Reflections on Society and Academia

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Cultures Adrift

by

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Preface

THE FOLLOWING CONTAINS selected examples of a lifelong preoccupation with general education. My early focus lay on the fine arts, on chess and socialism; my interests expanded to include mathematics, architecture, and planning; and I evolved gradually into a quantitative social scientists with a thematic priority on higher education management. I can easily claim to have become, in the original sense of the word, a true dilettante.

My professional meandering, guided more by curiosity than initial proficiencies, more by happenstance than by a laid-out plan, proved — in retrospect — fertile; and it shaped my views regarding education, professionalism and status. I do not want to claim that this is the road to take, because it is an arduous journey with an unknown destination; and we tried, therefore, to provide our children with different opportunities. *Bildung*, the old German concept of formation, cultivation or education, had once its roots in philology, philosophy or history, that is, in basic sciences used to understand life as it presented itself to the burgher of the 19th century; but today, these roots have shifted somewhat towards the sciences of the artificial (mathematics, information sciences, et cetera), towards engineering or the natural sciences, and the basic schism of the “two cultures” evoked by C.P. Snow needs to be bridged. For me, the constant search for the elusive became gratifying way before “trans-disciplinarity” became fashionable, and the exploratory retained its force.

This collection of book reviews and articles mirrors a wider spectrum of concern within the social sciences as well as design — or planning — issues. Review essays and articles are assembled here to allow for an easy — holistic — assessment of publications which cover various themes and were written during the past two decades. In addition, I am including four notes specifically written for this anthology, two dealing with my primary research focus, i.e. academic productivity (“Excellence” and “Productivity”), and the other two addressing aspects of economics (“Growth, Change and Excess”) and a discussion on concepts and design (“Form and Content”). I thank the two publishing houses, Springer Science+Business Media (`www.springer.com/gp/`) and the Taylor & Francis Group (`www.tandfonline.com`), for the permission to republish material used previously.

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Zürich and Promontogno November 27, 2017

1

Introduction

One of the first aspects that spring to mind when reading anew these papers and reviews is that they circumvent or ignore the language of the "politically correct". My abhorrence against this contemporary practice appears to have grown stronger as the years went by, and when I watch the various moderators on TV, or the politicians in parliament, expounding their views in politically correct speech, I cannot refrain from constant shudder[1]. It is as if an unknown rash had suddenly befallen mankind, and the M.D.'s and fashion columnists would admonish us to accept the skin eruption as the new standard of beauty. It reminds me of Hans Christian Andersen's tale of *The Emperor's New Clothes* — or of the various fig leaves which were used by artists of times past to cover up the genitalia.

It is not, of course, that I deny the role of language in shap-

[1]Politically correct speech is much more absurd in my mother tongue, German, than in English.

ing our thoughts. Indeed, I think the relationship is strong, and if one is concerned about thought, about concepts, one ought to pay attention to language. Language is a way to express or frame thought. As an expression, it is not that dissimilar to the approach of an operational philosophy [Rapoport, 1965]; and as a frame, it leaves room for interpretation. Frequently, language exposes thought. The language itself is tied to the concepts one wants to convey: there is a symbiosis of style and content. But language can also be used to cover up, to obfuscate, if only inadvertently so, and politically correct speech may have ended up to play this role. Instead of focusing on essential aspects, on fighting inequality, on equal rights and development prospects, on quality, for instance (Chapter 8), a cheap proxy or "signal" (Chapters 13, 17 and 19) — the politically correct language — is often used as a substitute.

Language has its own connotations. Words are normally used to designate something, and they may do so, implicitly or explicitly, in a derogatory way. The way columnists, politicians or administrators may refer to females, Jews, refugees or homosexuals should not be the prime concern; the focus ought to be on their stance: if that is objectionable, we are called to object. On the other hand, to refer — politically correct — to the female form of Jew ("Jewess") is, in most contexts (that is, outside of a discussion on the ordination of female rabbis, for instance), and in particular in connection with the holocaust, sheer — opportunistic — nonsense[2]; and to refrain — again politically correct — from calling Jews Jews[3], and to refer to them as belonging to the "Jewish faith", amounts to an attempt to Christianize a religion with a foundation in law (Chapter 11)[4]. Form and content are frequently

[2]It may even have racist connotations.

