but not all of the thinkers in this group sit neatly into that approach. All the thinkers in the group fall within the category we have elsewhere described as 'soft cybernetics', but so do some of the early cybernetics group, so we have chosen to describe this group in purely historical terms.

Complexity theory is an approach to the modelling of highly complicated and interconnected systems using techniques derived from the physical sciences, with a focus on self-organisation, emergence and nonlinearity. It takes inspiration both from general systems theory and cybernetics. Our grouping contains three scientists who have done crucial work in developing this approach to complex systems: Ilya Prigogine, Stuart Kauffman and James Lovelock. This grouping is slightly wider than complexity *science*, an approach initially developed at the Santa Fé Institute (where Kauffman is based); Prigogine and Lovelock take a somewhat similar approach in terms of computer modelling of complex systems and a focus on self-organisation, but the three thinkers developed their work largely independently of each other.

Learning systems is a broad group of thinkers with a common focus on the way people learn and the systems within which they learn. It begins with the important work of Kurt Lewin, who died young in the very early days of systems thinking but had a huge influence upon its developing work. The grouping continues with three thinkers who are strongly part of Lewin's tradition (as well as being influenced by other systems work) – Eric Trist, Chris Argyris and Donald Schön. The group ends with Mary Catherine Bateson, who presents one of the most refined and complete examples of a unified systems approach to learning and to life.

Acknowledgements

In conducting such a long and all-consuming project as this, we have been helped along the way by very many people, and while we can mention only a few of them, we are deeply grateful to everyone who has encouraged us through this journey.

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Bill Laidlaw, Tony Nixon, Becky Calcraft and Martin Reynolds were extremely helpful in reading drafts of various chapters and offering valuable advice on making them better.

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Introduction to the Second Edition

You hold in your hand (or have on your screen) a collective love letter to some of the most remarkable people in academia and professional practice over the past century. Authoring the first edition of the book was an incredible privilege and joy in a long project that took around 7 years (see the Afterword at the back of this book, which is unchanged from the first edition). Ten years have passed since the original edition, and the success of the Masters programme which it supported has created the opportunity to update and refine our work. We have spent about a year on this second edition, and it has been just as much of a joy and a privilege to read more about these thinkers. The goals of the book have always been both to introduce these 30 people to a wider audience and to encourage readers to find the works of these thinkers and read them in the originals.

I am more convinced than ever of the utter necessity of systems thinking to our world at this time. As I write this, the world is finally beginning to wake up to the climate emergency, finally listening to courageous young people on climate strikes and longer-established (but often ignored) climate scientists; yet real action to deal with the climate emergency is not yet happening. Meanwhile, the impact of the 2008 financial crash still remains unresolved in many parts of the world and has metastasised in all too many places into nationalism and autocracy, even in liberal democracies long free of such menaces. Mobile communications with their ubiquitous information and the nascent 'Internet of Things' are a great boon, but also risk creating societies where citizens' every actions are tracked, leading to phenomena such as what Zuboff (2019) calls 'surveillance capitalism'.

Many more examples could be given of issues in society which are characterised by deeply interconnected and highly complex amalgams of people, cultures, organisations, technology, politics and physical environment. The thinkers in this book, if taken seriously, between them have much to offer to those seeking an understanding of these difficult and complex issues in the world.

The second edition of this book is extensively revised from the first edition. We have studied each chapter thoroughly and amended it in the light of new scholarship about the thinkers and their work. My intention was to read, at least briefly, every article or book written about our thinkers since the publication of the original book (so roughly the period from 2008, when we handed over the book to the publisher, until 2019). There have been many such sources. First, many of our thinkers are still alive and writing new material. In almost all cases, there has been significant use of the thinkers' ideas by other authors, sometimes in ways that simply illustrate their importance and sometimes in ways that illuminate the original writings considerably. In several cases, there have been full-length biographies of the thinkers (including Warren McCulloch, Ludwig von Bertalanffy, Kenneth Boulding and Eric Trist) or books which discuss one or more of our thinkers at length (such as Kline 2015). These have provided new perspectives and insights into our thinkers' lives and ideas. Then, there have been anniversary conferences with published proceedings, such as the 50th anniversary of Norbert Wiener's death in 2014 and the 100th birthday celebrations of James Lovelock in 2019. And lastly, sadly, three thinkers have died since the first edition was completed (Chris Argyris, Russell Ackoff and Jay Forrester), giving rise to new resources through obituaries and the like.

Taking all these resources together, we have revised the 'narrative' parts of each chapter (describing the life and work of the thinkers, as opposed to extracts from their work). The original chapters were crafted with care through numerous drafts, so we have tried to preserve the integrity of each. However, with the perspective of time and continuing scholarship, the balance of what is most significant or relevant has sometimes changed, leading us to remove small passages that have become less relevant, while adding new insights, quotes and developments. The publisher (Springer) kindly agreed to let us increase the length of the book a little, but not by a huge amount, so we have sought to prune as well as grow the chapters.

There are things that in a different kind of revision we might have amended but have chosen not to change here. We have left intact the existing readings from the thinkers – we considered each one carefully, and all represent the authors well.

We have also not changed the list of thinkers discussed in the book. We thought long and hard about this issue. I have frequently been asked at conferences why particular authors were not included, sometimes with considerable passion. In the introduction to the first edition, we mentioned a number of names who could have been included and would stand by all these. The authors we most often have been asked to add, or ourselves regret not including, are Joanna Macy, Gordon Pask, Bela Banathy, Edgar Morin, Donald Mackay and Ken Wilber. However, to incorporate further authors would have meant increasing the book significantly, potentially unbalancing the groupings of authors, and also a considerable amount of work, so we decided not to do so in this edition.

We also decided not to remove any of the authors from those in the first edition. We gave our rationale in the previous introduction as to why we included our original authors. This rationale still stands good and still applies to all included. In each case, when reading the original chapter, we asked ourselves whether the author still had a place in the book and were very clear that this was the case for all 30 authors. All of the authors are important, and some are extremely relevant today, some even more so than when they first wrote, while some are not widely enough read (such as the work of Geoffrey Vickers and Donald Schön); others are more of their time and introduced important ideas which others have built upon.

Ten years have passed since the authorship of the original chapters, and as I have conducted most of the revision of the chapters, it may be helpful to know of my influences since that time. These have been fourfold.

First, I have spent much of the time focused on questions of information – the way in which multiple disciplines understand and conceptualise information differently. This has led to a number of academic conferences and workshops, an edited book (Ramage and Chapman 2011) and various special issues of journals.

Second, I spent more than 4 years as editor in chief of the long-established journal *Kybernetes* (working with three coeditors from The OU), which we had already cited a number of times in the book, and in that capacity spent a lot of time thinking about cybernetics and attending conferences of the American Society for Cybernetics.

Third, I have more recently been concerned with critical approaches to informational phenomena, working closely with colleagues who have a deep concern for the interaction between information technologies and race, gender and class (among other factors).

And fourth, I have written a number of papers which built on the scholarship that Karen and I gathered together for this book, and this has expanded my thinking about a number of the authors discussed here (Ramage 2009; Ramage 2011; Ramage and Shipp 2012; Ramage and Bissell 2015; Ramage 2017).

Each of these strands can be seen in places in the revisions of the chapters. We note two insights in particular. First, the multidisciplinary concept of information clearly has its roots in cybernetics but can be said to split into two broad forms (Ramage 2011) – a 'soft' view of information which emphasises the role of meaning and the observer, arising from Bateson's work, and a 'hard' view of information which treats information as a quasi-physical object removed from context, arising from Wiener's work. Second, there are striking similarities in the way that the use of diagrams developed in several areas of systems thinking, in each of which, there was a 'two-stage shift of technological to human modelling, and mathematical to qualitative modelling' (Ramage and Shipp 2012, p.122), Forrester's system dynamics, Beer's management cybernetics, Odum's systems ecology diagrams and the diagrams used to teach systems thinking for more than 40 years at our own base, The Open University.

So I have learnt much about the people and ideas in the book since its original publication. I remain captivated by some of the images that the authors introduced me to, from Ilya Prigogine's whirlpool of water (a dissipative structure) when emptying a bathtub to the idea that the crashing of waves at the seashore represents not their culmination but their death, from Stafford Beer (which inspired the image on the cover of this edition). I hope you find your own insights in this book.

For many years, editorials of the journal *Systems Practice* (now *Systemic Practice and Action Research*) would end with the phrase 'I wish you good systems practice'. We might close by wishing the reader of this second edition something similar – I wish you good systems thinking.

Lastly, I wish to add to the acknowledgements from the first edition. Thanks to those who have helped in the production of this edition at The Open University, especially Gill Gowans, Caz Williams and Gemma Byrne. Thanks to the encouragement from academic colleagues within the university and collaborators on some of the work mentioned above, especially Martin Reynolds, Ray Ison, David Chapman, Patrick Wong, Mustafa Ali, Derek Jones and the late Chris Bissell. Thanks to the inspiring and challenging discussions at conferences with Manfred Drack, Ockie Bosch, Wolfgang Hofkirchner, Nora Bateson and the late Ranulph Glanville. Thanks to Karen Shipp for coming out of retirement to spend a year working on this second edition with me. Thanks to my late father, Alastair Ramage, who throughout his final illness was always interested in my progress on the second edition. And lastly, thanks again to Becky and Alice for their support and encouragement and to Gregory who appeared in our lives the same month as the first edition and has inspired me with his questions ever since.

