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ARCHITECTURAL KNOWLEDGE: LACKING A KNOWLEDGE SYSTEM, THE PROFESSION REJECTS HEALING ENVIRONMENTS THAT PROMOTE HEALTH AND WELL-BEING

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Abstract. Results collected from outside the discipline coalesce into a knowledge system for architecture. Increasingly, this information does not come from the usual historical, philosophical, and social sources, but instead from AI, biology, mathematics, and neuroscience. This body of discovered and tested knowledge remains outside dominant architectural culture. Several distinct methods of data gathering necessary for adaptive design are reviewed here. Cumulative findings — from design patterns, eye tracking and visual attention scans, information compression via mathematical symmetries, physiological indicators, software trained on artificial intelligence, AI language models, and user surveys — reinforce each other. They reveal that traditional architectural design concepts and methods generate a significantly healthier environment than what architectural practice offers. The analogy of an "expert system" is suggested as a means of incorporating the collected results into current practice. Curricular changes are needed to cover this material in schools, especially the understanding of architectural knowledge. Nevertheless, as any change threatens the architecture-industrial complex, this proposal faces strong resistance from both academia and the profession. Society must drastically revise architecture to promote human health and well-being directly.

Keywords: *adaptive design; architectural education; architectural knowledge; artificial intelligence; biophilia; Christopher Alexander; design patterns; expert systems; eye tracking; healing environments; knowledge engineering; neuroscience.*

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1. Introduction

1.1. Where is the repository for architectural knowledge?

The built environment shapes the world, as humanity's major interaction now occurs increasingly with artificial structures. Anatomically modern humans were nomadic hunter-gatherers without buildings; then for many generations lived in a mixture of artificial with predominantly natural environments. Today, a large portion of energy — invariably, fossil energy — is spent on shaping and reshaping the built architectural scales, an exponentially increasing activity while the global population is becoming more urban. The knowledge base for shaping buildings and the urban spaces between buildings is a fundamental reservoir of human learning with immense significance for continued life on the earth.

This article is about architecture's role in creating healing environments that promote human health and well-being. Most people assume that this is (or should be) the mission of a global architecture-industrial complex and are shocked to discover that this is not the case. But most often, citizens all over the world are distracted by flashy new iconic buildings and never realize how those structures — including most of what is built today in a standardized manner — contradict human biology. Buildings and urban spaces rely upon a limited knowledge base that is applied for construction and design: this article discusses the method of acquiring and utilizing information relevant to building and urban space design.

In the author's opinion, the profession neglects to apply results about the effects that buildings have on their users when that information has been derived outside dominant architectural culture [1]. There seems to exist a barrier for discovered knowledge to cross disciplinary barriers into architecture, preventing essential and useful information from being implemented to improve building performance. This phenomenon may be the result of the "not invented here" (NIH) syndrome described in [2,3]. Architectural discourse does welcome selected philosophical notions that sidestep human emotional and physio-psychological responses.

Architectural history documents different strands of building cultures, styles, and techniques, and how those have evolved through the ages. Architectural libraries collect drawings and prints for reference purposes. This useful storehouse of physical examples provides an archive from which practical lessons can be learned, especially considering how particular typologies fare for long periods of time. Architectural information can be discovered in historical buildings, then codified and updated for more general use. But an architectural knowledge base is in practice quite distinct from historical information and the two should not be confused.

Architectural historians tend to be more judgmental, presenting historical styles prior to the 20th Century as not containing useful information for today's buildings. Standard courses on architectural history do not link to modernist studio instruction in our schools; indeed, any such correlation is explicitly discouraged [4]. This is the opposite conclusion drawn from recent scientific studies. It is essential to judge the various historical practices according to their degree of adaptivity to human well-being.

The present study re-orients architectural knowledge away from style-based concerns, and towards adaptive design defined as follows:

> *Adaptive Design:* The building's details, form, shape, spaces, and surfaces adapt to the biology of the human body, the user's motions, and unexpressed physio-psychological needs. They adapt to discovered sensory mechanisms of engagement, making sure those reactions have a positive emotional valence. Design adapts to a broad spectrum of such needs that users of different ages and backgrounds require. Design also adapts to evolved material culture and local natural conditions, because those elements are essential components of human life.

While many people will agree with these principles, current practice contradicts them. It can be argued that industrial modernism embodies adaptivity in the opposite sense: it attempts to adapt its users to an affordance and sensory framework defined by the building. The purpose of intentional environmental determinism is to change human behavior by force. Architects wishing to control people's lives reverse the notion of adapting the built structures to human biology. A top-down approach to designing the environment applies social engineering to shape humanity according to industrial ideas and principles (as discussed in Section 5, below).

Using scientific methodology for discovering architecture's knowledge system collects results from different topics. This process is in keeping with academic research programs in many rigorous fields. The results are contained in journal articles and research monographs that the makers of the built environment ignore. None of this hard research is ever referred to as a guide to design: not by architects, architectural academics, builders, or developers. Such neglect makes student learning at university next to useless, since most if not all the courses teach approved ideology and fashionable topics. Many of those courses are propaganda for famous name architects going back to early modernism.

The present study limits itself to human-building and human-space interactions, and ignores other technical knowledge on computer-aided design, construction, engineering, making blueprints and models, materials science, and tectonics. Concerns about the craft of architecture have an indirect bearing on how humans interact cognitively with the spaces and surfaces of a building. Adaptivity to human senses and uses depends on the geometry and not on the engineering. Knowledge of construction techniques is therefore outside the domain of this survey.

Architectural academia does not derive and document tested knowledge [5]. Its main purpose appears to be the artistic analysis of design styles. Design decisions are guided by an invented narrative instead of human biology and the physics of matter. This practice socializes students into an anti-scientific mindset, evading techniques of analytical thinking and discovery and contaminating facts with subjective opinions. Moreover, architectural education teaches insensitivity towards the user when it ought to be providing design tools for enhancing mental and physical health.

An exception to the dominant trend in architectural education is proposed by Ashraf Salama [6]. Drawing upon tested innovations in design pedagogy, it is possible to teach adaptive design to students, with some changes to the usual curriculum. Separately, the Building Beauty program teaches the work of Christopher Alexander on adaptive architecture [7,8]. Interested students have also been able to learn classical and traditional methods of design in a few institutions over the years [9,10,11]. Those programs lie outside the academic mainstream, with many international courses of study available only as independent summer schools, and such alternative approaches remain marginalized. There is a growing body of institutions that are teaching classical/traditional design methods (see the list of programs in the USA at [12]). Some of these classical/traditional programs are also incorporating more evidence-based and scientific-based approaches towards discovering and systemizing architectural knowledge. Despite having several programs in the USA, and witnessing the recent growth in their number, 95 percent of NAAB-accredited programs are still heavily rooted in modernism (for more discussion on the role of accreditation, see Section 5.1, below).

The author has pursued the discovery and systematization of architectural knowledge via scientific techniques [13,14]. This research focuses on mathematics and describes how geometrical symmetries such as fractal scaling and various types of plane symmetry help to organize visual information [15]. There is cross-over into the work of Christopher Alexander on design patterns and the Nature of Order, biophilic design, and Neuroarchitecture. It turns out that all the distinct topics discussed in the present paper reinforce each other, being in fact, pieces of a larger discipline.

Artificial intelligence (AI) and mathematics revolutionize architecture's knowledge system. Able to combine and parse enormous amounts of data, AI realizes what would previously have taken teams of humans working over a long time. New diagnostic software uses AI's ability to extract results on how the environment affects human physio-psychology. Mathematical techniques for compressing geometrical information describe processes that occur in nature, and which subsequently directed the development of our neuronal system. These tools underlie adaptive design, but do not affect global architectural practice.

Investigating the epistemology of architecture is sorely needed at a time when basic knowledge is present in many disconnected components, mostly outside the discipline. Considering the immediate impact that architecture has on human life, this gap is perhaps surprising. A later section of this paper conjectures on possible reasons for this incompleteness. Media coverage of iconic buildings hides what lies beneath the images [16,17]. Misled by the propagandistic effects, people do not delve deeper into what this physical structure is doing to the body and psyche of those who experience it in person.

Sensing existential threats to its global hegemony, the architecture-industrial complex applies knowledge contamination and information pollution to the knowledge system presented here. Data that are not explicitly excluded from architectural academia and practice are deliberately obscured, mixed with hero-worship coming from the standard industry narrative. This tactic confuses both architects and students, giving the (intended) false impression that scientific research supports anxiety-inducing buildings and designs.