[3]"A Newark Jew?" Yes, Philip Roth [2017] (adapted from a speech delivered in 2002) concurs. "But an American Jew? A Jewish American?" No.

[4]This may be part of the proselytizing culture of the Christian church, a possible taking-in of a kindred "faith" and, by this quasi-absorption, an implicit negation of Judaism (including its agnostic variants). There are other forms used to

tied, and we appear to be ill-advised, in most cases, to separate them (Chapters 10 and 20).

Language, in the context of the sciences, has a broader meaning: it is tied to concepts, to models, to theories, to "images" of the referent [Boulding, 1961]. These images are, as the new sociology of knowledge would point out — and in spite of the proper objection to the "fashionable nonsense" of postmodern currents [Sokal and Bricmont, 1998] — , author-specific in that they express the views of those who created, copied, amended or modified the picture (Chapters 3, 16 and 19). Particularly the social sciences can be subsumed under such a conception (Chapters 13, 14 and 15). As in the arts, and specifically in the context of photography, scientific concepts can be viewed within a triangle of relationships [Barthes, 1980]: (i) the scientist as author and the subject matter; (ii) the recipient or reader of the scientist's concept and the subject matter; and (iii) the recipient or reader and the author of the concept. The reception of the first relationship from the point of view of the second amounts to a — critical or not so critical — assessment; and the assessment is predicated, to some extent, by the third relationship, i.e., whether the reader and author belong to the same group (i.e. share the same "paradigmatic" view).

Viewing, interpreting, is one thing; doing, effecting change, is something else. This duality — and possibly ambivalence — covering the descriptive and the normative, the *Vita contemplativa* versus the *Vita activa* (Hannah Arendt), is particularly relevant if one extends the (descriptive) sciences to embrace as well (normatively based) engineering, architecture and design, economics, planning and management, medicine, and information sciences. The ambivalence between that which is and what ought to be is critical, and questionable if the "ought to be" is derived, in a historicist fashion perhaps, from the "what is", or if "what is" and

negate Judaism, for instance by referring to the "Jewish origin" or "decent" of people — again in line with the Christian concept to tie a religion to faith.

"what ought to be" become interchangeable. This trap is old, affecting a good part of political economics of the 19th century, but it is still a device with which to catch social scientists and neoclassic economists of today (Chapters 13, 14, 15, 16 and 19).

The doing comes in different modes (Chapters 2 and 16), is motivated by various stimuli (Chapters 4, 7 and 12), and takes place in a range of environments (Chapters 5 and 6). Whereas the philosophy of science has come to dominate a prolific discussion on the descriptive, the philosophy regarding normative matters [Churchman, 1961], so eminently important in a world governed by extended, unchecked markets with their significant external effects, has not kept pace. Doing things has implications which ought to be imagined — affecting, perhaps, the doing (Chapter 19). Acting can be thought of as a cascade of steps that produce, shape or effect something, that form a situation or an artifact. In its distributed, uncoordinated form, acting has direct social significance, producing ill-defined — "wicked" — problem situations [Rittel and Webber, 1973] (Chapter 16). The form that action produces is tied to content. Organizational forms should mirror — or embrace — that which is organized; architecture needs to host; design leads and directs; forms resulting from distributed, uncoordinated activities require anticipation. As the particular language is tied to the concepts one wants to convey, as models and theories in their specific outline are used to transport meaning, so are normative outcomes related to that what is wished: there is a symbiosis of form and content (Chapter 20).