Milton Keynes Magnus Ramage
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Part I
Early Cybernetics

Exploring parallels between the behaviour of cognitive and engineered systems, with a focus on feedback and information.

Chapter 1
Gregory Bateson

Gregory Bateson, anthropologist and philosopher, was a deeply original thinker who crossed multiple disciplines, always sitting on the edge between them. He began only late in life to attempt to synthesise his work, and eventually described his intellectual journey as: "from biology at the beginning, into anthropology, into systems of ideas, pathologies of systems of ideas, and then to systems of ideas which are how we all try and live together – and 'we all' includes the animals and the plants as well as you and me" (G. Bateson speaking in 1976, quoted in N. Bateson 2011).

He was perhaps the most wide-ranging and profound thinker in early cybernetics, and his work provides a foundation for much of the important work that followed, and a still-challenging insight into the problems of the world today. Practically every discussion of Bateson's work contains a different list of his disciplinary interests. He worked at one time or another in zoology, anthropology, cybernetics, communications theory, psychiatry, ethology (animal behaviour) and philosophy; and he also had a strong impact on family therapy, the environmental movement and organisational theory. His contribution to each of these fields was profound, but he was always ready to move on – as one biographer put it, he "posted himself to the margins of not one, but multiple disciplines from which he secluded and then absented himself" (Lipset 2005, p. 911).

Although he was an outsider in terms of disciplinary allegiance, he was part of a formidable intellectual dynasty. His grandfather, William Bateson, was a modernising Master of St Johns College, Cambridge. His father, also William, was a key early geneticist, who coined the word 'genetics' and brought the concepts of Gregor Mendel to wider attention. Gregory Bateson was married for more than a decade to the celebrated anthropologist Margaret Mead. Two of his daughters, by different mothers, Mary Catherine Bateson and Nora Bateson, have themselves become well-respected systems thinkers, drawing on their father's life and legacy as well as going beyond his ideas (M. C. Bateson 2004; N. Bateson 2016).

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Bateson's relationship with his father was not an easy one – Gregory was William Bateson's youngest son but both his elder brothers died (one in the First World War, the other through suicide) so that the considerable weight of his father's expectations fell upon Gregory. He inherited a deep intellectual self-confidence as well as an admiration for influential outsiders (such as William Blake, a hero of both father and son). Toulmin (1984, p. 3) summarises this background as follows:

> His strong physical presence – his great height and eagle profile – and the blend of intellectual confidence and personal diffidence that he inherited from the Cambridge tradition of natural science (his father, William Bateson, was a founder of modern genetics) gave him the personal and intellectual power to move in quietly on virtually any debate and reshape it according to his own perspective. With his biological background, he was fully aware of current scientific orthodoxy, but he treated it as a theme on which to compose personal variations, and these, while sometimes eccentric, illuminated whatever they touched.

Bateson was born in 1904 in Cambridge and died in 1980 in San Francisco. His list of institutional affiliations is long, including St Johns College (Cambridge University), the University of California Medical School, the Veteran's Administration Hospital in Palo Alto (California), the Oceanic Institute (Hawaii) and the University of California at Santa Cruz. He also held many visiting professorships at other institutions. His research was carried out in a wide variety of contexts – as an anthropologist, with peoples in New Guinea and Bali; during the war, with the US Office of Strategic Services (forerunner to the CIA); with psychiatric patients; with porpoises and dolphins; and on environmental issues.

However, perhaps Bateson's strongest 'institutional' affiliation was to a different form of group: the Macy conferences on cybernetics, discussed in the chapters on Wiener and McCulloch. He was a member of the core group at these conferences, attending all ten conferences in the series and having a strong influence (along with Margaret Mead) as a social scientist who took seriously the concept of cybernetics as it unfolded. He had independently developed the concept of positive feedback, but the idea of negative feedback, and the general framework of cybernetic ideas, was of great importance to him. He later referred to the Macy conferences as "one of the great events of my life" (quoted by Brockman 2004) and there are frequent references to cybernetics in most of his subsequent writings.

Bateson's contributions to knowledge are almost as hard to summarise as his disciplinary or institutional connections. Some of these can be found in specific ideas, which have been important in various fields: the anthropological concept of *schismogenesis* (positive feedback loops leading to increasing destruction of relationships); the psychotherapeutic concept of the *double bind* (patterns of interaction where people are required to behave in two mutually incompatible ways simultaneously); and the concept of *levels of learning* (observing that some forms of learning are at a higher logical level than others, and form various ways of learning how to learn).

To these we can add ideas which are widely quoted, such as his definition of information as the "difference that makes a difference" (G. Bateson 1972, p. 453) and his use of the phrase (borrowed from Alfred Korzybski) that "the map is not the territory" (G. Bateson 1972, p. 449). As Mead (1977, p. 171) summarised these ideas, they "have all been about relationships between individuals or groups of individuals, elaborated and stylized by experience or culture". These are important ideas, and they have had a significant impact – the concept of the double bind was the foundation for the field of family systems therapy, and that of levels of learning has directly contributed to organisational learning via the work of Argyris and Schön.

Bateson's understanding of information in particular treats it as a form of meaning-creation by human beings, rather than quasi-physical process, and is at the heart of a form of 'soft cybernetics' (Ramage 2009) that is somewhat different from the work on second-order cybernetics discussed later in this book. The phrase 'the difference that makes a difference' has inspired many subsequent thinkers about the nature of information (e.g. Hofkirchner 2011; Ramage and Chapman 2011).

However, if we were to take these concepts alone as an indicator of Bateson's thinking or his impact, we would lose most of its essence. In the final decade of his life, Bateson came to realise that in fact all his ideas were closely linked – that he "had not been merely blundering from field to field but had been struggling to develop a way of thinking that would be transferable, systematically, from one subject matter to another" (M. C. Bateson 2004, p. 50). In 1970, he gave the annual Korzybski lecture under the title "Form, Substance and Difference". This forms the most concise description of his thought as a whole, and our extract below is taken from it. Later he wrote that in preparing this lecture (G. Bateson 1972, p. xvi):

> I found that in my work with primitive peoples, schizophrenia, biological symmetry, and in my discontent with the conventional theories of evolution and learning, I had identified a widely scattered set of bench marks or points of reference from which a new scientific territory could be defined.

What was the nature of this new scientific territory? It had several aspects, summed up in his conception of an "ecology of mind":

1. He was concerned with issues of *epistemology*, which for him had become corrupted by centuries of Cartesian dualism with its split between the physical and the mental, and which needed to be reformed around the unity of physical and mental processes.
2. Secondly, Bateson was concerned with issues of *cognition*, which he viewed as a fundamental process in nature, spread across animals as much as humans, and even in humans not confined to events occurring in the brain.
3. Lastly, he was concerned with the nature of *relationship*, of the patterns between mental and physical processes in different parts of nature. In referring to this as an ecology, he was writing as a biologist, and using the term to refer to a set of interacting entities in an environment, rather than the popular use of ecology to refer to issues around the survival of the natural environment.

This last aspect was summed up in his phrase "the pattern which connects". In his book *Mind and Nature* (G. Bateson 1979) this concept was used to explore the patterns which connect all living creatures – that is, the relationship between their similarities and differences. This pattern, he observed, has two major features – first, it is a 'metapattern', that is to say a pattern of patterns, which exists at a higher level of abstraction than simply the immediate similarities and differences between species; and second, it is dynamic rather than static – the relationships are constantly changing, forming “a dance of interacting parts only secondarily pegged down by various sorts of physical limits” (G. Bateson 1979, p. 13). As an illustration of the importance of relationships, he liked when giving talks to ask audiences to look at their hands and observe that as well as having five fingers, they could just as well be said to have *four relations between fingers*, and that this perspective was just as useful as the conventional one.

The range of different concepts that Bateson was able to draw patterns between in this way was quite dizzying, as described by Keesing (1974, p. 370): “What form of madness is it to see as similarly pattern the axial symmetry of marine organisms and Iatmul initiatory grades, or patterns of armament races and falling in love, or leaves and sentences, or mother-child interactions and a muddled telephone exchange, or the play of otters and Russell’s Theory of Logical Types?” All these situations were fundamental to Bateson’s interests – but so were the work of William Blake, the biblical Book of Job, the behaviour of people with schizophrenia, and the nature of thought and mind. He defied categories – although a lifelong atheist, his final work, completed posthumously by his daughter, was an investigation in the nature of spirituality and its connection to the natural world (Bateson and Bateson 1987).

Bateson’s eclectic mix of interests and his marginality led to a curious phenomenon during his life which has continued posthumously – he has been both lionized and ignored. Individual parts of his writing have had considerable impact upon a range of fields, but the whole pattern of his work has taken a long time to be understood and appreciated. There are some signs that this is happening but it is still a work in progress. As one of his former colleagues argued in a celebratory conference on his legacy: “The professionalization of academia has not helped spread Bateson’s message. He had no patience for revisionists and his multidimensional mind does not fit into any discipline.” (Wilder 2013)

He was a teacher of many, and many former colleagues and students took him to their heart: his colleagues in the Palo Alto group where double-bind theory was developed; students at the New School in New York at the University of Santa Cruz in California; visitors to the Esalen Institute where he spent his final years; and many others. One of his students, later a distinguished improvisational violinist, wrote that:

> Gregory taught by encouragement. Much of his subject matter – how pathology works, whether at an interpersonal level or at the level of human beings wrecking their own environment – was not cheerful, but as a person and teacher he was full of jokes and stories. Gregory loved to laugh, that is probably the first thing I noticed about him. He encouraged me to keep exploring as an artist, he encouraged other students to be scientists and dig deep with good questions, he encouraged all of us to write and think. He did not say that these were futile gestures in the face of species doom. (Nachmanovitch 2013, p. 1444)

In the final decade of his life, Bateson’s work took on a new focus. In 1968, Bateson wrote that “it may well be that consciousness contains systematic distortions of view which, when implemented by modern technology, become destructive of the balances between man, his society, and his ecosystem" (G. Bateson 1972, p. 440). This formed the basis of a conference he organised on the "Effects of Conscious Purpose on Human Adaptation" (M. C. Bateson 1972). Through this conference, Bateson came to the conclusion that the danger of environmental destruction – the risks of which were by then already apparent – arose from the deep-seated Western worldview that it is possible to make a separation between the organism, or species, and its environment.