1.2. Revising the curriculum to include a course on architectural knowledge

A new curriculum is recommended to replace what is now taught to architecture students. Those courses will cover the knowledge system outlined in this paper, divided into distinct subsections for convenience and practical applications. Students need to be trained in techniques of knowledge appropriation: selecting the best tools to apply to solve a design problem. There is too much new information to lump together into a single general course, and, moreover, each related tool will need to be taught in a hands-on manner.

A new sequence of courses will introduce architecture students to an appreciation of the meaning of knowledge. This understanding will bring a concern for user health to the design profession. In today's practice, which lacks an adequate knowledge system, it is all too easy to be misled by nice-sounding hype that has no basis in fact. A knowledge system, correlated by inference and reasoning, applies a tested methodology for adaptive design to implement an entirely new approach to shaping the built environment.

At the same time, a new type of course is necessary to teach students about architectural knowledge. Nothing like it has ever been part of the curriculum, or the accepted way of thinking about design. An independent course will show new generations of architects how to discover and master knowledge, and how that can contribute to creating healing environments. It will also teach the value of knowledge together with criteria for distinguishing facts from irresponsible speculation and wishful thinking.

1.3. Outline of this paper

The aims of adaptive architecture are defined as creating healing environments to promote human health and well-being (Section 2). This definition distinguishes the present paper from very different conceptions of architecture that drive current practice.

Section 3 lists methods and foundational results of adaptive architecture. An effort is made to refer to as many of these topics as possible, and not to separate the results from the discovery tools. The topics discussed include Christopher Alexander's design patterns (Section 3.1); design insights from classical and traditional architectures (Section 3.2); practice-based research (Section 3.3); Biophilia and the ten biophilic qualities (Section 3.4); results from Mathematics and "Symmetry-deficit disorder" (Section 3.5).

Alexander's later work *The Nature of Order* derives geometrical results for adaptive design (Section 3.6). The topics continue with architecture's genetic analogy

(Section 3.7); results from neuroscience (Section 3.8); eye tracking and eye-tracking simulation software (Section 3.9); direct medical measurements (Section 3.10); experiments using virtual reality (Section 3.11); using artificial intelligence (AI) for indirect diagnostics (Section 3.12); user preferences and post-occupancy evaluations (Section 3.13); using AI language models such as ChatGPT (Section 3.14); discovering and applying design patterns using AI-trained software (Section 3.15); results from affordances and ecological psychology (Section 3.16).

Section 3.17 summarizes biological responses that establish whether a subject is reacting with empathy to a building's geometry and surfaces. The previously-listed sensors can gather information to detect an empathetic response, or its opposite, alienation, anxiety, or repulsion.

Section 4 summarizes how the consolidation of architectural knowledge will create a knowledge-based system for architecture. Mathematics unifies the distinct strands of architectural knowledge, acting to prevent epistemic fragmentation (Section 4.1). Drawing a useful analogy, Section 4.2 proposes a knowledge-based model by describing the construction of "expert systems" in AI. Establishing architecture's knowledge system still needs something akin to an "expert system shell" as its supporting framework.

Section 5 touches upon the sensitive topic of why dominant architectural culture so far ignores the knowledge system that is presented in this paper. The system in place rejects discoveries of how architecture affects the human body and health (Section 5.1). Important ergonomic decisions such as ceiling heights and kitchen dimensions are determined by slogans without any experimentation, and those persist. Even when architects rediscover some useful fact, it is not incorporated into a knowledge system, hence promptly forgotten (Section 5.2). An explanation is attempted in Section 5.3, which proposes dominant architecture to be a mythology-based and not a knowledge-based system. This assumption explains some things about the discipline that otherwise make no sense. Section 5.4 points out that students are never taught that knowledge defines a networked system: once they discover one part, they need to be curious and search for related pieces of knowledge.

Section 6 investigates further into how dominant architecture engages in "information pollution" or "knowledge contamination" to maintain its control over shaping the environment. Genuine knowledge derived outside architecture is perverted so that it becomes confused and contradictory, hence useless for effecting needed change. Readers unaware of this will be misled by texts that twist the data reported here into supporting the standard architectural narrative. The discussion in Section 7 summarizes the results of this paper, adding observations on the needed reform. Section 7 also explains why the above comprehensive list does not overtly emphasize environmental psychology.

2. The Aims of Architecture

Different authors would likely state the aims of architecture using different descriptions [18]. For the purposes of the present study, the following criteria are chosen with the admission that they are not universally accepted:

1. To provide solid structures for housing human beings and their activities and protect them from exterior conditions.

2. To facilitate human functions through the appropriate design of the built geometry and spaces, both exterior and interior.
3. To implement adaptive design solutions that protect human health and lead to healthy practices encouraged by the design.
4. To enhance human life through physiologically nourishing geometries and surfaces perceived unconsciously.
5. To create psychologically positive emotions and a mental state that helps higher functions such as learning, loving, problem-solving, thinking, etc.

A concern with the users' health and well-being prioritizes the above tasks and how they are influenced by built structures. Contemporary practice diverges from these aims. Insufficient attention has been paid to the less tangible aspects of adaptive design because architects tend to focus more on design formalism and tectonics. Recently, energy efficiency and green building policies draw the industry's and the public's attention. While those goals are indirectly related to adaptivity, they are not part of human health effects [19].

Dominant architectural culture applies formal typologies that do not require knowledge and verification of user-centered design techniques. Architects invented those typologies as a personal artistic gesture, and this is sufficient for the profession. The architecture-industrial complex is not interested in a built product that engages users positively; that encourages human interactions; and that promotes positive-valence emotions and health, which depend on a discovered knowledge system. Instead, a made-up design is imposed as a building without worrying how that affects the users' lives.

Another factor taking the profession away from the proposals of this paper is that the industry is profit-driven. While construction is necessarily part of the capitalist economy in democracies, the model lends itself to abuses when developers are driven to minimize costs at the expense of human well-being. Checks and balances work sometimes but not always. The same phenomenon occurs in centralized governments, where the state-controlled industry adopts non-adaptive models in the drive for "efficiency" [20]. Non-adaptive building projects that are unfriendly to their users abound in every country regardless of its government's political orientation, with structures looking very much the same everywhere [21].

José Cornélio da Silva summarizes the contradiction between formal architecture as a discipline and actual human needs. Humans require and seek comfortable environments for their body and mind in which to carry out life's everyday functions. But living on the run in a stressful world that we have built has no concern for any of the universal perspectives of the past. Humans need nourishing emotional comfort in the background much more than any formalized, top-down architecture [22].

3. Architectural Knowledge Obtained Through Different Methods

At a recent research symposium at the University of Notre Dame, Michael Mehaffy identified three categories of research outputs in applied design: (1) What is already known but not widely shared or recognized. (2) What is partly known but scattered across disciplines or otherwise fragmented. (3) What is not known and needs to be investigated though new research. Each of these knowledge categories must be tackled separately at first, and it will eventually be possible to consolidate them into a more coherent system.

Several branches of architectural knowledge are summarized below. The present paper attempts to survey distinct data-gathering techniques. It is not the intention to collect all the findings relevant to architecture's knowledge system: only to point to the diversity of topics. Existing knowledge is dispersed in the literature among different disciplines, some of them totally unfamiliar to architects. Methods of inquiry include architectural, scientific, and technical tools, but architecture students are never trained to read this literature. Students are not even taught the architectural methods included here.

Therefore, just as important as the material described below is the observation that dominant architectural culture willfully ignores it. This body of correlated knowledge is integral to guaranteeing human health and well-being in buildings and urban spaces. Some results are new, whereas others have been accumulating for decades — yet remain outside the mental framework of both architectural academics and practicing architects. All students must be exposed to this knowledge, so it influences the building industry, and they must also be taught how to create a knowledge system.

3.1. Design Patterns

Christopher Alexander and his colleagues introduced Design Patterns in the classic 1977 book *A Pattern Language* [23]. A design pattern is an observed design solution discovered in the built environment that combines geometry with human actions. It usually involves a recurring solution across different cultures and times. In practice, a design pattern poses a constraint for the architect to satisfy — for example, a range of associations, dimensions, orientations, sizes — within which built examples prove more successful. If an architect follows this constraint on design, then the result has more chance of being felt as accommodating by the user.

Design patterns represent evolved design solutions in cultures where awkward or hostile models of building in a certain manner would not have been repeated. Just as in biological evolution, the most "comfortable" typologies, both physiologically and psychologically, survive for centuries or even millennia. It therefore makes sense to use this discovered knowledge to inform a design project today, independently of any style. Some additional patterns that address contemporary design problems are published by Michael Mehaffy *et al.* [24].