The following notes basically deal with the themes just mentioned. They express views of a distant — and concerned — observer with an eye for the outcast, for the non-selected, the circumvented, the peripheral, for views which stand in contrast to mainstream and fashion. They focus on subject matters that I had to deal with in my later professional life, like higher education management (Chapters 4, 5, 6, 7, 8, 9, 12, 17, 18), but they also draw on earlier experiences, on planning issues which appear out-moded today, on economics (Chapters 2, 12, 13, 14, 15, 16, 17, 18, 19), or even on general subject matters, e.g. chess and artificial intelligence, Naziism, Judaism, architecture and design (Chapters 3, 10, 11, 20).

2

Strategic Planning

By his own account, Henry Mintzberg [1973] was "a bashful academic who, in the late 1960s, [...] ventured out [...] to observe what real, live managers [...] really do" [p. 99]. He concluded that

> [...] with few exceptions managerial activities [...] concerned specific rather than general issues. During working hours it was rare to see a chief executive participating in abstract discussion or carrying out general planning [...] Clearly, the classic view of the manager as planner is not in accord with reality.

During subsequent years, Henry Mintzberg published on matters pertaining to management, strategy formation and planning and has assumed the position that his cited descriptive observation is of general normative validity. To buttress this view, he published his "Rise and Fall of Strategic Planning" [Mintzberg, 1994].

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[0]Book review of *The Rise and Fall of Strategic Planning* [Mintzberg, 1994], published in *Tertiary Education and Management* [Herbst, 1998].

Mintzberg is very critical of planning. He assembles a whole array of reasons why planning doesn't pay, reasons he culls from opponents and proponents of planning alike. In assembling these reasons, or this "evidence", as he calls it, he doesn't pay great attention to the context in which planning is or is not applied. If planning is not applied in a particular context, he reads this to mean that planning has not been suitable; if planning was successfully applied, he questions the causality of the planning activity. He uncritically cites authors who call planning 'imbecilic' (because everything can change tomorrow), 'useless', 'harmful' (in its proper functioning), having 'negative impact', being 'backward' oriented, etc. In over 300 of the 400 pages of his book he bashes the field of planning while offering his consoling thoughts only in his last chapter. "What is it about planning", he asks, "that causes us to close down our minds, to block our perceptions? Are we that afraid of uncertainty? Or that enamored of our own formal powers of reason?" [p. 188].

Clearly, Mintzberg sees planning as an antithesis to creative management. He chides the inflexibility of plans and planning; he criticizes planning's alleged inclination to be incremental rather than strategic or its supposed concern with means, not ends; he discounts the role of deeper, quantitative or structured analysis. His anecdotal evidence on the failure of planning is frequently hard to refute because planning — like other human endeavors as well — does fail. What we lack, however, is a clearer notion on the systematic of failure. Does planning fail because it purports to be strategic? Does it fail in all contexts? Are there activities we can substitute for planning? Why would some engage in planning at all?

To illustrate the inappropriateness of a planned approach, Mintzberg uses metaphors as a didactic device. In one example he refers to the game of chess [p. 238] and cites Alexander Kotov [1971], a grandmaster of repute some decades ago: "I tried to play in a planned fashion, working out a plan right after the opening to take me into the ending, but for all my efforts and deep thought on the subject, I got precisely nowhere [...]". Now I do not want to quarrel with Kotov who was not only a player of rare intuitive powers but of analytical skills as well. Nor do I want to discount the important role of intuition, a great gift of the human mind and an enormous asset in the game of chess. What Mintzberg fails to see, however, is that chess epitomizes planning: if we understand the basic processes of chess, we have learned a great deal about planning and purposive behavior as well.

Mintzberg subsumes his illustrative example of chess under a general discussion of forecasting. He argues that processes which cannot be forecasted well cannot be planned. In chess, the charm of the game is tied to an inherent difficulty to forecast one's opponent's moves. In fact, this difficulty is due to one characteristic of chess: the large number of possible moves of the game. Although chess is a finite game, i.e. a game with a finite number of possible system states, the number of these states is very large. The largeness of possible system states is due to the combinatorial nature — or combinatorial complexity — of the game. This combinatorial complexity is characteristic of many man-made situations we confront in the field of planning and it generates numbers of system states which are easily larger than astronomical [Ashby, 1964] (see Chapter 3).