This is a call to a new form of epistemology, which understands humanity within its environment, and Bateson's answer to it lay within his conception of an ecology of mind. As Mary Catherine Bateson (2000, p. xiv) wrote, "Bateson was haunted in his last years by a sense of urgency, a sense that the narrow definition of human purposes, reinforced by technology, would lead to irreversible disasters, and that only a better epistemology could save us". Perhaps it is only now, as ecological disaster becomes more and more pressing, that Bateson's originality and importance can begin to be fully appreciated.

Reading from G. Bateson's work

We can now say – or at any rate, can begin to say – what we think a mind is. In the next 20 years there will be other ways of saying it and, because the discoveries are new, I can only give you my personal version. The old versions are surely wrong, but which of the revised pictures will survive, we do not know.

Let us start from the evolutionary side. It is now empirically clear that Darwinian evolutionary theory contained a very great error in its identification of the unit of survival under natural selection. The unit which was believed to be crucial and around which the theory was set up was either the breeding individual or the family line or the subspecies or some similar homogeneous set of conspecifics. Now I suggest that the last 100 years have demonstrated empirically that if an organism or aggregate of organisms sets to work with a focus on its own survival and thinks that that is the way to select its adaptive moves, its "progress" ends up with a destroyed environment. If the organism ends up destroying its environment, it has in fact destroyed itself. And we may very easily see this process carried to its ultimate *reductio ad absurdum* in the next 20 years. The unit of survival is not the breeding organism, or the family line, or the society.

The old unit has already been partly corrected by the population geneticists. They have insisted that the evolutionary unit is, in fact, not homogeneous. A wild population of any species consists always of individuals whose genetic constitution varies widely. In other words, potentiality and readiness for change is already built into the survival unit. The heterogeneity of the wild population is already one-half of that trial-and-error system which is necessary for dealing with environment.

The artificially homogenized populations of man's domestic animals and plants are scarcely fit for survival.

And today a further correction of the unit is necessary. The flexible environment must also be included along with the flexible organism because, as I have already said, the organism which destroys its environment destroys itself. The unit of survival is a flexible organism-in-its-environment.

Now, let me leave evolution for a moment to consider what is the unit of mind. Let us go back to the map and the territory and ask: "What is it in the territory that gets onto the map?" We know the territory does not get onto the map. That is the central point about which we here are all agreed. Now, if the territory were uniform, nothing would get onto the map except its boundaries, which are the points at which it ceases to be uniform against some larger matrix. What gets onto the map, in fact, is *difference*, be it a difference in altitude, a difference in vegetation, a difference in population structure, difference in surface, or whatever. Differences are the things that get onto a map.

But what is a difference? A difference is a very peculiar and obscure concept. It is certainly not a thing or an event. This piece of paper is different from the wood of this lectern. There are many differences between them – of color, texture, shape, etc. But if we start to ask about the localization of those differences, we get into trouble. Obviously the difference between the paper and the wood is not in the paper; it is obviously not in the wood; it is obviously not in the space between them, and it is obviously not in the time between them. (Difference which occurs across time is what we call "change".)

A difference, then, is an abstract matter.

In the hard sciences, effects are, in general, caused by rather concrete conditions or events – impacts, forces, and so forth. But when you enter the world of communication, organization, etc., you leave behind that whole world in which effects are brought about by forces and impacts and energy exchange. You enter a world in which "effects" – and I am not sure one should still use the same word – are brought about by *differences*. That is, they are brought about by the sort of "thing" that gets onto the map from the territory. This is difference.

Difference travels from the wood and paper into my retina. It then gets picked up and worked on by this fancy piece of computing machinery in my head.

The whole energy relation is different. In the world of mind, nothing – that which is *not* – can be a cause. In the hard sciences, we ask for causes and we expect them to exist and be "real". But remember that zero is different from one, and because zero is different from one, zero can be a cause in the psychological world, the world of communication. The letter which you do not write can get an angry reply; and the income tax form which you do not fill in can trigger the Internal Revenue boys into energetic action, because they, too, have their breakfast, lunch, tea, and dinner and can react with energy which they derive from their metabolism. The letter which never existed is no source of energy.

It follows, of course, that we must change our whole way of thinking about mental and communicational process. The ordinary analogies of energy theory which people borrow from the hard sciences to provide a conceptual frame upon which they try to build theories about psychology and behavior – that entire Procrustean structure – is non-sense. It is in error.

I suggest to you, now, that the word "idea", in its most elementary sense, is synonymous with "difference". Kant, in the *Critique of Judgment* – if I understand him correctly – asserts that the most elementary aesthetic act is the selection of a fact. He argues that in a piece of chalk there are an infinite number of potential facts. The *Ding an sich*, the piece of chalk, can never enter into communication or mental process because of this infinitude. The sensory receptors cannot accept it; they filter it out. What they do is to select certain *facts* out of the piece of chalk, which then become, in modern terminology, information.

I suggest that Kant's statement can be modified to say that there is an infinite number of *differences* around and within the piece of chalk. There are differences between the chalk and the rest of the universe, between the chalk and the sun or the moon. And within the piece of chalk, there is for every molecule an infinite number of differences between its location and the locations in which it *might* have been. Of this infinitude, we select a very limited number, which become information. In fact, what we mean by information – the elementary unit of information – is a *difference which makes a difference*, and it is able to make a difference because the neural pathways along which it travels and is continually transformed are themselves provided with energy. The pathways are ready to be triggered. We may even say that the question is already implicit in them.

There is, however, an important contrast between most of the pathways of information inside the body and most of the pathways outside it. The differences between the paper and the wood are first transformed into differences in the propagation of light or sound, and travel in this form to my sensory end organs. The first part of their journey is energized in the ordinary hard-science way, from "behind". But when the differences enter my body by triggering an end organ, this type of travel is replaced by travel which is energized at every step by the metabolic energy latent in the protoplasm which *receives* the difference, recreates or transforms it, and passes it on.

When I strike the head of a nail with a hammer, an impulse is transmitted to its point. But it is a semantic error, a misleading metaphor, to say that what travels in an axon is an "impulse". It could correctly be called "news of a difference".

Be that as it may, this contrast between internal and external pathways is not absolute. Exceptions occur on both sides of the line. Some external chains of events are energized by relays, and some chains of events internal to the body are energized from "behind". Notably, the mechanical interaction of muscles can be used as a computational model.

In spite of these exceptions, it is still broadly true that the coding and transmission of differences outside the body is very different from the coding and transmission inside, and this difference must be mentioned because it can lead us into error.

We commonly think of the external "physical world" as somehow separate from an internal "mental world". I believe that this division is based on the contrast in coding and transmission inside and outside the body.

The mental world – the mind – the world of information processing – is not limited by the skin.

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Chapter 2
Norbert Wiener

Norbert Wiener, founder of cybernetics, was a unique personality, a larger-than-life character famous for his very wide interests, extremely incisive mind and personal warmth, but also for his absent-mindedness, low self-esteem, and severe mood-swings. He was born in midwestern USA (Missouri) in 1894 to a Jewish family – his father had emigrated from Russia and his mother from Germany. Although the family were descended from the great twelfth century philosopher Moses Maimonides, their Jewishness was hidden from Wiener during his childhood, and he practised no religion until late in life.

Wiener was a child prodigy: he learned his alphabet at 18 months, obtained his bachelors degree at age 14 (from Tufts), and his PhD at age 18 (from Harvard). This was partly due to his exceptional ability, but also to the teaching regime of his father. Leo Wiener insisted on absolute correctness in all of young Norbert's work, responding indifferently to correct answers but with great anger to errors. When Norbert Wiener married in 1926, it was with much relief at gaining freedom from his father (Conway and Siegelman 2005). After postdoctoral work in Europe and a number of short-term jobs, Wiener took up a post as an instructor at the Massachusetts Institute of Technology (MIT) in 1919. He stayed at MIT for the rest of his life, becoming a full professor in 1931.

At MIT, Wiener was famous as a walker. He would walk around the corridors endlessly, talking to everyone he met (regardless of status or academic discipline), or absorbed in his own thoughts. His route was known as the *Wienerweg* (the German *weg* means walk or route) and he always took the path he insisted upon, regardless of what else was happening on it. Many anecdotes are told of Wiener's insistence on sticking to his route and his absent-mindedness. In one story, recounted by Heims (1980) among others, Wiener was said to have met a student around mid-day. After a long conversation, Wiener asked the student "can you tell me which way I was walking when we met – towards the canteen or away from it?" It was only the student's response that enabled Wiener to remember whether or not he had yet had lunch.