There are nevertheless negative aspects inherent in the persistence of designs. Whenever a design typology is selected by decision-makers such as powerful developers or government agencies principally for its "efficiency", or for some cost-cutting measure, it might run against user adaptation. There is no further selection against it because vested interests support its repeated implementation. Therefore, a repeating design typology may be an "antipattern" rather than a true design pattern, hence it will not represent adaptive design [25]. An antipattern is easily described, and repeats by being implemented over and over just like a design pattern, but its effect is noxious. The crucial determining factor that distinguishes patterns from antipatterns is how far the design solution helps towards generating positive mental and physical health in the user [26].

3.2. Classical and traditional architectures

The classical tradition contains a derived body of knowledge and practice that is used to create wonderfully adaptive buildings and cities [27,28]. But the classicists fail to present this as general knowledge on adaptive, human-scale architecture independently of a specific style, because their design vocabulary is specific, i.e., columns and pediments. Therefore, people confuse the visual style with the underlying adaptive knowledge, which inhibits any application to other styles. The architecture-industrial complex twists this confusion to reject any knowledge associated with classical architecture, judging it by superficial appearance alone. Classical buildings have style-independent adaptive principles in human-scale detail, spaces, and surfaces that are not specific to this design style.

The same thing occurs with traditional Islamic architecture, a separate and highly adapted storehouse of knowledge, but wrongly identified as belonging to a specific style [29,30]. The architecture-industrial complex again rejects this knowledge system for stylistic reasons, ignoring its essential adaptivity. The collective West neglects the terrible damage that imported architectural styles have done to the East, yet the fault lies in the enthusiastic adoption of industrial-modernist styles detached from any knowledge basis. Architects and decision-makers in the East betrayed their accumulated knowledge and traditions in pursuit of an elusive modernity [31,32,33].

A toolkit of invaluable knowledge from various regional and traditional architectures can have beneficial influences today. This set of resources validates distinctive ethnicities and their adaptive evolved solutions [34,35,36,37]. Unfortunately, the handful of people who determine the industry's direction close off contemporary design to traditional knowledge sources [38,39]. The majority of architects are not included in this privileged group and are compelled to abandon their local, traditional knowledge to conform to mainstream architectural norms; hence this information never enters the profession's knowledge base.

The contemporary relevance of these traditional styles lies in their adaptation to human biology. Applied in today's practice, as is done in countless examples of informal building around the world, generates a healthier environment that enhances user well-being through appropriate human-scaled construction details, spaces, surfaces, and volumes. Integrating this inherited knowledge into design is forbidden by an ideological barrier against pre-modernist styles.

Neo-Classical architects occupy a profitable niche in today's marketplace because of the continued popularity of Classical design with the public. Traditional practitioners have had to fight against the onslaught of industrial modernism taking over the building industry after the beginning of the 20th century. Those architects use an architectural form language going back to ancient Greece and Rome, relying upon historical typologies that convey the collected wisdom of thousands of years in accommodating human reactions. This represents knowledge embedded in buildings, but not an explanatory framework. Nevertheless, learning classical architecture exposes a student to the mathematical symmetries responsible for adaptive design, which are absorbed unconsciously and applied to subsequent projects.

3.3. Practice-based research

Ashraf Salama has worked to develop the knowledge space of architectural and urban traditions independent of style [40,41,42]. This cross-disciplinary direction of inquiry attempts to establish a knowledge system through environment-behavior and phenomenological investigations. Data is obtained by studying different building and place typologies such as community heritage, housing, and vernacular settlements from around the world. In a parallel with the Design Pattern approach, architectural traditions can be separated into those specific to a geographical location or tradition, from those that are more generally applicable. Unless restricted by top-down impositions, such a knowledge space is continuously evolving.

An exclusive focus on artistic innovation creates a barrier to adopting practice-based research in architectural education and practice. Most fanciful artistic expressions are incompatible with the results of adaptive design because the latter tend to look "old-fashioned" as they are constrained by the human scale. The solution is to teach students to privilege the users' health and well-being over their own ego.

A similar research endeavor is situated within efforts that go back to Donald Schön [43]. Schön privileged direct experience over linear, rationalist thinking; but he unfortunately called for separating the artistic, intuitive process from the scientific method. Reflective practice tries to ground design thinking on the human cognitive system, to prioritize the connection between the brain and the environment. An attempt was made to link the profession to James J. Gibson's ecological approach to perception in environmental psychology [44]. Dominant architectural culture cherry-picked some tools from this program, ignoring those that could lead to adaptive design.

3.4. Results from Biophilia

Biophilia denotes the innate love that humans have for life and life forms. Our evolutionary past shaped our body to function in natural environments. The concept of biophilia was introduced separately by Erich Fromm (in psychology) and Edward O. Wilson (in biology), then developed in the context of the built and natural environments by Stephen R. Kellert. The 2006 conference on biophilic design [45] marked a watershed by introducing biophilia as a major component of adaptive design (the reader can find comprehensive references in that book).

This positive emotional connection that humans experience in the presence of biological forms extends to artificial structures possessing specific informational properties [46]. Understanding and implementing Biophilia has tremendous potential for achieving adaptive and healing (salutogenic) design. Recovering hospital patients heal faster after surgery if they have a view with real trees instead of a blank wall [47,48,49,50,51]. Biophilia is experimentally measured as one essential component for promoting human health. The present author has proposed the following list of ten biophilic qualities:

1. Sunlight: preferably from several directions.
2. Color: variety and combinations of hues.
3. Gravity: balance and equilibrium about the vertical axis.
4. Fractals: things occurring on nested scales.
5. Curves: on small, medium, and large scales.
6. Detail: meant to attract the eye.
7. Water: to be both heard and seen.
8. Life: living plants, animals, and other people.
9. Representations-of-nature: naturalistic ornament, realistic paintings, reliefs, and figurative sculptures—including face-like structures.
10. Organized-complexity: intricate yet coherent designs—and extends to symmetries of abstract face-like structures.

The central assumption of biophilic design is that the more of these qualities the user experiences, the more intense his/her state of well-being. A rapidly growing experimental basis supports this claim. Restorative environments help people recover from mental fatigue [52,53,54]. Initially, the biophilic effect was thought to come only from direct exposure to natural environments, which encouraged the introduction of green spaces into buildings and cities. Now it is known that biophilia arises from geometrical principles, which also apply to ornamentation in and on buildings themselves. Biophilia in a dense urban setting therefore needs ornament as well as pockets of vegetation.

Even more impressive, the biophilic content of learning environments influences student outcomes. A pilot study demonstrated that exposing students to organic visual patterns in a classroom improves learning dramatically [55]. The study used two similar classrooms: one with prevailing gray, minimalist surfaces was left as a control; the other redecorated with biomorphic patterns on the carpet, ceiling, and walls. In addition, the window shades were imprinted with patterns of tree shadows. Students self-reported feeling less stress in the biophilic-decorated classroom. This finding was independently confirmed by measuring body stress indicators. Most dramatic were the learning outcomes: students in the biophilic-decorated classroom scored significantly better than those in the control classroom. The average Mathematics test score gain was more than three times that in the control classroom.

3.5. Results from Mathematics

The ability to compactify visual information so that it can be processed faster by the animal brain offers an evolutionary advantage [56]. This is achieved through redundancy and similarity, which extends the old Gestalt notions that help in visual comprehension, now in a more mathematically sophisticated framework. Redundancy is the opposite of random information, as trying to process uncorrelated data tires the brain by using up processing energy. Different types of symmetries compress visual information, making it more immediately accessible for human (and animal) neuronal processing. Two principal symmetry categories combine to generate organized complexity in the visual field:

1. Scaling symmetry is responsible for fractals. A geometrical shape is repeated, approximately or exactly, at different magnifications. In more regular fractals, the repetition occurs at consecutive scales that are related by some scaling factor. Exact mathematical fractals repeat at decreasing sizes down to the texture in the materials. Richard Taylor has published extensive research on architectural fractals and how humans respond to them [57,58,59,60,61].
2. Plane symmetries create geometrical redundancy, where a basic geometrical unit repeats in an ordered manner. Reflectional symmetry joins two mirror images into a coupled bilaterally symmetric unit. Translational symmetry repeats the same unit along some direction. Rotational symmetry repeats a unit going around a circle. Compound symmetries combine these three basic symmetries to generate complex but ordered shapes.

Around World War I, the West’s dominant intelligentsia began to deny and suppress complex symmetries of all kinds from artifacts and buildings. Since that time, and up until today, the artificial world suffers from an increasing poverty of complex symmetry. This drastic loss of environmental symmetry has led to a measurable pathology called "Symmetry-deficit disorder" [62]. This term is used by analogy to Richard Louv's term "Nature-deficit disorder", which is especially damaging for children [63]. The reader is referred to extensive studies where non-symmetric, unbalanced buildings create anxiety in the viewer. Remarkably, monotonous repetition, which eliminates scaling symmetries, generates headaches [64,65,66].