Despite the fact that chess is combinatorially complex, efforts have been expanded to model chess playing very early in the development of computers and artificial intelligence [Shannon, 1950; Simon, 1991]. The aims were two-fold: to improve chess playing abilities, to be sure; but more important was the aspect of human simulation, the aspect of gaining insight into thought processes underlying purposive behavior. The connection between chess and planning was clearly seen and gave rise to a publication in the late 1960s by a former World Champion of chess, Mikhail M. Botvinnik

[1970], stressing this connection.

I have stated that chess epitomizes planning. In chess — as in other games of this nature — a player tries to see a few moves ahead to evaluate his options. This evaluation will be based on a general strategy or on a general game plan. On the basis of this, he will eventually select his next move. If the player's evaluation has been sufficiently deep, he will generally not be surprised by the move of his opponent and he will follow or modify his game plan according to how the game unfolds. A player who fails to look sufficiently far ahead is subject to surprises. He will stumble into all sorts of traps and might lose immediately; in the derogatory words of the members of a chess club he is a *patzer*.

In a second example, Mintzberg presents car driving as a metaphor to illustrate the supposed unsuitability of the planning approach. He cites a planning proponent: "The faster one drives, then the further one's headlights must throw their beams" [Godet, 1987], a sensible rule for anyone accustomed to night driving. He then proceeds to discount this rule: "[A] problem with planning [...] is precisely this: it can look into the future only in the way headlights look down a road [...] So planning [...] cannot do much more than extrapolate the known trends of the present" [p. 182]. Does this imply we should drive differently? I hope not. Does it imply we should not engage in planning, not in forecasting? Not at all. In fact, there are many activities where our foresight is somehow synchronized with the speed with which we move, lest we might meet disaster or have to confront costly backtracking. Take the example of climbing a mountain: we have a notion of the general direction and select our immediate steps to correspond with an approach path we are able to see; and as we move — and as we are confronted with new information — , we will modify our approach, to bypass the crevasses that come into sight or to cross the river at a more appropriate location. Medical diagnosis and treatment might serve as another example.

The problem with Mintzberg is that he has a very restricted view of planning and plan making. In his version of planning many of the essential ingredients of planning as I see it are excluded: intelligence, creativity, adaptiveness and flexibility, etc. He appears to negate the fact that planning is an old human activity: it is part of many professions, practiced over a range of planning horizons, and very much in demand today. Because he is so negative about planning, he is — despite perhaps, or because of his very verbose approach — unable to provide a reasonable definition of what planning is. Although Mintzberg cites a number of classic thinkers on planning, C. West Churchman, for instance, or Russel L. Ackoff, he does not properly cover their very extensive body of discourse and fails to present their argument.

One basic flaw of Mintzberg's view is his insistence to exclude strategy formation from his concept of planning. He claims to rely here on empirical evidence. Reporting on a study he did on an airline, he concludes that "[in that context] formal planning [...] did not constitute strategy making but in fact positively discouraged it, impeding strategic thinking and strategic change" [p. 112]. Depending on the form of planning chosen, this may indeed have been the case. But in many instances, strategy formation forms the very core of planning. Planning is being initiated because the problems we want to solve are ill-structured, the aims to be pursued are vague, and the means at our disposal are far from clear. Planning is being used as a structuring device, as a process which moves in successive steps from an initial problem situation to a solution [Quade and Boucher, 1968]; in that way, planning is being used to find strategies (see Chapter 16).

Mintzberg also fails to pay proper attention to the context within which strategic planning is or is not applied. It's one thing to claim that in many of today's businesses more extended planning approaches are frequently ill-advised: CEO's are familiar with the markets their companies operate in, they are familiar with their own product palette and production systems and, hence, there is no need to engage in broader planning approaches. Smaller companies might find their niche almost irrespective of what they produce, provided their products are of high quality and cost-effective. If the market demands a change in the product line or a change in the production system, these changes in demands will be readily recognized and the proper measures implemented. It is another thing, however, to provide the reader with the impression that the formerly sketched approach has generic value: that it is equally valid for other types of businesses — or even for the public sphere.