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He was a traveller in many other ways, "a man in near perpetual motion" (Conway and Siegelman 2005, p.82). He was a visiting scholar at a number of universities outside his country, mostly notably in Cambridge (England), Göttingen (Germany) and Mexico City – in the 1920s in particular his mathematical work was better appreciated in Europe than in the United States. He also made significant academic visits to China, Russia and India, with big impacts on scientific work in each country. Indeed he died on an international visit, of a heart attack on the steps of the Royal Institute of Technology, Stockholm, in 1964.

He was also an intellectual traveller. Although he always saw himself as a mathematician, he forged close working links with biologists, physiologists, engineers and social scientists. Two of his most important collaborations were with biologists, Arturo Rosenbleuth and Warren McCulloch, and these led directly to the development of cybernetics. He became well-known as a public figure for his scientific and social statements, and also had a poetic side. Writing on the concept of homeostasis (the self-regulation of living things) and its link to personal identity, Wiener remarked that "We are but whirlpools in a river of ever-flowing water. We are not stuff that abides, but patterns that perpetuate themselves." (Wiener 1954, p.96).

As a summary of Wiener's personality, one of his biographers (who worked with him on his later mathematical work) describes him as:

> Proverbially absent-minded, amusingly quirkish and idiosyncratic, he was fundamentally a gentle and humane soul. He was, however, given to recurrent manifestations of petulance, egoism, emotional instability, irrational insecurity and anxiety. His moods could swing from euphoria to gloom or vice versa on slight provocation (Masani 1990, p. 16)

Wiener's work can be approximately split into three areas: his mathematical work, his work in cybernetics, and his work as a social and political commentator, and we shall discuss each of these in turn.

It is tempting to think of Wiener largely as a cybernetician. This was not his own self-image, and indeed for the majority of his time at MIT, he was attached to the Department of Mathematics. Wiener's doctoral work was an extension of the logic of Bertrand Russell, then recently published in the great *Principia Mathematica* (1911). Following his doctorate, and still less than 20 years old, Wiener obtained a 2 year fellowship from Harvard to do postdoctoral work in England and Germany, with some of the great minds of his time within pure mathematics – Russell himself and G.H. Hardy in Cambridge, and David Hilbert in Göttingen.

His key mathematical work, however, was in the field of applied mathematics, in which area he made many important contributions in the 1920s and 1930s. Perhaps most notable was his work in extending the theories of Lebesgue, Gibbs and Einstein to construct a technique for the statistical analysis of wave patterns, still known as the Wiener measure. He began this work in relation to Brownian motion (the semi-random movement of particles), leading ultimately to the statistical analysis of control systems and of communication which would be so important in the development of cybernetics. This work was also a major contributor to the theory of stochastic process, the foundation of modern probability theory.

Wiener's contribution to the founding of cybernetics cannot be overestimated, although many others played a part as well. He introduced the word 'cybernetics', a coinage from the Greek *kubernētēs*, 'steersman' (the navigator of a ship), as a term for "the entire field of control and communication theory, whether in the machine or in the animal" (Wiener 1948, p. 11). The term was also intended to refer back to the 'governor', the portion of an engine that ensures its effective operation. The word 'governor' is derived from a Latinized form of *kubernētēs*, and indeed the French physicist André-Marie Ampère used the term *cybernétique* to describe a theory of government in the nineteenth century, although Wiener was unaware of this when he coined the modern term. Through the publication of his book *Cybernetics* (1948) and the more popularly-focused *The Human Use of Human Beings* (1950), the concept became known rapidly to a wide public audience.

Wiener's definition of cybernetics contains two important paired concepts. He was clear that control (in physiological and engineering terms) and communication were highly related phenomena, and could be expressed in terms of *feedback*. He wrote that control and communication "centred not around the technique of electrical engineering but around the much more fundamental notion of the *message*, whether this should be transmitted by electrical, mechanical, or nervous means. The message is a discrete or continuous sequence of measurable events distributed in time" (Wiener 1948, p. 8). This concept of the message was crucial to the early development of communications theory, formalised on similar lines by Shannon and Weaver (1949), as was Wiener's definition of *information* as "a measure of [the] degree of organization" of a system (Wiener 1948, p. 11) and the mathematical negative of the entropy of that system – which he referred to as *negentropy*. Wiener regarded negative feedback as much more important and useful than positive feedback, leading to stability and effective control – he saw positive feedback as dangerous and unstable.

The other pair of concepts in Wiener's definition of cybernetics were the machine and the animal. In the 1930s and early 1940s, Wiener had conducted two major research projects – with Arturo Rosenbleuth on feedback within human and animal physiology; and with Julian Bigelow on the building of control systems for anti-aircraft weaponry (during World War II), again based on feedback principles. Rosenbleuth et al. (1943) put these projects together with the statement that "all purposeful behaviour may be considered to require negative feedback" (p. 19). This article is one of the most important early documents of cybernetics, along with an article by McCulloch and Pitts (1943), discussed in the chapter on McCulloch.

The parallel between human and machine activities was particularly important to the development of digital computers, then in its early stages. For this reason, cybernetics became rapidly identified in the public mind with these new technologies – hence the modern use of the term 'cyber' in compound words such as cyberspace. As Hayles (1999, p. 7) has written, "humans were to be seen primarily as information-processing entities who are *essentially* similar to intelligent machines". The equating of human and machine activities was to prove extremely important in a wide range of disciplines (including computing, psychology and management among others) but then was an almost entirely new concept, and it was the field of cybernetics which played a big part in making the concept widely known.

Wiener's final crucial contribution to cybernetics was his central role in the Macy conferences. This conference series – 10 two-day conferences from 1946 to 1953 – is frequently regarded as the founding event of cybernetics. Wiener was "the dominant figure at the conference series, in his role as brilliant originator of ideas and *enfant terrible*" (Heims 1980, p. 206). These conferences, organised and chaired by Warren McCulloch, at first had the rather clumsy (if descriptive) title of the Conference for Circular Causal and Feedback Mechanisms in Biological and Social Systems. This title in itself expresses Wiener's range of concerns very clearly, and his role as the 'founding father' of the conferences and the field. This role became even clearer at the sixth Macy conference (in 1949) when, at the suggestion of Heinz von Foerster, the title of the conference series was amended to the Conference on Cybernetics, a decision that moved Wiener greatly (von Foerster and Poersken 2002, p. 136).

Von Foerster's later introduction of the term 'second-order cybernetics' – the inclusion of the observer as a component of the cybernetic system under study – is often taken to exclude Wiener, to cast him on the 'wrong' side of a conceptual divide. This is not accurate, as a number of commentators have discussed. In a conversation with Gregory Bateson and Margaret Mead (both participants in the Macy conferences), discussing an input-output model with a box that encloses the feedback loops of a cybernetic system, Brand (1976) observed that "the engineer is outside the box … and Wiener is inside the box" – that is, considering himself to be part of the system. Bernard-Weil (1994) has similarly argued that a number of the concepts key to second-order cybernetics, such as autonomy, dialogue and self-organization, can be found in Wiener's work, albeit not as central concerns.

Wiener later quarrelled with McCulloch for personal reasons, and never spoke to him again despite both working at MIT. This split in the founders of cybernetics impacted profoundly upon the discipline, leading to a lack of integration between the approaches of Wiener (mathematical and largely focused on analogue communications phenomena) and those of McCulloch (neurophysiological and increasingly focused on digital communications).

Wiener's technical work in cybernetics continued long after the end of the Macy conferences. Although he refused to accept government or military research funding, he was involved in significant work on prosthetics (hearing aids and artificial arms) which fitted closely with his conception of cybernetics. However, in the final years of his life, he was most prominent in spreading the ideas of cybernetics and in warning about its impact upon society.

Wiener devoted much of his time in the last 20 years of his life to discussing the social and political implications of cybernetics, automation and the modern role of science. Although he had been actively involved in military research during World War II, he refused to co-operate with military work after the war, writing in a public statement that "the experience of the scientists who have worked on the atomic bomb has indicated that in any investigation of this kind the scientist ends by putting unlimited powers in the hands of the people whom he is least inclined to trust with their use" (Wiener 1947). From that point on, Wiener also refused to receive funding from military (and later government) sources and to participate in conferences sponsored by the military.

This stance gained him considerable public respect, but was a difficult one to take in the US of the late 1940s and early 1950s – not least because he was based at MIT, the bulk of whose research was funded by the military in that time. In the American political purges of the early 1950s led by Senator Joseph McCarthy, Wiener was investigated by the FBI but his public profile as an independent intellectual protected him and he escaped any persecution. He also used this profile to promulgate a view of cybernetics somewhat different from its public image:

> Wiener promoted cybernetics as a civilian science and tried to control its image by distancing it from the military and from fringe groups. To him, it was a means to bridge engineering and biology for peaceful purposes, not a Cold War science, science fiction, nor a scientific fad. (Kline 2015, p.83)

Wiener also commented frequently on the effects of cybernetics upon the fabric of society. His book *The Human Use of Human Beings* (Wiener 1954), from which our reading is taken, describes the nature of the forthcoming cybernetic developments for a popular audience but also tempers them with a moral humanism, continuing his view that technologies can never be neutral. Some of his writing has become still more relevant due to technological advances. As Hill (2015, p.72) observes:

> One of the technologies that worried Wiener most was the one he was most directly responsible for creating, automation. Today we are hearing a striking amount of public discussion and debate about the impact automation is likely to have on employment. That intelligent machines might be used by owners and managers to eliminate or demean jobs on a massive scale was a prospect that Wiener spoke of often.