Yannick Joye argues that the biophilic effect (Section 3.4) is due to the mathematical symmetries that nature and living forms represent, rather than some mysterious vitalistic force [67,68]. The biophilic healing effect is activated by representations of nature, although sometimes in reduced intensity from the real experience. Abstract complex symmetries, if they are coherent, nested, and emphasize the vertical axis, will give a positive-valence effect comparable to exposure to natural information. Therefore, human health is connected to complex, coherent symmetries through biophilia, which implies that their absence might have negative effects on the body.

3.6. Geometrical lessons from Alexander's The Nature of Order

Christopher Alexander extended his earlier work on Design Patterns to develop universal geometrical rules for creating spatial coherence [69,70,71]. These are known as the "Fifteen fundamental properties" [72,73]. Initially derived empirically, the 15 properties are found in the most-loved human creations — artifacts and buildings of all cultures — throughout history. The present author established the link between some of the 15 properties and the mathematical tools leading to organized complexity [74]. Mathematical organization through ordering symmetries is a unifying concept for establishing architecture's knowledge system.

Alexander's thinking and reasoning finds a remarkable parallel in the work of Iain McGilchrist on the competition between the two sides of the brain [75]. Or Ettlinger describes how the present-day world is fascinated with the mechanical at the expense of the living and sees everything as made of objects instead of relationships. This division corresponds to the distinct manner in which the two brain hemispheres interpret the world; it is precisely the contrasting approach of Christopher Alexander to design compared to that practiced by dominant architectural culture.

Verifying how the human brain is structured to interpret specific geometrical and other patterns opens opportunities for research. Alexander's 15 Fundamental Properties describe how to approach and construct systems of organized complexity; hence they clash directly with contemporary architectural culture, whose principal stylistic goals are (*i*) empty minimalism, and (*ii*) disorganized complexity. Architects can immediately see that their standard design toolkit is invalidated by Alexander's organizational principles, which is the reason why they dismiss them.

3.7. Architecture's genetic material

Over generations, adaptive architectural practice discovered design solutions using available materials. Following ecosystem and organismic analogies, evolved design and tectonic typologies optimized for human health and well-being by combining general characteristics with local specifics. The DNA of architecture provides a useful knowledge system for building today [76,77]. This repository of design knowledge underwent changes, sometimes drastic, as living conditions changed, and as new building materials became available. However, details, proportions, spaces, surfaces, and volumes that promote health remained invariant.

Adaptive design arises from physio-psychological needs (biological DNA), otherwise the body does not fit emotionally into the built environment. The opposite approach, forcing people to inhabit generic structures that follow some formal definition, is not a good idea. A further lesson from biological DNA is how the local chemical field influences the growth of an embryo as it develops. For this reason, every organism is different. Translating this adaptive mechanism to design, local conditions will influence how a building looks. Industrial-modernist replication goes against organismic development.

Some architects use the same idea not to develop adaptive design, but to evolve organic shapes randomly, selecting for their abstract artistic appeal. Such images might initially look interesting but would alarm the user when built full-scale. In that body of design research, the terms “DNA” and “genetic architecture” do not seek to approach healthy architectural solutions iteratively. Truly adaptive design agrees with the other methods listed in this paper, marking consilience as a basic criterion for distinguishing healthy design from work that happens to be labeled in the same way [78].

3.8. Results from Neuroscience

Neuroscience studies uncover the underlying mechanisms for the body’s reactions to external stimulations, both negative and positive [79]. It is essential to remember that, in guaranteeing evolutionary success, the animal sensory system weighs negative stimuli several times more than positive effects, around 6X. During animal (and human) development, it was necessary to protect the organism by reacting swiftly and unconsciously to threats (fight-or-flight response), while relegating the positive benefits of attraction (reward-seeking) to a secondary level. This built-in response is known as negative-positive asymmetry embedded in autonomic approach and avoidance behavior [80,81].

Measurements evaluating architectural settings document how users respond unconsciously to forms and surfaces [82,83,84,85,86,87]. The architectural environment establishes a state in the body, changing with position and orientation, which influences well-being [88]. Short-term stress on the body, even if it is low-intensity, builds up over repeated exposure to generate pathologies in the long term [89]. This mechanism is the basis for how architecture’s visual appearance affects human health, as distinct from non-visual environmental factors such as odors, pathogens, pollutants, sounds, toxins, etc.

Results from neuroscience experiments on what environmental qualities promote a healing environment, versus those that generate anxiety, confirm what is independently documented from biophilia, the mathematics of organized complexity, and traditional design techniques. Knowing the neurological mechanisms behind human responses helps in accepting their psycho-social implications, discovered separately, as being based on biology. This association validates the use of design elements identified as positive for human health in building today.

Neuroscience findings raise ethical concerns of continuing to use anxiety-inducing designs and typologies. Insisting on those even after science has discredited them appears to be deliberate and willful, insensitive to possible harm inflicted on the users. Accumulating evidence showing that the basic design principles of industrial modernism aim to manipulate user behavior is equally disturbing.

The negative-positive asymmetry inherent in the autonomic nervous system [90] suggests a simple computational model for explaining and predicting unconscious responses to non-adaptive architectural styles. Inserting two minimalist or disruptive "contemporary" structures into an ensemble of ten coherent traditional ones (by replacing two of them) is enough to lower the overall coherence — hence to destroy the environment's salutogenic effect ([91], Section 5.4). But the opposite attempt of inserting/renovating two buildings among a set of ten minimalist or "contemporary" ones to a traditional style fails to raise the overall attractiveness above the homeostatic balance threshold. One needs to upgrade six of those ten buildings to achieve a salutogenic effect.

3.9. Experimental techniques such as eye tracking and eye-tracking simulations

Experiments determine clearly for the first time how the eye-brain system engages with a building. Ann Sussman and collaborators have done foundational work in establishing this technique for architectural evaluation [92,93,94,95]. Findings contradict long-accepted design principles established during the 1920s and implemented by the construction industry because of enormous profits. Some key results of this ongoing research include: (1) blank, minimalist façades fail to engage a viewer; (2) a person's attention is drawn to contrasting, detailed regions; (3) as the ordered complexity increases, the eye roams uniformly over the entire scene [96]. But non-uniform attention is focused upon fixed points that the eye-brain system might interpret as posing a danger, such as sharp corners and protruding objects.

The original eye-tracking experiments were done by Alfred Yarbus and involved a subject wearing a headset sitting in a very bulky apparatus [97]. Nowadays, portable eye-tracking glasses are worn, and these can be employed either in front of a monitor displaying a static scene or video or while moving outside in a real physical setting [98].

An additional revolution has taken place with the development of eye-tracking simulation software that can process an image to give an approximate heatmap of where the eye is expected to focus on. Because the software was trained using Artificial Intelligence, the claimed accuracy is 92% or more compared to direct eye-tracking measurements [99]. This visual diagnostic enables the evaluation of a user's engagement with a building based on its image (rendering or photo) [100].

3.10. Direct medical measurements

For many years, the health-care community performed non-invasive experiments to measure body state indicators and to find out how those change in different environments [101,102]. Measurements indicate whether the induced physiological state is positive (healing), neutral, or negative (stressful). Investigation was limited initially by several factors: (1) before the availability of high-definition screens and Virtual Reality the subject had to react to a photograph; (2) an actual physical experience was impossible because of the bulky instruments needed; (3) the subject was in an awkward, fixed position inside a scanner. Despite such limitations, some very important results have come out of this research [103].

With recent technological advances, however, such experiments are now carried out using lightweight, portable apparatus, leading to a revolutionary improvement in the ease of data gathering [104,105]. Several research groups are now collecting data on a subject's reactions to different architectural environments using portable, wearable sensors. Those instruments collect objective physio-psychological measures of stress, including skin conductance, respiration rate, and variability in the heart rate [106]. Results support what is discovered using the other techniques described here, but so far, these measurements have not led to changes in architectural designs or practice.

Identifying the qualities of healing environments reveals elements of industrial modernism and its later variants promoted by the architecture-industrial complex that create feedback in the human body having the opposite (negative) valence. This should have been sufficient for the health care profession to call for a moratorium on building faceless concrete blocks and the standard glass-and-steel high-rises. Nevertheless, architecture's missing knowledge system coupled with media praise for non-adaptive buildings help to perpetuate an endemic confusion.

3.11. The use of virtual reality

This category overlaps with several others in this list yet merits a separate mention. The increasing realism of visual environments accessible through virtual reality (VR) has greatly facilitated experiments that measure user reactions. Image representation on a screen is highly detailed and can be analyzed on the desktop using a multitude of wearable body sensors to judge physio-psychological feedback. VR can also be used to experience motion from a video. Therefore, it is no longer absolutely necessary to be present at a physical scene to accurately measure its effects [107]. "Walking through" variations of a design helps to choose from among them based on sensory feedback.