In the case of larger companies, and particularly those with a narrow spectrum of products, the situation is commonly different: product development is costly and the production itself is very capital intensive, making proper planning — and risk assessment — almost inevitable. Today's automobile manufacturers may serve as an example. Other industries require planning for different reasons. Think of utility companies in the telecommunication or energy fields:

> When you design any system, you must do long-range planning, including determining what demands on the system will be, how often extraordinary high demands will occur; and how long they will last. You must also think about the possibility that your estimates of these quantities might be wrong, and plan to monitor them and re-examine your predictions from time to time. And then you must design the system so that when demand does exceed capacity (as it surely must unless you are willing to supply unreasonable amounts of equipment which will almost never be used), it will fail gracefully [Machol, 1997].

Finally, there are the many activities in the public domain which rely on planning. We could not properly harness the water resources of the major river systems of the various continents, unless we engaged in planning; we could not be thinking of constructing new trans-alpine rail transit routes; we could not devise new social security schemes or public health plans; we could not hope to clean the waters of the Mediterranean Sea; we could not fight air pollution, nor global warming; et cetera. And we couldn't do a range of the smaller projects on our agenda either: we couldn't pass new zoning ordinances or model cities programs; we couldn't repair our vast network of public roads; we would have difficulties reorganizing hospitals and schools; and we would be unable to preserve many of our cultural and natural resources.

Let us turn now to Mintzberg's consoling thoughts presented in the last chapter of his book. Here, he identifies activities which he associates with his view of planning, and he points out specific roles for planners. Under planning, he subsumes three primary activities: coupling intuition with analysis, the programming of strategies, and communicating plans. While I would regard the three activities as being necessary for most forms of planning, I wouldn't see them as being sufficient. He specifically excludes, once again, strategy formation from planning:

> Organizations engage in formal planning, not to create strategies but to program the strategies they already have, that is, to elaborate and operationalize their consequences formally [p. 333].

But when Mintzberg turns to a description of roles of planners, he specifically includes what he has just excluded. He sees planners in the role of "finders of strategy" [p. 361] and, to solve the riddle he posed, he states:

> [My] contention is that many of the most important roles played by planners have nothing to do with planning or even plans per see [p. 361].

Now I grant that planning is a complex activity and that there are various views on planning. I also grant that planning is not easily defined. This is not a unique problem of planning, however. Other activities pose the same problem. Think of medicine, for instance, or management, or science for that matter. In most cases, we define such an activity not directly, but indirectly, through a description of sub-activities we think are characteristic for the primary activity. These indirect definitions may take the form of scripts which describe vital aspects of a particular professional practice we would like to preserve or initiate. Or we may not normatively define a practice, but descriptively, through a sociological approach. In other words, we use the observed practice to buttress our theories, we use — in contrast to Mintzberg's argument — the observed roles of planners to better understand planning as such. Paraphrasing Churchman [1961] we may then conclude: planning is what planners do.

Why is all this relevant for higher education management? Because in higher education, as in other fields, we adapt approaches originally designed for different purposes. We adapted planning, but also decision-support or budgeting systems, total quality management or reengineering, etc. In fact, some of these approaches are adopted in such an all-encompassing way that not much room is left for alternatives or complements. At the same time, we reject approaches we cherished in the past as being outdated, outmoded. Instead of modifying or adjusting these practices to serve our needs, we replace them — if only by name.

Today, it has become fashionable to be disrespectful of planning. Despite some recent additions to the literature [Peterson et al., 1997], planning is frequently portrayed as a fossil amongst normative approaches: planning appears something of the past. It is being replaced by activities with a more contemporary aura, a more modern ring. And yet we might not know what we lose when we shun planning. Many of the problems we face today we could have easily foreseen, could have easily avoided. Many of the daily tasks which cross our desks may not have become necessary had we been more courageous in looking at things in a more systematic, comprehensive way. Planning is not unlike investment. We should invest in a prudent way, in line with our assets and in line with our aspirations and the risks involved. We will have to divert resources in order to do it, resources we could use for other things. But if we fail to invest, we will not be able to reap the fruits, will not be able to harvest. If education is a proper investment, planning is as well.