Notwithstanding his concerns about the impact of his work, Norbert Wiener's contributions had a ground-breaking and long-lasting effect in a huge range of fields, both theoretical and practical. He was a true pioneer.

Reading from Wiener's work

Extract from pages 16–18 and 24–27.

In giving the definition of Cybernetics in the original book (Wiener 1948), I classed communication and control together. Why did I do this? When I communicate with another person, I impart a message to him, and when he communicates back with me he returns a related message which contains information primarily accessible to him and not to me. When I control the actions of another person, I communicate a message to him, and although this message is in the imperative mood, the technique of communication does not differ from that of a message of fact. Furthermore, if my control is to be effective I must take cognizance of any messages from him which may indicate that the order is understood and has been obeyed.

It is the thesis of this book that society can only be understood through a study of the messages and the communication facilities which belong to it; and that in the future development of these messages and communication facilities, messages between man and machines, between machines and man, and between machine and machine, are destined to play an ever-increasing part.

When I give an order to a machine, the situation is not essentially different from that which arises when I give an order to a person. In other words, as far as my consciousness goes I am aware of the order that has gone out and of the signal of compliance that has come back. To me, personally, the fact that the signal in its intermediate stages has gone through a machine rather than through a person is irrelevant and does not in any case greatly change my relation to the signal. Thus the theory of control in engineering, whether human or animal or mechanical, is a chapter in the theory of messages.

Naturally there are detailed differences in messages and in problems of control, not only between a living organism and a machine, but within each narrower class of beings. It is the purpose of Cybernetics to develop a language and techniques that will enable us indeed to attack the problem of control and communication in general, but also to find the proper repertory of ideas and techniques to classify their particular manifestations under certain concepts.

The commands through which we exercise our control over our environment are a kind of information which we impart to it. Like any form of information, these commands are subject to disorganization in transit. They generally come through in less coherent fashion and certainly not more coherently than they were sent. In control and communication we are always fighting nature's tendency to degrade the organized and to destroy the meaningful; the tendency, as Gibbs has shown us, for entropy to increase.

Much of this book concerns the limits of communication within and among individuals. Man is immersed in a world which he perceives through his sense organs. Information. that he receives is coordinated through his brain and nervous system until, after the proper process of storage, collation, and selection, it emerges through effector organs, generally his muscles. These in turn act on the external world, and also react on the central nervous system through receptor organs such as the end organs of kinaesthesia; and the information received by the kinaesthetic organs is combined with his already accumulated store of information to influence future action.

Information is a name for the content of what is exchanged with the outer world as we adjust to it, and make our adjustment felt upon it. The process of receiving and of using information is the process of our adjusting to the contingencies of the outer environment, and of our living effectively within that environment. The needs and the complexity of modern life make greater demands on this process of information than ever before, and our press, our museums, our scientific laboratories, our universities, our libraries and textbooks, are obliged to meet the needs of this process or fail in their purpose. To live effectively is to live with adequate information. Thus, communication and control belong to the essence of man's inner life, even as they belong to his life in society. […]

For any machine subject to a varied external environment to act effectively it is necessary that information concerning the results of its own action be furnished to it as part of the information on which it must continue to act. For example, if we are running an elevator, it is not enough to open the outside door because the orders we have given should make the elevator be at that door at the time we open it. It is important that the release for opening the door be dependent on the fact that the elevator is actually at the door; otherwise something might have detained it, and the passenger might step into the empty shaft. This control of a machine on the basis of its *actual* performance rather than its *expected* performance is known as feedback, and involves sensory members which are actuated by motor members and perform the function of *tell-tales* or *monitors* – that is, of elements which indicate a performance. It is the function of these mechanisms to control the mechanical tendency toward disorganization; in other words, to produce a temporary and local reversal of the normal direction of entropy.

I have just mentioned the elevator as an example of feedback. There are other cases where the importance of feedback is even more apparent. For example, a gun-pointer takes information from his instruments of observation, and conveys it to the gun, so that the latter will point in such a direction that the missile will pass through the moving target at a certain time. Now, the gun itself must be used under all conditions of weather. In some of these the grease is warm, and the gun swings easily and rapidly. Under other conditions the grease is frozen or mixed with sand, and the gun is slow to answer the orders given to it. If these orders are reinforced by an extra push given when the gun fails to respond easily to the orders and lags behind them, then the error of the gun-pointer will be decreased. To obtain a performance as uniform as possible, it is customary to put into the gun a control feedback element which reads the lag of the gun behind the position it should have according to the orders given it, and which uses this difference to give the gun an extra push.

It is true that precautions must be taken so that the push is not too hard, for if it is, the gun will swing past its proper position, and will have to be pulled back in a series of oscillations, which may well become wider and wider, and lead to a disastrous instability. If the feedback system is itself controlled – if, in other words, its own entropic tendencies are checked by still other controlling mechanisms – and kept within limits sufficiently stringent, this will not occur, and the existence of the feedback will increase the stability of performance of the gun. In other words, the performance will become less dependent on the frictional load; or what is the same thing, on the drag created by the stiffness of the grease.

Something very similar to this occurs in human action. If I pick up my cigar, I do not will to move any specific muscles. Indeed in many cases, I do not know what those muscles are. What I do is to turn into action a certain feedback mechanism; namely, a reflex in which the amount by which I have yet failed to pick up the cigar is turned into a new and increased order to the lagging muscles, whichever they may be. In this way, a fairly uniform voluntary command will enable the same task to be performed from widely varying initial positions, and irrespective of the decrease of contraction due to fatigue of the muscles. Similarly, when I drive a car, I do not follow out a series of commands dependent simply on a mental image of the road and the task I am doing. If I find the car swerving too much to the right, that causes me to pull it to the left. This depends on the actual performance of the car, and not simply on the road; and it allows me to drive with nearly equal efficiency a light Austin or a heavy truck, without having formed separate habits for the driving of the two. […]

It is my thesis that the physical functioning of the living individual and the operation of some of the newer communication machines are precisely parallel in their analogous attempts to control entropy through feedback. Both of them have sensory receptors as one stage in their cycle of operation: that is, in both of them there exists a special apparatus for collecting information from the outer world at low energy levels, and for making it available in the operation of the individual or of the machine. In both cases these external messages are not taken *neat*, but through the internal transforming powers of the apparatus, whether it be alive or dead. The information is then turned into a new form available for the further stages of performance. In both the animal and the machine this performance is made to be effective on the outer world. In both of them, their *performed* action on the outer world, and not merely their *intended* action, is reported back to the central regulatory apparatus. This complex of behaviour is ignored by the average man, and in particular does not play the role that it should in our habitual analysis of society; for just as individual physical responses may be seen from this point of view, so may the organic responses of society itself. I do not mean that the sociologist is unaware of the existence and complex nature of communications in society, but until recently he has tended to overlook the extent to which they are the cement which binds its fabric together.

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Chapter 3
Warren McCulloch

Warren McCulloch resembled an Old Testament prophet – he had a long beard, bright and intense eyes, great personal warmth but also great passion. Indeed Gregory Bateson (1991, p. 225) describes him as "like Moses, a leader who could and did bring us to the edge of the promised land, where he himself could never enter". His prophetic status can also be seen in a remark he frequently made, "Don't bite my finger, look where I am pointing" (quoted by Seymour Papert, introduction to McCulloch 1965, p. xxviii).

In very many ways McCulloch was, as Dupuy (2000, p. 112) says, "the leading figure of the cybernetics movement". Although the term 'cybernetics' was Wiener's, it was McCulloch who organised and chaired the celebrated Macy conferences, McCulloch who published the first logical model of the mind, and McCulloch who supported and acted as mentor to many of the key later figures of cybernetics. Yet as Dupuy (p. 111) also says, "McCulloch seems almost to have faded from view: even in the fields in which he made lasting contributions, many of the heirs to his legacy are unaware even of his name". By looking at McCulloch's intellectual and personal stances, we can learn just as much about the origins of cybernetics as by looking at those of Wiener. As McCulloch (1974, p. 13) characterised the distinction between the two, "he was a roundhead; I, a cavalier!" (The analogy is with the competing sides in the English Civil War – McCulloch was describing himself as flamboyant and easy-going, while Wiener was intense and serious.)

Warren Sturgis McCulloch was born in 1898 in New Jersey, and died in 1969. Although American himself, his family had Scottish roots, and he saw this connection as important to his personality. His initial training was in philosophy, psychology, logic and neurophysiology. It was in this last field – the study of the physiology of the nervous system – that he made his first contributions, working at Yale on the cerebral cortex of monkeys, and from 1941 in the psychiatry department of University of Illinois. His core intellectual concern was a philosophical one, which he described in an anecdote about a conversation with an early mentor at the age of 19:

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> That winter Rufus Jones called me in. "Warren," said he, "what is thee going to be?" And I said, "I don't know." "And what is thee going to do?" And again I said, "I have no idea; but there is one question I would like to answer: What is a number, that a man may know it, and a man, that he may know a number?" He smiled and said, "Friend, thee will be busy as long as thee lives." I have been. (McCulloch 1965, p. 2)

This was indeed McCulloch's preoccupation for the whole of his life. He frequently characterised his work as 'experimental epistemology', the study of the nature of knowledge through understanding the nature of the brain within which it resides. He conducted this work at Illinois for 10 years, moving to MIT's Research Laboratory for Electronics in 1952. Although a close colleague of Wiener's in the 1940s while cybernetics was becoming established, the two had fallen out by the time he moved to MIT, and they did not work together there.