Discovering user reactions to different visual environments enables the subsequent documentation of healthy versus unhealthy design elements. User immersion in virtual reality has been coupled with neurosensors to measure responses to different components of biophilic design [108]. Thus far, however, current applications of VR in architectural design and research merely generate fanciful settings without diagnosing their effects on the users. Surely, the profession wishes to know which environments are more attractive emotionally? No. Limited by an accepted form language, commercial virtual worlds are designed using the same industrial-modernist typologies dating back to the 1920s. Instead of treating VR as a discovery tool, the standard canonical images were imposed on it. This misstep led to enormous financial losses for the industry as potential users reacted negatively to the visual experience [109].

3.12. Indirect diagnostics made possible by artificial intelligence (AI)

Artificial Intelligence (AI) makes it possible to use indirect data gathering to assess the physiological states of subjects exposed to different visual environments [110]. This helps to understand the corresponding reactions that influence human behavior. Among several related techniques, facial expressions and speech patterns unconsciously reflect the user's emotional condition. Programs trained on artificial intelligence can process videos to identify a subject's immediate feelings, even if the subject is not consciously aware of them [111]. AI-based programs discover the effects of environment-induced stress because it generates subtle "ugly" expressions in a person's face [112,113,114]. By "reading" facial muscle activity, diagnostic tools use AI to infer the unconscious emotional state of the subject [115,116].

Another promising direction of research uses portable EEG (electroencephalogram) devices to measure a subject's reactions as he/she moves in the physical environment [117,118]. The same can be done in front of a monitor showing images or videos of scenes. The subject's corresponding emotional state is computed by

AI-trained software in real time. This mechanism evaluates the degree of fit of a design to human biology.

Analyzing the speech patterns and vocabulary of ordinary conversations measures differences in the state of well-being that is being influenced by the physical setting [119]. The subjects are not aware that their speech patterns are providing information on how comfortable they feel to be and work in a particular environment, which helps to bypass any subjective opinions. Studies carried out so far confirm results obtained from other sources indicating that people feel most comfortable in environments with biophilic and traditional design characteristics.

3.13. User preferences and post-occupancy evaluations

Human aesthetic preference for visual information combines objective with subjective components. Recent scientific research has been able to clarify some of this division [120]. Starting in the 1960s, user surveys revealed the type of architecture that the public prefers [121]. General preference polls are distinct from specific post-occupancy evaluations of individual buildings. The commercial sector undertakes detailed surveys as part of consumer research to determine what type of product sells best, and subsequently adjusts the product to meet user demands: in architecture this exploration is limited to shopping center design [122,123]. What needs to be done is to integrate user feedback into design iterations — virtually before the design is finalized, and again after it is built — and to note these findings for application to a similar future project.

The public is intuitively tuned into the previous millennia of human building activity and feels which environments make it comfortable. Extracting re-usable design components from the discovered preferences among different design typologies is analogous to "pattern mining" used in putting together a pattern language (Section 3.1). The difference is that public opinion chooses in a survey, whereas pattern mining is done by a specialist group discovering patterns embedded in the historical built fabric. Yet the necessary feedback loop whereby discovered knowledge is fed back into the design process to prevent the same problems from occurring again has failed to materialize [124].

Preference surveys among the public consistently reveal that common people prefer more traditional architecture, whereas trained architects prefer what the architecture-industrial complex produces and promotes [125,126]. There is a huge gap between architectural education and public preferences. Architectural curricula diverge from common preferences for reasons that are discussed in Section 5, below. This split in opinion is a result of design professionals holding a strong opinion of what constitutes a beautiful or ugly building [127,128,129,130,131,132]. Architects select according to how far a design conforms to "canonical" design styles. Opinion polls are limited because of subjective influences such as attributed meaning and familiarity, hence are best combined with other tools.

The literature and media confuse these two opposite reactions to buildings by an unfortunate choice of words: labelling "novices" ordinary people who react spontaneously through evolved biological responses (condemned as being ignorant of architectural knowledge); while individuals who have been psychologically conditioned by architecture school are labelled "experts" [133,134,135]. This biased terminology gives a false authority to persons who, through their training, suppress human neurological responses. True expertise relies instead upon familiarity developed with a verified knowledge base.

A recent survey revealed overwhelming public preference for US federal buildings in traditional versus modernist styles [136,137]. For the first time, independent scientific methods were used to support common architectural opinion (against the prejudices of mainstream professional architects). This independent Harris Poll showed that preference is distributed equally among political party affiliations. Eye-tracking experiments and eye-tracking simulation software independently verified the survey's results [138,139,140]. Mapping visual attention uncovers an unconscious component beneath attitudes and beliefs. Nevertheless, the architecture-industrial complex disqualified this important finding by stirring up a very emotional political controversy, which the media misinterpreted in polarizing partisan terms [141].

Post-occupancy evaluations survey a structure after it is built to determine how far it is successful in its intended uses, and especially how comfortable users feel emotionally and physically [142,143]. A relevant body of literature has evolved using self-reported user surveys [144]. Two distinct limitations have prevented post-occupancy evaluations from having the full impact expected of this assessment mode: (1) personal answers to surveys tend be colored by subjective judgments, hence cannot always be considered as unbiased; (2) the profession has ignored post-occupancy evaluations when those identify flaws in buildings that were expected to be perfect because of favored style, or the prestige of the architect [145]. These problems are now overcome by supplementing user surveys with diagnostic tools such as visual attention scans [146].

3.14. ChatGPT extends the survey pool to billions of people

Whereas old-fashioned surveys of preferences and reactions to architecture involve a limited number of persons (typically 10 to 50 in a group setting; up to several hundred in a nationwide or international poll), artificial intelligence programs extend the pool by several orders of magnitude. An intelligently-worded question to AI language models will return general preferences of the entire population. Equally important is the determination of what people dislike because that makes them feel anxious or uneasy. Results verify what is independently known from other methods of evaluation: ordinary people prefer human-scaled architecture containing the design and mathematical characteristics listed above [147,148].

Care must be taken with the questions in employing clever "prompt engineering" [149] to ask not about architecture directly, but to list the characteristics of a healing, emotionally-nourishing, and uplifting environment. AI will return the collected opinion from hundreds of millions of people on what details, spaces, surfaces, etc. make them feel comfortable. As AI draws from published data sets about buildings, however, it is unable to distinguish between genuine physio-psychological user responses and the profession's self-serving hype. Asking ChatGPT for characteristics of award-winning, famous, or iconic buildings will not reveal information on adaptive design.

3.15. Pattern combining and mining using AI-trained software

Design with the use of patterns as constraints can be enormously facilitated by using computing power to evaluate the different combinations for adaptive design. Bruno Postle has developed a program that generates design variations, and then selects from among them using chosen design patterns [150]. This is an intelligent application of evolutionary or genetic computing that is based upon incremental changes to the design. In these computations, the pattern language takes the role of defining fitness criteria for selection.

In an entirely separate development, artificial intelligence programs can use visuals to discover and evaluate the design patterns embedded in a particular design [151]. This task is very tedious for a person to do because several patterns are usually working together, and overlap. The analysis uses AI that is trained on the two existing Pattern Language books to extract which patterns were applied (consciously or unconsciously) by the architect of that project. Initial results of extracting design patterns through AI are very promising.

These exciting possibilities for developing new design patterns will assume a central role in the profession after practitioners begin to use patterns once again. So far, design patterns have been embraced enthusiastically by the self-building public but play only a marginal role in dominant culture, despite their immense utility. Architects driven by a quest for artistic originality have shunned the constraints imposed by design patterns. Future generations of practitioners will have the AI tools to derive a set of new design patterns specific to their project, to supplement existing patterns.

3.16. Affordances, ecological psychology, proprioception, and real or suggested handles

Adaptive design leading to salutogenic environments relates to concepts in ecological psychology, i.e., the affordance theory of J. J. Gibson. People maintain their mental health when they can engage with their surroundings by perceiving affordances [152]. Juhani Pallasmaa introduced the human senses of grasping and touch into architecture, although these ideas did not make significant inroads into practice [153,154]. Prompted by more recent developments in measuring human responses to the visual environment, workable design rules are finally beginning to coalesce. New design pattern 12.1 from Mehaffy's *A New Pattern Language* summarizes the concept of "handles" [155]:

> *Handles:* "Pay special attention to include structural features that are shaped to be easily 'graspable' by the hand, which fit comfortably, even if we never need to physically grasp them. Actual handles should revert to older ergonomic design and abandon the ubiquitous uncomfortable shapes due to abstract 'design'."