3

Chess and the Brain

Chess is a very old game, hundreds of years old in the form it is played today, with a splendid intellectual history and an extensive literature surrounding it. Chess is a complex, beautiful game that relies on relatively simple rules, and it is the complexity and beauty that makes it so attractive. To master chess, like music, talent and devotion are required.

Chess is a finite game. There are only a finite number of variations possible, and we could, in principle, select a sequence of moves that would lead to the best attainable position, irrespective of what our opponent does. The finiteness of the game assures that this sequence of moves could be known before the game starts, provided that the computation of such moves is feasible, and in that case win, draw or loss would be clear prior to the first move. But be-

[0]Book review of Rasskin-Gutman [2009] published in *European Legacy* [Herbst, 2015a].

cause the number of potential moves within a game is very large, the computation of moves is infeasible and the game retains its charm.

Claude Shannon [1950] had appraised that the number of possible chess positions is of the order of 10^{43} and the number of variations of moves of the order of 10^{120}, i.e. more than the estimated number of elementary particles in the visible universe. If a computer were to evaluate these moves at a pace of one pico-second (i.e. 10^{-12} of a second) per variation, it would require roughly 10^{100} years — much longer than the presumed elapsed time since the Big Bang — to assess the entire decision tree and to choose the first move. This is why chess is a demanding game.

In "Chess Metaphors" Diego Russkin-Gutman explores the interlinking of chess, chess programming, artificial intelligence, and the brain. We know from experience that the brain is very effective, and current research tries to explore why. Until recently we could not conceive of a machine beating a grand master in the game of chess. Indeed, in 1968, the Scottish chess champion David Levy was betting against John McCarthy, the prominent American computer scientist and recipient of the Turing Award and Kyoto Prize, that no computer would be in a position to beat him in chess by 1978. Levy won that bet. However, in 1997, the then reigning World Champion of chess, grand master Gerri Kasparov, was defeated in a six-round match by IBM Supercomputer Deep Blue (by a score of $2\frac{1}{2}$ to $3\frac{1}{2}$ in favor of Deep Blue).

From the early days of computer science, chess has provided a testing ground for artificial intelligence. The hope was that computer programs could somehow be used to emulate mental processes and, in doing so, to explore the working of the brain. Furthermore, Shannon [1950] had the vision that chess programming would help to attack "other problems of a similar nature and of greater significance", such as "performing symbolic (non-numerical) mathematical operations" (implemented in the mean-time by programs such as Mathematica or Maple), music composers, language translators, or computer generated mathematical proof systems (all available today in various forms of sophistication).

This hope did not materialize for two reasons. First, today's chess playing programs are strong not because they emulate the way chess masters think; they are strong because they exploit the processing power of modern computers and because they have access to vast libraries of chess openings, middle games, and endgames. In fact, modern chess playing programs are basically the same today as when they were originally conceived [Botvinnik, 1970]. As Levy [1976, 137] pointed out, they focus on tactics, not on strategy: "Since 1948, when Shannon wrote his classic paper, there has been very little conceptual progress in computer chess".

The situation during the past 35 years, since Levy's statement, has not changed substantially because computer programs (like Deep Blue) relied on progress in computing speed, not on new visions of programs (according to Moore's Law, we can assume that computing speeds have improved by factors of roughly 10^6 to 10^7). Deep Blue, as Rasskin-Gutman remarks, calculated "more than 200 million moves per second" and could, under the time limits of a tournament, evaluate game positions "up to a depth of sixteen moves": that is far more than what one can expect from a human being. If humans are in a position to do reasonably well against modern chess computers, it is due to some mental abilities that are not emulated by the corresponding programs.