In other ways, McCulloch can be described as an early founder of cognitive science and the related field of artificial intelligence. We can see this in two ways.

First, he did significant work on the relationship between machines and minds – the process that Dupuy (2000), in the title of his book, calls the "mechanization of mind". A view that minds and machines are equivalent (now fairly commonplace but then a radical departure from a view of mind as something quite separate from physical reality) was at the core of McCulloch's thinking. In 1955 he wrote that "everything we learn of organisms leads us to conclude not merely that they are analogous to machines, but that they are machines. Man-made machines are not brains, but brains are a very ill-understood variety of computing machines" (McCulloch 1965, p. 163).

Second, McCulloch, working with Walter Pitts, constructed a logical model of the nature of mental activity, and in particular the computational behaviour of the neuron (McCulloch and Pitts 1943). This article proved important in the history of artificial intelligence (AI) research, as one of the first computational models of mind, although AI research took a different path for many years and it was not until the 1980s that neural networks became an important area within AI. By the time AI research became prominent, cybernetics was not very much in vogue and the connection with McCulloch was not stressed. John McCarthy, who coined the term 'artificial intelligence' in 1955, has written that "one of the reasons for inventing the term 'artificial intelligence' was to escape association with 'cybernetics' " (McCarthy 1988, p. 227).

As a person he was warm, energetic, and highly supportive of others – "the most loose and spontaneous, least machinelike of men" (Heims 1991, p. 39). He was famous for his bohemian lifestyle, with large summer gatherings of family, colleagues and friends at his farm in Connecticut. At the farm he "undertook crazy schemes – from constructing a sizable dam (referred to as a 'pond'), to building a quasi-cathedral (referred to as a 'barn')" (Beer 1999, p. 434).

McCulloch was a very generous man, both in practical terms (helping out students and young colleagues financially and by having them stay at his house) and in the intellectual support he gave to younger colleagues. The list of people who later described him as their mentor is a long one. As well as Walter Pitts, his close collaborator and almost an adopted son, notable people in the systems field who he influenced included Heinz von Foerster, Gregory Bateson, Stafford Beer and Stuart Kauffman. McCulloch's influence can be strongly seen on the work of all four of these thinkers and through them on both cybernetics and complexity theory. As his biographer Tara Abraham (2016, p. 75) observes, he was always an "egalitarian mentor", without a sense of status or hierarchy.

Despite this deep personal warmth, the mechanistic approach – the close analogy between humans and machines – remained important to McCulloch throughout his life. In the Hixon symposium in 1948, the founding conference of cognitive science, he used the vivid image that "for us in the biological sciences – or at least, in psychiatry – we are presented with an alien, or enemy's, machine. We do not know what the machine is supposed to do and certainly we have no blueprint of it" (Jeffress 1951, p. 32).

This mechanistic approach was part of the reason for his vehement opposition, within psychiatry, to Freudian psychoanalysis – Blum (2016) referred to him as "the anti-Freud" (p. 39). His anti-Freudianism also came from his belief that psychoanalysis was over-dominant in American psychiatry of his time – McCulloch said in 1952 that "Psychoanalysts … formed a sect in psychiatry where there should be none. This sect so controls the teaching hospitals of our city [Chicago] that no one may be a resident of psychiatry unless he is approached by them for membership in their sect" (quoted by Abraham 2016, p. 118).

Notwithstanding McCulloch's mechanistic approach, it was as a result of his work that the relativist approach to cybernetics which became known as second-order cybernetics began to form. This was partly due to his influence on Heinz von Foerster (the founder of second-order cybernetics) and on Gregory Bateson (with his work on communication, paradox and the distributed nature of mind). But McCulloch's focus on experimental epistemology made it a possibility that his understanding of the nature of knowledge would shift with his results, and this in fact did happen with the paper "What the Frog's Eye Tells the Frog's Brain" (Lettvin et al. 1959). Although the experimental work for this paper was done by Jerome Lettvin and Humberto Maturana, it was conducted in McCulloch's laboratory, he discussed its ideas as the paper was written, and he appears as a co-author. The paper argues that "the eye speaks to the brain in a language already highly organized and interpreted, instead of transmitting some more or less accurate copy of the distribution of light on the receptors" (Lettvin et al. 1959) – the frog's eye is constructing a model of reality as it views objects rather than reflecting an existing reality to the brain. These results would later form a key part of Maturana's view of the biology of cognition.

Perhaps McCulloch's greatest contribution to cybernetics was institutional. He instigated and chaired all ten of the celebrated conferences on cybernetics funded by the Macy Foundation, running from 1946 to 1953. These are often associated with Norbert Wiener, but it was McCulloch who was at their core. The list of participants in the conferences is extraordinary: simply among the better-known ones are Gregory Bateson, Alex Bavelas, Heinz von Foerster, Ralph Gerard, Kurt Lewin, Margaret Mead and John von Neumann (with guests including Claude Shannon and Wolfgang Köhler). It was McCulloch who held this group together.

He was a strong chair of the conferences, who "exercised considerable control over who was allowed to speak and who was not" (Hayles 1999, p. 57). Indeed, Bateson and Mead in a dialogue remarked that "McCulloch had a grand design in his mind … on how the shape of the conversation would run over 5 years – what had to be said before what else had to be said. ... He was very autocratic." (Brand 1976).

By McCulloch's account, the early conferences were very argumentative: "The first five meetings were intolerable. Some participants left in tears, never to return. We tried some sessions with and some without recording, but nothing was printable. The smoke, the noise, the smell of battle are not printable" (McCulloch 1974, p. 12). The conferences were to lead to the foundation of more than one new discipline, and to a much greater understanding between participants of the possibilities and limits of interdisciplinarity: "we have learned to know one another a bit better, and to fight fair in our shirt sleeves" (McCulloch at the final conference in 1953, quoted by Heims 1991, p. 277). The conferences were celebrated even as they were happening, and were one of the chief reasons for the public awareness of cybernetics as a new (and mysterious) enterprise.

Of course, the Macy conferences did not happen in a void. As Heims (1991) discusses, it was no accident that they took place post-war, given the strong emphasis on team-working among scientists during the war (and consequent blurring of disciplinary boundaries). It was also a time in the United States of growing social and political conservatism, which made the social sciences vulnerable to colonisation by perspectives from biology, physics and mathematics.

From one perspective, McCulloch's approach to cybernetics formed part of that colonisation –McCulloch's transdisciplinarity was partly about boundary-crossing but also about taking over a wide set of domains with the approaches he championed. As Abraham (2016, p. 127) argues:

> In [cyberneticians'] goal of applying mathematical and theoretical practices to problems in the life and human sciences, they were striving for transdisciplinarity—seeking to lay over a new way of looking at the world that would transform scientific practice across fields.

Political context proved important in the later stages of McCulloch's life. In 1964 (the same year as Wiener died), at the height of the Cold War, officers from the Central Intelligence Agency (CIA) became concerned that the United States was falling behind the Soviet Union in the field of cybernetics, which had been named and shaped in the US but was becoming central to Soviet science (Kline 2015). Part of their response was the establishment of the American Society for Cybernetics, which is still active today, and McCulloch was persuaded by the CIA to become its first president. This might seem shocking to contemporary observers, although as Guddemi (2015) has observed, CIA support of academic work that formed an alternative to Soviet approaches, was not unusual for the time.

McCulloch was a paradox: the humanist who advocated mechanism; the realist whose work led to relativism. He had a fascinating blend of intellectual ideas, and his influence lives on in very many ways. At the end of his life, he described himself as follows (M. C. Bateson 1972, p. 24):

Here, then, is the first technically important difference between us and robots. In them we cannot afford to carry out any computations, no matter how simple, in a hundred parallel paths and demand coincidence. Consequently, no computing machine is as likely to go right under conditions as various as those we undergo. […]

A nervous impulse is also a signal. It is true if what it proposes is true, otherwise it is false. It is false if it arises from any cause other than the adequate, or proper, excitation of the cell. The threshold of the dark-adapted eye for light is about a photon in several seconds. Pressure applied to the eye will evoke impulses, but the energy required is many million times more. Press on the eye and you see light when there is no light. The signals are false. Thus nervous impulses are atomic signals, or atomic propositions on the move. To them the calculus of propositions applies provided each is subscripted for the time of its occurrence and implication given a domain only in the past. In terms of such a calculus applied to nervous nets, Pitts and I have been able to prove that even nets devoid of circles can realize any proposition which is a logical consequence of its input. As this is the most that *any* net *can* do it is obviously an adequate theory. We know, of course, that facilitation and extinction occur, and we showed that whatever these can effect can be done digitally, or discretely, by go, no-go devices. In our first essay, we were unable to obtain much more than the calculus of atomic propositions; but, by introducing circles in which a train of impulses patterned after some fact could circulate, we did get existential operators for time past. […]

There are other closed paths important in the origin of ideas, circuits which have 'negative feedback'. In terms of them reflexes were first defined as actions starting in some part of the body, setting up impulses to the central nervous system, whence they were reflected to those structures in which they arose, and there stopped or reversed the process that gave rise to them. All inverse feedbacks have this in common, that each establishes some particular state of the system, for they bring it back toward that state by an amount which increases with their deviation from that state. They are, as we say, error-operated. The state toward which they return the system is the goal, or aim, or end *in and of* the operation. This is what is meant by function. On these circuits Cannon founded his theory of homeostasis, and Rosenblueth and Wiener their theory of teleological mechanisms. […]

Neurons are cheap and plentiful. If it cost a million dollars to beget a man, one neuron would not cost a mill. They operate with comparatively little energy. The heat generated raises the blood in passage about half a degree, and the flow is half a liter per minute, only a quarter of a kilogram calorie per minute for 10^{10}, that is, 10 billion neurons. Von Neumann would be happy to have their like for the same cost in his robots. His vacuum tubes can work a thousand times as fast as neurons, so he could match a human brain with 10 million tubes; but it would take Niagara Falls to supply the current and the Niagara River to carry away the heat. So he is limited to about the thousandth part of man's computer. He has to be very careful to specify in detail which relays are to be connected to a given relay to trip it. That is not the case in human brains. Wiener has calculated that the maximum amount of information our chromosomes can convey would fill one volume of the *Encyclopaedia Britannica*, which could specify all the connections of ten thousand neurons if that was all it had to do. As we have 10^{10} neurons, we can inherit only the general scheme of the structure of our brains. The rest must be left to chance. Chance includes experience which engenders learning. Ramon y Cajal suggested that learning was the growing of new connections.