Support for this pattern is indirect, presenting an excellent opportunity for further research using the latest equipment to gather data. Note that the "handles" referred to include frames, moldings, ornament, trim, and window mullions and muntins, which are central components of traditional architectures. Even mentioning those design elements generates tremendous hostility among contemporary architects; therefore, this question has significant consequences for the profession's future.

Proprioception, or the affordance of 3-dimensonal space for the human body, is another related topic [156]. Some of the original design patterns (see Section 3.1, above) documented how well the body and its movements fit into built spaces and their subdivisions. Spatial accommodation is related to geometrical descriptions such as fractal subdivisions [157] (see Section 3.5, above). An interactive approach to space design based on human perception is very different from what has been standard practice. Instead of accepting a formal, insensitive design for interior and exterior spaces, designers must be particularly accommodating to feelings and judge the design using subtle feedback from their own body. Using full-scale mock-ups and virtual reality makes such evaluations possible.

3.17. Architects are trained to suppress empathy and intuition

Critics of 20th-Century architecture and its offshoots point to their architects' lacking empathy for nature and people. Human intuition that developed as essential for evolutionary survival shows this. While some recent discussions confront the problem, the situation is muddled by an incongruity between the way architects and non-architects perceive the world. Empathy correlates with physio-psychological characteristics and signals in the body. This effect involves the action of mirror neurons, whereas cortical damage and post-traumatic stress disorder (PTSD) are both correlated with a loss of empathy.

Several tools measure components of empathetic responses: (1) Galvanic Skin Response shows increased conductance with emotional arousal, and there are wearable GSR sensors; (2) Heart Rate Variability increases with heightened empathy and a subject can wear a portable heart-rate monitor; (3) Eye-tracking reveals longer fixations on objects with which the subject empathizes, and wearable eye-tracking glasses are available; (4) Facial expressions can be read directly using portable cameras or inferred using AI expression-analysis software and reveal empathetic responses; (5) Thermal Imaging indirectly shows increasing skin temperature using a portable thermal imaging camera, which correlates with emotional arousal; (6) Functional Magnetic Resonance Imaging measures changes in blood flow in the brain, which in specific regions indicates empathetic responses; (7) Electroencephalography uses electrodes placed on the scalp to measure increase in alpha and gamma signals, which correlate with emotional processing, and portable EEG headsets are available.

Empathy is the effect of an emotional connection having positive valence. Empathy is central in establishing social contact and relations. A person automatically engages with living and natural structures through empathetic connection, but can do so only with artificial structures having attractive characteristics. One of the aims of traditional architectures and artifacts was in achieving such an emotional connection with the user, eliciting positive feelings when experiencing a particular space or structure.

More experiments are needed to confirm the geometrical characteristics that trigger empathy from people; existing results already establish all the qualities documented above in built and natural structures. Society must recognize that dominant architectural culture prefers buildings lacking empathetic qualities and instead seeks to induce an alarming or numbing effect. The misleading excuse of prioritizing efficiency over emotional engagement only obscures fashion, ideology, and power as being the real drivers.

4. Architecture as an Expert System: How Mathematics Consolidates Architectural Knowledge

4.1. Testable sources of architectural knowledge

An expert system is the type of operational framework that would be useful in structuring architecture's knowledge system. This idea — of organizing how architectural knowledge is best collected and organized — is novel. While mathematics provides a unifying principle, the application of expert systems comes from computer science and information engineering. Architecture needs to undertake this transformation to remain viable in a technological future. The dominant system has not addressed the existential problem of lacking a knowledge system; instead, co-opting AI tools to perpetuate itself without changing its approach to design [158,159].

A diagnostic toolkit is essential for evaluating existing structures to establish what supports user health and well-being versus what does not. This way, design mistakes that create functional difficulties or generate anxiety will not be repeated elsewhere. A predictive set of criteria can help a designer anticipate some of these key questions before something is ever built. By diagnosing competing designs beforehand, it is easy to choose from among a set of options using health-based diagnostics, something impossible to do after construction.

Natural systems follow special mathematical ordering to achieve stability, and the human neural system consequently evolved to interpret such visual information for survival. Those descriptors define healthy elements of design. Helping to establish epistemic rationality — mapping beliefs onto the measurable physical world — the geometry comes first and serves as the framework for an architectural epistemology.

Architecture should generate its knowledge system by acquiring useful information, regardless of where it was derived. Design that is good for its users applies multiple pieces of evidence from independent sources. Knowledge engineering empowers an architectural practitioner to work within constraints that help to generate a healthy and healing building or urban setting. Otherwise, how can one have any indication of whether a proposed structure will be emotionally comfortable to be in; or the opposite, generate anxiety in its users?

It was convenient here to mix three aspects of architecture's knowledge system: (1) the specific methods by which architectural knowledge is discovered and verified; (2) the documented results themselves; (3) a classification or taxonomy to keep these results conveniently grouped so that practitioners find them easy to apply. The knowledge system builds its structure from these three major components. But architects and students will have to abandon their learned prejudices that prevent them from acquiring architectural knowledge.

Voluminous texts on what is claimed to be architectural theory have no direct connection with how the built environment influences the users' health and well-being [160,161]. Speculations about buildings by famous architects are accepted through wishful thinking without experimental validation. Epistemic fragmentation works against a shared knowledge system because individuals cannot communicate their basic feelings with each other and are forced to accept a manufactured narrative.

The "design methods" movement of the early 1960s sought to input research from a wide variety of fields [162,163]. Adaptive design was identified as a "wicked problem" with an infinite number of acceptable solutions [164,165,166]. Realizing the fundamental role that psychology plays in design, environment-behavioral studies and user-centered design began to generate a knowledge system for adaptive architecture. Schools of architecture saw these efforts to understand the biological context — necessary for aligning design with human needs — as irrelevant to their adoption of formalism and "art for art's sake" [167,168].

4.2. Architecture can benefit from creating its own "expert system shell"

AI proves to be an extremely powerful multi-disciplinary field that contributes to build up an architectural epistemology through its knowledge-gathering capabilities. AI's performance in discovering and verifying adaptive design tools contrasts markedly with how thousands of architecture students are cognitively limited by an extremely narrow design vocabulary. Applying a set of industrial-modernist images requires no intelligent reasoning. Fears that architects trained in the present self-referential studio system will soon be replaced by AI are entirely justified [169,170,171,172,173].

AI systems in computer software suggest a useful framework for building up a knowledge-based architecture [174,175,176]. An expert system is created and trained to solve problems, mimicking the analytical decision-making skills of an experienced human. “Expert systems” have proven very useful for decision-making in business, engineering, geology, healthcare diagnostics, manufacturing, etc. In architecture, this would involve an adaptive decision-making function that is knowledge-based instead of the present mythology-based system (as explained in Section 5.3, below).

The first step in knowledge engineering is to create an expert system shell, which is a knowledge representation scheme coupled to a set of logical rules for discovering new information. A reasoning component known as an “inference engine” is responsible for making decisions using the acquired knowledge base.

The second step is to set up an empty framework in an expert system shell in which to store the knowledge. This is a structured skeleton that organizes incoming information represented in a convenient way. It is essential to be able to quickly retrieve stored information from templates.

The third and final step is collecting the knowledge base. Relevant factual and heuristic knowledge and rules for their combination are selected from available information on architecture linked to human life. Domain knowledge search is coupled with validation techniques that check data using empirical tests. While a classification skeleton for ordering different pieces of architectural information relevant to adaptive design is being developed, the “expert system shell” is built upon inference relations and logical rules. The following section attempts to explain why dominant architectural culture lacks the operating shell of a knowledge-based system, along with its intrinsic processing and reasoning methods.

5. Rejecting Architectural Knowledge to Maintain a Mythology

5.1. Why dominant architectural culture rejects objective knowledge

The author agrees with Richard Buday [5] in doubting Julia Robinson’s optimistic assessment that architecture is in the process of evolving into a discipline with its own body of knowledge [177]. As proof of the continuing lack of clarity within the discipline, where are the courses that teach all the topics mentioned in this paper? Professionals regularly read journals, but those invariably publish projects (sometimes paid for by their architect) without substantive text; or merely a press statement promoting the building. The images act as visual memes to propagate a set of preferred design styles without deeper analysis.

Ergonomics and optimal dimensions define an entire discipline that needs to be treated in depth elsewhere. But the most important design decisions, such as ceiling heights, window placement and size, the arrangement and dimensions of kitchens, etc., are now determined by what someone asserted in the early 20th Century. Architects have mindlessly followed those slogans without ever experimenting to verify them according to human emotional feedback. Design patterns and virtual reality experiments correct those misunderstandings yet the discredited typologies continue to be used.