Second, the hope that chess playing programs could "act as wedge in attacking other problems" (referred to above) did not materialize because chess programming turned out to be a dead end: many computer programs evolved in the various fields of artificial intelligence that do not rely on chess programming (in an extended way). However, the basic questions retain their significance, namely (i) why are biological systems so effective, and (ii) how could one use biology to solve problems?

Let me turn to the first question which I intend to extend, not to answer. As I said, we know from experience that biological systems are very effective. One of the earlier models in this respect is the honeybee. Its brain is very small, roughly 1mm^3 (or weighing 0.001g), but the bee is in a position to navigate over long distances to harvest nectar, it recognizes high nectar sites and recalls the flowers it has already visited and, upon returning, it is in a position to tell the story to the members of its hive [Sejnowski and Churchland, 1992]; furthermore, bees appear to be in a position to engage in a form of collective decision-making [Imhoof and Lieckfeld, 2012]. Modern science, computer technology, and neuro-morphic engineering are nowhere near in duplicating that feat: biological systems are much more effective (with regard to energy use and weight efficiency in relation to computing power) by a long stretch. This is why neuroinformatics is such an explorative and challenging field.

Brains are very attuned to pattern recognition, to data-filtering, to the ability to generalize, and (today's) computers are not. Brains, after a certain learning phase, can almost instantaneously 'grasp' patterns (of sound or images), classify objects or 'see' analogies, and modern science knows almost nothing about how such perception works. Humans can normally match photographic pictures taken during childhood or adolescence of a person with the adult they encounter; art historians are in a position to identify individual works of art they have never seen before; monkeys quickly learn to distinguish between novel food and non-food; and chess masters can often correctly assess a position on the board without much conscious calculations. We are aware of these human or mammalian abilities, and we count on them in our daily lives, but we do not know that much about their inner working.

Brains, human brains, store and process information in much greater numbers than the few dozen billion neurons they are composed of. How can this be? We barely know. However, one answer may have to do with combinatorial complexity: combinatorics can generate large numbers, very large numbers. How large? Ross W. Ashby [1964], the cybernetician, illustrated this in the following way: "Suppose we have a square block of lamps, for displaying visual patterns, measuring 20 by 20 lamps, and suppose that each lamp is either off or on". How many patterns can be generated in this fashion? "... 2^{400} pictures — about 10^{120}". Recall that we encountered the finite number 10^{120} before, in the context of assessing the number of variations of moves in the game of chess, but we have found that such numbers are — in the words of Ashby — not "physically achievable". The QR (quick response) code, a matrix barcode, developed originally for the Japanese automotive industry in the 1990s, does exploit the vastness of such an arrangement. If system states of such immense potential variety can be generated with a binary machine containing merely 400 switches (i.e. lamps), it should be clear that a (human) brain is, for all practical purposes, limitless; at least we can say that the number of neurons alone cannot form a limiting factor.

However, brains are more than just an assembly of neurons; they also contain synapses, linking nerve cells; and neurons process information in an analogous — not a binary — fashion. The two additional information processing layers that separate the brain from today's computer, the synapses and analogous information processing, vastly expand the already vast combinatorial complexity of the brain; and they appear to be critical to suggest the stupendous performance of the brain *vis-à-vis* the computer.

Finally, I shall try to extend the second question mentioned above, regarding the problem of how to use — or mimic — biology to solve problems. Shannon (and others) looked into the converse direction, from problem-solving to biology, and Russkin-Gutman, a biologist, follows Shannon's notions. His enchantment with chess, we presume, may have prevented him to focus on his own fields, biology, as a problem-solving engine. He still believes in the old approach:

> The founders of artificial intelligence believed in the computability of the intellect and learning and used chess as a testing ground for modeling the mind"; and "[t]he machine has finally triumphed over human chess … [p. 162].

But this vision, as I have pointed out, did not prove productive (at least thus far): chess programming did not elucidate the working of the brain; and whether the machine has indeed triumphed over humans in chess is debatable. More interesting, but unexplored in Russkin-Gutmann's "Chess Metaphors", is the problem-solving route rooted in biology, e.g. why are biological systems so effective? or what are the features of a (simple) biological computer?