I do not doubt that the cerebral cortex may be the most important place in primates. But it is certainly the most difficult place to look for change with use. Think of it as a laminated felt of fibers which serve to associate neighboring rough columns of cells nearly a hundred high and linked together vertically by their axons. These columns are then connected to distant columns by axons which dip into the white matter and emerge elsewhere into the cortex. These last connections I have studied for many years but have at best a general picture of how areas are related, certainly nothing that could give the detail necessary to distinguish between its connections before and after learning. […]

This brings us back to what I believe is the answer to the question: Why is the mind in the head? Because there, and only there, are hosts of possible connections to be formed as time and circumstance demand. Each new connection serves to set the stage for others yet to come and better fitted to adapt us to the world, for through the cortex pass the greatest inverse feedbacks whose function is the purposive life of the human intellect. The joy of creating ideals, new and eternal, in and of a world, old and temporal, robots have it not.

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Chapter 4
Margaret Mead

Margaret Mead was one of the most well-known and influential social scientists of the twentieth century. She worked as an anthropologist, carrying out fieldwork over a number of years on a number of south Pacific islands. Her fame arose from the clarity of her writing, from her ability to express anthropological ideas in a way that the public could appreciate, and from the way she analysed her own culture (the United States) based on fieldwork elsewhere. Mead is not widely known as a systems thinker, yet she was deeply involved in the birth of the systems movement, and her work shows clear systemic elements.

Margaret Mead was born in 1901, in Philadelphia, and died in 1978, in New York. She was educated at Barnard College and Columbia University (both in New York). As an undergraduate (initially studying psychology), she took a course in anthropology with Franz Boas – the centre of a group working on a cultural approach to anthropology – and his student Ruth Benedict, and their ideas formed a basis for all her future work. Mead's primary institutional affiliation, where she was based for 50 years as assistant curator and then curator, was the American Museum of Natural History in New York.

Mead was an active member of the Episcopal Church throughout her adult life, and highly motivated by an idea of service to humanity. In persuading her to leave psychology and devote her career to anthropology, Benedict told her that "Professor Boas and I have nothing to offer but an opportunity to do work that matters" (Mead 1972, p. 114), and this approach echoed throughout Mead's life. The epitaph on her tombstone, a quote from her writing, reads "to cherish the life of the world" (M. C. Bateson 1984).

Mead saw little separation between her work and her personal life (Howard 1984). Many of her deepest personal relationships were with people who she also worked closely with, both men and women. She was married three times (to Luther Cressman, Reo Fortune and Gregory Bateson) and also had long relationships with Ruth Benedict and Rhoda Metraux. She worked closely over a number of years with Fortune, Bateson, Benedict, Metraux and her daughter Mary Catherine Bateson.

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Metraux (1980) has divided Mead's working life into four key phases. From 1925 to 1939, she was intensely involved in fieldwork, making five major trips and studying eight different peoples (all on the South Pacific islands). The first of these, which Metraux notes was her only solo field trip, was on Samoa, and resulted in her celebrated early book *Coming of Age in Samoa* (Mead 1928), which not only presented a detailed anthropological study in a way that was accessible to the general public but also formed a reflection on her own society (in relation to the status of young people). This style, of describing cultural patterns in another society with respect and in great detail, while relating these patterns to issues in American society, was one that Mead repeated through several further works.

Her fieldwork led her to write extensively on the relationship between gender and sex, and the culturally-created nature of gender, arguing that "standardized personality differences between the sexes are … cultural creations to which each generation, male and female, is trained to conform" (Mead 1935, p. 48). This view of gender led her to be criticised by social conservatives (and was not always popular with later feminists such as Betty Friedan), but remains highly pertinent today. Visweswaran (1997) describes her work as a form of 'feminist ethnography' and argues that Mead "was possibly not the first social scientist to develop a distinction between biological sex and sociologically distinct gender roles, but she was certainly the first to use ethnography to do so" (p. 601).

From 1939 to 1948, she was involved in public life on a series of applied problems relating to American society during World War II (notably the Committee on Food Habits on which she served with Kurt Lewin), when she "grasped how essential interdisciplinary thinking was in approaching these problems" (Metraux 1980, p. 266). During this time she also became a mother, to Mary Catherine Bateson, and typically approached Catherine's early life and upbringing in a spirit of inquiry, experiment and study. Mead (1972, p. 261) later wrote that "bringing up Cathy was an intellectual as well as an emotionally exciting adventure."

In a third phase of her life, from 1948 to 1953, she established (with Ruth Benedict) a series of projects on national cultures, again explicitly interdisciplinary. They designed a series of comparative studies of seven cultures, carried out over a number of years by a team which Mead coordinated following Benedict's death in 1948.

In the fourth phase of her life (1953–1978), Mead's diverse interests came together in a range of public settings. She taught in a number of institutions, took part in many conferences, served on several public policy committees, and published many books and articles accessible to both scholarly and popular audiences. She was a visiting professor at a number of universities. She also played a significant part as a public intellectual, writing a regular column in the popular magazine Redbook (often with Rhoda Metraux), to influence the thinking of the general public on a variety of cultural issues. As Sabloff (2011, p. 410) observes, she had an influence on public perceptions of anthropology which has subsequently become lost, and that she "may not have been beloved by all in the anthropological community, but she definitely had a significant, positive impact on public views of key issues".

Mead's view, as described by Miller (1996), was that "the other social sciences … looked at only parts of a society but anthropology was concerned with the whole system so the emphasis on 'wholes' in systems theory was important". Others have noted the importance of her systemic approach – Henshaw (2019, p. 77) writes of her insight that "human cultures are socially not biologically inherited systems of information"; and Varenne (2000, p. xxi) noted that her analysis of the United States during wartime was grounded in cybernetics – "America is approached as "teleological" process, that is as a set of interactions through which miscellaneous participants react to each other as they struggle for a particular goal".

However, it was unusual for her to explicitly use the *language* of systems in her scholarly writing. In essence, this seems to be because her anthropological understanding of holism was sufficient for her needs. She reflected at times on this lack of use of systems language, though she said it was common to most anthropological work. Commenting on cybernetics, she wrote that "anthropologists participated in the initial formulations and a few anthropologists have used the families of models that come from information and communication theory; but the use of such models has not penetrated the central core of the discipline" (Mead 1961, p. 479).

In closing, we can clearly see Mead's overall view of the relation between anthropology and systems ideas in an article that was published during her time as president of the SGSR:

> General systems theory has taken its impetus from the excitement of discovering larger and larger contexts, on the one hand, and a kind of microprobing into fine detail within a system, on the other. Both of these activities are intrinsic to anthropology to the extent that field work in living societies has been the basic disciplinary method. It is no revelation to any field-experienced anthropologist that everything is related to everything else, or that whether the entire sociocultural setting can be studied in detail or not, it has to be known in general outline. (Mead 1973, p. 8).

Reading from Mead's work

Mead, M. (1968) Cybernetics of cybernetics, In von Foerster, H. et al. (eds.), *Purposive Systems*, New York: Spartan Books. Institute of Intercultural Studies, Inc., New York.

I suppose that one of the reasons that I am contributing to this endeavor is that I myself was at the small Josiah Macy Foundation Conference on cerebral inhibition– in the middle of World War II – at which we began planning for the Macy Conferences which became the Conferences on Cybernetics (Mead et al. 1950–56). That first small conference was so exciting that I did not notice that I had broken one of my teeth until the conference was over.

I was a member of that first group as an anthropologist. The competence I had –and have – comes from the intensive analysis of very small, relatively isolated, and intimately known communities which serve as living models from which one can sometimes develop larger, more formal models. Besides the anthropologists' experience with the small societies which are their laboratories, anthropologists have a second task: to interest themselves in what is happening in our own culture, to stand outside it and look at it as a whole.

As an anthropologist, I have been interested in the effects that the theories of cybernetics have within our society. I am not referring to computers or to the electronic revolution as a whole, or to the “implosion” and the end of dependence on script for knowledge, or to the way that dress has succeeded the mimeographing machine as a form of communication among the dissenting young. I specifically want to consider the significance of the set of cross-disciplinary ideas which we first called “feedback” and then called “teleological mechanisms” (Frank et al. 1948), and then called “cybernetics” – a form of cross-disciplinary thought which made it possible for members of many disciplines to communicate with each other easily in a language which all could understand. This was an important motive for those of us who worked in those first conferences at the end of the 1940s. We were impressed by the potential usefulness of a language sufficiently sophisticated to be used to solve complex human problems, and sufficiently abstract to make it possible to cross disciplinary boundaries. We thought we would go on to real interdisciplinary research, using this language as a medium. Instead, the whole thing fragmented. Norbert Wiener wrote his book *Cybernetics* (Wiener 1948). It fascinated intellectuals and it looked for a while as if the ideas that he expressed would become a way of thought. But they didn’t.