Knowledge about adaptive architectural practice, derived outside the discipline, does not enter architectural education except for engineering and materials science.

Adapting each building to the user would ruin the promise of an industrial "universal style" that supposes the opposite causality. Forcing the user to adapt to a standardized building does not require the research reported here. What is taught during the 4 to 5 years that a student needs to complete his/her diploma is not tested (and is frequently not testable) knowledge. And students are not motivated to seek new information, being drawn through narrative transportation to an architectural culture of hero-worship (see Section 6, below).

The current educational system encourages artistic design and creative expression without a knowledge system to anchor this process. In what appears bizarre to scientists, architects exhibit artistic objects — termed "explorations" — and treat them as hard data, while regarding philosophical speculations as having equal value to scientific research. The dominant architectural mind-set never makes any effort to comprehend the physical world using the scientific method. Canonical images and slogans define architectural reality for a profession stuck inside an "informational echo chamber" isolated from reasoned analysis.

It is easily verified by searching the standard curriculum online that the topics discussed in this paper are not taught to architecture students. School accreditation requires a standardized list of courses with very specific content: national agencies insist on course uniformity to certify an architecture program. Despite repeated attempts to change those rigid accreditation requirements, the profession remains steadfastly tied to modernist studio practice [178,179]. Furthermore, this omission occurs throughout the world with very few exceptions. Architectural education has become globalized and conforms to the same narrow set of pedagogical principles.

Society strongly criticizes what it sees as extravagance, megalomania, and narcissism in iconic buildings; but also, in large-scale undertakings such as housing projects and even completely new cities. Industrial-modernist architecture overrides cognitive responses and physiological experience such as proprioception. How do architects justify the beliefs upon which their work is based, and are those beliefs rational? What is the origin and scope of architectural knowledge? Should common people accept what dominant architectural culture presents as its aesthetic prejudice, or should they question it? A knowledge basis reflects what people believe about the nature of reality: do architects and the public share a common reality?

Fearing change, and fearing the questioning of accepted principles, the profession closes itself off from adaptive architecture and interdisciplinary collaboration. Many of the deniers do not realize that what they are doing is damaging to human health because they have been persuaded, during their formative years, to believe they are doing the right thing. They prioritize image appeal at the expense of human health and well-being. Architecture professionals are afraid that their status as "experts" is in peril, and they prefer not to even try to understand the possibility of harming people.

5.2. Re-discovering the wheel, then promptly forgetting it

Lacking a knowledge system, architects who re-discover some elementary result believe that it is novel, even though it has been known and developed in depth elsewhere. Or they convince themselves that a false new assumption is true. The insular academic institution accepts made-up and primitive results. This display of ignorance is embarrassing in a scientific milieu, but not for an architectural culture that observes the "not invented here" syndrome (see the Introduction).

Knowledge producers outside architecture publish findings with a bibliography and references and try to correlate results across distinct domains. But those trained through architectural education naïvely believe that they are discovering novel information on a topic, being ignorant of what was discovered previously. The chasm between architecture and epistemic disciplines permits the rediscovery of results that are soon forgotten. A rediscovery never makes it into a permanent knowledge base when that does not fit the invented narrative.

Architectural academia adopts a collective amnesia towards knowledge that does not conform to the established narrative. Evidence-based results that contradict favored typologies never make it into the database. Researchers coming from the outside are surprised to find published hard data on design that were forgotten, to be re-discovered years later, or even a second and third time around. Books containing those arguments appear, then disappear, because academics act as gate-keepers to block their influence on students.

Dominant architectural culture draws its working tools from an extensive internal database. Stored information includes stylistic details from canonical buildings, the actions and slogans of admired modernist architects, etc., situated inside an epistemic bubble. A narrow collection of rules based on assumed prestige has no explanatory capabilities. This is not a knowledge system since it is invented — made-up rather than discovered — and does not employ inference and reasoning to interpret data and draw conclusions. There is no validation mechanism in place.

Access to the database is carefully guarded, keeping the existing system disconnected from reality. Architects' public relations statements promoting their own projects shape the narrative and substitute for a knowledge system. Genuine discoveries on human physio-psychological responses are avoided because those threaten the privilege of belonging to dominant architectural culture. Something else is driving the design profession and global building industry, but it is not an intelligent informational framework.

5.3. The mythology of contemporary and modernist architecture

Architecture since the 1920s has established a common language that is used for community building and cohesion within the profession; but its foundational principles have never been tested. Time and again, scientific results question architecture's epistemological basis (or lack thereof), and the system reacts by becoming ever more insular. It is able to do that because of the power of the architecture-industrial complex, which depends upon successful public relations.

A conventionally trained architect will insist that contemporary architectural culture does indeed possess a database, inherited from the early modernists, and supplemented by more recent architectural theory that describes the technicalities of design software. But on closer examination, that typically incomprehensible body of writings is neither derived nor tested knowledge, but a collection of declarations to promote idiosyncratic, individual beliefs. The profession simply does not distinguish knowledge from public relations.

What should one call the texts taught in architecture schools all over the world for several decades, and which the profession uses in lieu of a knowledge basis? For want of a better term, it is accurate to label architecture's belief system as modernist "mythology". As in any mythology, the modernist corpus is a collection of stories and statements that followers believe in and use to structure their professional lives and practice [180,181].

Those rituals, stories, and symbols are almost entirely subjective: they substitute for and replace physical reality in an architect's mind [182,183]. James Stevens Curl discusses the mythology and cultic religious practices of modernism in academia and practice [1].

Modernist symbols are categorized by the present author within the explanatory framework of "memetic transmission" (see [14], Chapter 12). These principally visual "memes" work as simple images — "canonical" buildings — that are copied unthinkingly, thus propagating the characteristic architectural styles of modernism, postmodernism, deconstructivism, and related variations. A tested knowledge basis is not necessary if architectural practice is based on visual memes, and indeed, creating one may threaten the present system's continued existence.

Therefore, architectural knowledge today is tacit: both students and professionals learn by unconsciously imbuing approved images, which then inform any future design output [184,185]. The discipline is driven by expertise established by an official narrative — a set of "canonical" treatises — that has become normative and guides architects' actions and beliefs. Schools discourage knowledge production and self-reflection, instead linking slogans with symbols into permanent mental patterns. Accepted authority keeps the focus away from uncomfortable new facts by creating pre-emptive distrust for external results.

The stories of modernism recount the lives and statements of a small number of selected architects who have practiced within the modernist memetic universe. Beginning with modernism's founders in the 1920s and continuing with succeeding modernist and postmodernist architects, the list includes present day "starchitects". These celebrity heroes of the mythological narrative are idolized in a ritual promoting a personality cult. Architecture schools teach multiple courses about what this group of persons said and did. Nevertheless, at no time are their actions and sayings subjected to scientific scrutiny to determine their validity.

A discipline that is driven by mythology lacks a mechanism for revising the mythology. The nature of a mythology is that it becomes a sacred tradition set up to continue indefinitely [186]. A hermetic mind-set closes every application to checks, revisions, and outside influence. Any attempt at questioning the canon is perceived as an existential threat coming from the outside, or an apostasy from the inside, which triggers an automatic reaction for protecting the narrative. The architecture-industrial complex cannot allow its sustaining myths to fail.

A mythology also assumes moral value for those who believe in it. Attempts at revision undermine the principles to live by that the mythology establishes, causing alarm to those who have become dependent on them. Modernist discourse is permeated with ethical and moral claims for specific design materials and typologies. The modernist architectural vocabulary is justified to students with a narrative that is based on absolute claims linking it to ethical practice. Those claims have no basis in fact, yet having different sources repeat the same misinformation endows it with a false validity.

Therefore, although architectural mythology is based neither on analysis nor logic, it defines a binding "group logic" for its followers. Belief shapes the adept's worldview and interpretation of reality that is at odds with empirical observation. The profession draws strength from its opposition to anything that resembles traditional architecture, methodically discrediting results outside the narrative. Followers prove their devotion to the mythology by condemning new knowledge that fails to support the industrial-modernist canon. In their eyes, "rationalization" of design means aligning it to the mythology.

5.4. Teaching that discourages curiosity

Human intelligence drives curiosity that normally expands knowledge in two directions: (1) horizontal/cross-disciplinary; and (2) vertical/temporal. In the first instance, the curious person seeks related findings that support and are supported by a piece of information as a starting point. In the second instance, the researcher follows a result that others have developed in time, to discover what further insights it might have led to subsequently. Horizontal and vertical integration together build up the knowledge system.