I would now like to consider cybernetics as a way of looking at things and as a language for expressing what one sees. We might look at the history of thinking about the relations between the United States and the Soviet Union. There was a time about 20 years ago when the two countries were so preoccupied with each other that they acted as if they were the only two countries with any political significance on this planet. Specialists in each nation expended enormous energy trying to penetrate the secrets of the other system. The Soviets made a great many hypotheses about the way our system worked which were based on their own highly centralized form and which led to false conclusions, such as the assumption that both American political parties were run from “Wall Street” – a sort of capitalist counterpart of the Kremlin. This belief of theirs and our adverse views of the Kremlin have now coalesced in the present mythology of “the establishment” or “the industrial military complex”. Twenty years ago, even 10 years ago, it was possible to think of the United States system and the Soviet system as two relatively self-contained and independent systems, coupled together by mutual suspicion, passionate attention, and intermittently successful espionage. It was even possible to propose – as I did a few years ago – that, if we wished for a more reliable form of knowledge and understanding between the two systems than espionage could provide, we should use cybernetics as a cross-cultural vocabulary for expressing the relevant differences between the two systems. I suggested this at a time when it seemed that cybernetics was ideologically free and was developing very rapidly in the Soviet Union. Many more young people there were learning about it than there were in this country, and it seemed that here was a possibility that two rival nations, with very different ideological premises, could develop a language in which their systems could be described in a way that was ideologically neutral. As there were many unadmitted occasions when the United States and the Soviet policy-makers did want to agree, such a language would have been useful.

Today there are new developments which make me less hopeful that such a venture could succeed. We have now developed an interest – and interest in Soviet affairs always contains a certain element of fear – in the possibility that the Soviet system may become totally cyberneticized, in the technical sense, as a way of controlling everything within its borders and possibly outside, with thousands of giant computers linked together in a system of prodigious and unheard-of efficiency. If this is so, or if we continue to discuss the computerization of the Soviet economy in terms of emulation and dread, cybernetics as a way of thought will cease to be ideologically free. There has also, however, been a marked decrease in the extent to which the United States and the Soviet Union are exclusively preoccupied with each other. […].

As the world scene broadens, there is a continuing possibility of using cybernetics as a form of communication in a world of increasing scientific specializations. The possibilities are fascinating if we can only get a large enough number of welldefined elements in large enough systems. It is argued, e.g., that Lake Erie is not only dead because there was no agency equipped to think ecologically about what was happening to its waters, but that, in fact, Lake Erie and its environs is too small a system to have been dealt with if, in fact, there had been any group or agency charged with preventing the Lake Erie disaster. It is further argued that if, instead, the whole Great Lakes region is considered together, then it might be possible to make the kind of predictions which could be tested in advance. In such a plan it should be possible to introduce correctives for too much linear and too little lateral planning, and linear planning is the besetting difficulty of most of the planning in the world today. It is argued that with large, inclusive, and well-analyzed systems we might be able to do a better job. There we find, on the one hand, tremendous hope about our capabilities to deal with complex systems if we can only identify the right system of the right size with the right variables. Although these are a great many ifs, they are not serious ifs. For we are free now from the superstition of some sociologists in the 1950s that we would never be able to deal with more than seven variables at once. And we have also gotten out from under the tyranny of the law of parsimony so that we can't be bullied quite so easily into thinking that the simplest solution to a problem is the best.

But, at the same time, I think we ought to look very seriously at the current state of American society within which we hope to be able to develop these very sophisticated ways of handling systems that are, indeed, in dire need of attention. Problems of metropolitan areas, the growth of such areas, and the choice of areas appropriate for planning certainly represent one such field. The interrelations between different levels of government, the efficient redistribution of income through procedures like the negative income tax, and the linkages necessary among parts of large industrial complexes that are widely separated in space are cases where a systems analysis is necessary. But the new kind of analysis of these complex systems on which predictions can be eased must be undertaken in a world which is made up of individuals who hold a great variety of positions of power within the various bureaucracies, in government, in industry, in the armed services. And these powerful people – who must order, provide for, and utilize such system analysis – are living in a world in which there are a large number of breakdowns in thinking. These breakdowns are of an order that I think should concern those of us who hope to promote the ability to think in cybernetic terms. […].

Yet it seems that interest in the human components of complex automated and computerized systems is decreasing rather than increasing. First we looked at men and turned them into "human components", and then we stopped looking at them at all. We are educating the future human components, upon whose precision and accuracy and sense of responsibility the operation of future systems will depend, by training them to be trigger-happy in multiple-choice tests, by out-educating from their minds the fundamental human quality of responsibility based on accurate reasoning. I recently attended a large, expensive, and important conference on a subject of interest to many millions of people. The young and enthusiastic organizers, when queried about some of the arrangements they were making, simply replied: "We have decided we just have to risk failure". This is a form of ethical heroism appropriate perhaps in individual life but highly inappropriate in the design of national conferences on airport lighting, in fact in any of the increasing number of circumstances in which – as in parachute jumping – it is necessary to get it right the first time. We have not yet built into our educational system any recognition of the points where precision is essential, and yet we are living in a society where one mistake can dislocate the lives of thousands of people, wreck distribution systems, and distort life-history data, and subsequent career lines. […].

In World War II, anthropologists developed ways of thinking about old nations like Japan. Japanese culture was very easy to schematize in ways that were adequate for effective prediction. All that was needed was some hard work by experienced analysts. It was possible to probe and sample at anyone of many available points in order to get material for a systematic description. But new nations, amalgams of different cultures at different levels, within the present world framework, cannot be dealt with this way. We have no tools for doing a comparable analysis of Nigeria torn by civil war. We are dealing with new kinds of partial organization among areas of much higher and much lower organization which none of our theories take into account. In the past, it was possible to view opposing and organized systems in some degree of isolation. Today we are dealing with a sort of social metastasis in which there are fragments of formerly highly organized behavior which are unsystematically related to each other. We have no way of thinking about this.

If we think of the steps through the early interdisciplinary development of cybernetic models, through general systems theory and our growing willingness to include more and more complex systems, I think that now we have to take another step and develop ways of thinking about systems that are still bounded but within which there are loci of very contrasting degrees of organization and disorganization. If we approach them with our former methods, if we treat some of these organized pieces in isolation, we may get something that can be treated as a system, but we learn nothing about the way in which it is embedded in intractable ways in some larger and less organized context, and we may also do a great deal of harm.

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its own, according to any change in situation affecting it" (Time 1949). The Homeostat was not universally supported in the cybernetics community: when Ashby presented it at the ninth Macy conference in 1952, a number of participants criticised its model of the brain and the extent to which it actually could be said to be learning (Kline 2015, p. 53). Wiener, however, regarded the homeostat highly, calling it "one of the great philosophical contributions of the present day" (Wiener 1954, p. 38).

The Homeostat and its design formed the basis of the first of Ashby's two highly significant books, *Design for a Brain* (first published in 1952, with a much revised second edition in 1960). His goal in this book was to consider in more depth the question of adaptive behaviour, and its working in the brain, and "to show that a system can be both mechanistic in nature and yet produce behaviour that is adaptive" (Ashby 1960, p. 1). That is, he sought to create a mechanistic model of the brain and its ability to learn. The Homeostat formed the experimental evidence for this work, while cybernetics (and information theory) formed the theoretical basis. In many ways the book is now a historical curiosity – while there are still many theorists with the same goal as Ashby, especially within cognitive science, the methods they use have changed. However it influenced many scholars – the economist and cognitive scientist Herbert Simon wrote in his memoirs that he "stayed up all night to finish *Design for a Brain*" on its publication in 1952 (Kline 2015, p. 146).

The book also introduced his concept of ultrastability, a generalisation of the self-regulating property of the Homeostat. He describes this mechanism as 'double feedback', and argues that the mechanism must always be present in any system which has adaptive behaviour altered by interaction with its environment. This concept would later form the basis of Argyris and Schön's (1978) distinction between single- and double-loop learning.

Ashby's second book, *Introduction to Cybernetics*, had a wider and more lasting impact than his first. For many years it was the major text in the field of cybernetics. He described cybernetics as a theory of machines, within which category he included living organisms and their brains as much as machines built by humans (a common view among many early cyberneticians). He argued that cybernetics is a general field of study of theoretical validity in its own right (see the reading from his work below).

The generality which Ashby applied to systems through his use of cybernetics was close in its goals to that of general systems theory (GST). Ashby became very interested in this approach, and was closely involved in the early days of the Society for General Systems Research – he attended its founding conference in 1955, and was president of the society from 1962 to 1964. However, his approach to general systems theory was somewhat at odds with that of many others within GST, notably Ludwig von Bertalanffy (whose work is discussed in the following chapter). As seen in the extract which follows, Ashby defined cybernetics as "the study of systems that are open to energy but closed to information and control—systems that are 'information-tight'" (Ashby 1956, p. 4). This contradicted Bertalanffy's view that the openness of systems to external inputs was crucial to enable them to change radically, which to him was very important when studying social systems and which