Architecture courses taught ever since the early 1920s suppress epistemic curiosity in students. Tens of thousands of architecture students are conditioned not to question the narrative. Data within the mythology are logically isolated from external knowledge on purpose, to protect the mythology. Science relates data through inference, mutual validation, and synthesis. But in architecture, disconnected pieces of information are tied together by the narrative, not by any logic, thus circumventing the mechanism whereby consilient knowledge creates a system of interconnected parts.

Students never learn methods of discovery and verification, nor the relational basis of intelligence. Innate curiosity becomes a victim of this limited way of interpreting reality, since peer pressure actively discourages pursuing interesting ideas outside the mythology. Whenever architecture students discover a piece of information relevant to adaptive design, they stop there and do not pursue connections to other related information. They are never taught the concept of a knowledge system as a network comprising mutually-supporting findings; hence they do not follow up to see what else has been discovered.

Architectural mythology's alleged completeness works against acquiring knowledge for problem-solving. Teaching mythology as a self-contained and sufficient body of rules for an architect's professional life and practice, there is no need to look elsewhere for additional knowledge. The mythology already incorporates all acceptable design solutions. Science is made irrelevant except for selecting buzzwords out of context to use in public relations. Misusing science, or, more specifically, scientific vocabulary, is typical and pays off to increase an architect's prestige.

6. Dominant architectural culture employs information pollution and knowledge contamination to manipulate public opinion

When architectural knowledge discovered using the scientific method cannot be kept out of academia and professional practice, it is sabotaged. The practice of manipulating knowledge to preserve architects' privileges prevents results outlined in this paper from making their impact in the field. Industrial-modernist visual memes are deliberately mixed with healthy design solutions to create confusion and contradiction. The intention is to preserve the architectural narrative by losing the original meaning of the data.

The mainstream contaminates architectural knowledge with unstructured clutter — irrelevant data — that overwhelm any analytical discussion. All sorts of information unrelated to healing environments is brought into the narrative. The point is to baffle the mind's natural mechanism seeking relationships, which is the basis of intelligence. One's natural sensitivity is dulled and can no longer be used to discover objective truth. Even people who do not accept the propaganda are left so bewildered that they cannot rationally judge a bad building.

Knowledge contamination is widely practiced by authors who write articles and books funded by the architecture-industrial complex. Architectural academics, journalists, and even neuroscientists publish contradictory texts in which correct results are subverted by mixing in praise for anxiety-inducing buildings and designs. Students reading them are left permanently confused yet convinced that science validates the official narrative. This is a subtle and very effective application of bait-and-switch propaganda techniques.

The architectural press published a set of strange-looking buildings meant to be used as clinics. Health care administrators never tested their effect on patients, especially as though those broken, twisted, and unbalanced forms could be generating a negative neurophysiological experience. Yet people accept them as paradigmatic examples of healing environments! Knowledge contamination became part of the narrative because a highly regarded architectural critic promoted architects who were his personal friends. Journalists simply repeat misinformation for a gullible public.

A culture of hero-worship founded upon inconsistent statements results in mental conditioning that dissolves the clarity of normal discourse. Learning to live with logical inconsistency — having to accept it and master it to survive in architecture school — changes one's thinking processes. By the time a student graduates, his/her command of language to describe fact-based knowledge has been corrupted. Attempting to integrate scientific results with already internalized illogical texts ends up contaminating genuine knowledge.

Sometimes the public will pick up on alarming contradictions between what architects claim and practice, and what science is revealing (which corroborates common intuition). The entrenched system reacts by appropriating results relevant to adaptive design, then "re-interpreting" them to fit the accepted narrative. Architectural authorities employ the standard practice of contaminating evidence-based knowledge to render it ineffective.

Information pollution shapes people's belief systems by drawing attention away from human empathy and intuition. People are not accustomed to checking the authenticity of information about architectural matters. Worst of all, authority figures outside the discipline, who are expected to be impartial, are often bought off by grant money to propagate the building industry's standardized products. The media typically promote the architecture-industrial complex, never investigating or questioning its claims even when those are outrageous.

7. Discussion

An architectural knowledge system encompasses two categories of bodily responses. Firstly, a set of sensory mechanisms that all organisms employ to interact with their environment defines perceivable qualities required for life. Without these, biological forms cannot survive. Secondly, humans possess a set of special cognitive/sensory characteristics above and beyond other animals. Those much more advanced interaction mechanisms engender analytical skills. Human nature requires complex informational input, both visual (spatial) and aural (temporal), from the environment.

Adaptive architecture is intimately tied to the organized complexity of natural patterns, and the structure of the eye-brain system. The human brain developed by responding to the natural environment; therefore, capacities such as emotion, language, and reasoning evolved from perception. Understanding the mechanisms for complex interactions that makes us human argues against immersing humanity in an industrial-modernist universe with which we cannot engage. Yet people accept the mythology behind the present global design movement and acquiesce by suppressing their empathy and intuition as demanded.

The remarkable success of expert systems in decision making, applied for decades in many different fields, suggests a method for re-shaping architecture. Used impartially, AI helps to replace a mythology-based system (such as architecture in its current manifestation) with a knowledge-based system that works on facts and heuristics. Designers are implementing AI to build software that replaces the legacy design methods still taught in architecture schools everywhere. This effort is part of a general drive towards establishing AI in learning [187].

A special set of mathematical relations ties together the diagnostic tools for adaptive architecture presented here. A design or built structure can be judged by whether it generates stress or can contribute towards a healing environment. Fashionable architecture violates this respect for the user's health [188]. Disruption as a design goal includes empty minimalism; lack of nested and scaling symmetries; impeding mirror, rotational, and translational symmetries; deliberate violation of the vertical, etc. Those visual design rules work together with emotionally hostile overhangs, spaces, surfaces, etc. against engagement.

Architecture' knowledge system distinguishes technical facts coming from engineering, materials science, and tectonics from knowledge on how built structures affect human health and well-being. The former topics are supported by the disciplines of Applied Physics and Engineering. The second set of topics document practical knowledge discovered during decades in Biology, Medicine, and Psychology, which have been neglected so far by the architecture profession. An expert system built from those knowledge sources makes intelligent decisions based on analysis and comparison.

The knowledge system is open to fine-tuning and iterative updating through feedback to improve its performance. Architectural knowledge consolidates methods such as design patterns and practice-based research together with external frameworks and tools including biophilia, neuroscience, and results obtained from Artificial Intelligence and AI language models such as ChatGPT. A mathematical foundation ties all of these results and tools together.

Environmental psychology ultimately shapes human behavior through the design of the environment [189,190,191]. Discussions from the 1960s are being updated, as neuroscience reveals the mechanisms that generate psychological effects on people. The architectural literature, however, contains misunderstandings. Professionals automatically assume that industrial-modernist typologies produce positive psychological effects. This claim is now refuted [192,193,194], yet dominant architectural culture ignores an inconvenient truth. Here is an instance of narrative transportation, where individuals lost in the architectural narrative — unverified concepts perpetuated by confirmation bias — become detached from the real world.

Almost none of the verified discoveries in architectural psychology over the past several decades have made any difference in architectural practice, which continues to base itself on abstract formalism and copying canonical images mechanically. Studio culture applies the same century-old mythology to shape students' minds into accepting an alternative reality. Institutions not only do not generate knowledge, but they resist knowledge that threatens to revise the accepted narrative. Attractive new techniques are adopted only if those can be commandeered to support existing typologies.

Enormous possibilities open for healing design motivated by intelligent thinking. The irony is that this development is most likely to come from artificial instead of human intelligence. Training young practitioners to replicate images in studio does not require intelligence [195,196]. Creative design requires innovative solutions to complex problems that satisfy many constraints in keeping with design as a “wicked problem”. AI programs such as ChatGPT have (almost) passed the Turing Test [197], won games of chess [198] and Go [199], and are ready to solve adaptive design problems.

8. Conclusions

This article collected foundational architectural knowledge that the present author and many colleagues consider as a necessary part of future practice. A list of topics and results immediately relevant towards achieving adaptive design helps to guarantee user health and well-being. The effect on people is dual: the environment has both physiological and psychological impacts, and, furthermore, those effects are felt unconsciously. The accumulation of stress due to hostile design and geometry over the long term may lead to pathologies. As this is a matter of public health, the health-care profession should take the initiative to fix it.

Public health practitioners develop behavioral change models. It is well-known that neither knowledge nor logical reasoning change behavior: applying psycho-social methods does. Forces outside architecture are needed to improve general health and well-being through designed environmental conditions. The prerequisite to achieving this goal is a set of design principles implemented towards improving the general quality of life. Assessing the fundamental causes of problems that prevent optimal living and working environments begins with establishing a knowledge system for architecture.

Architects will also need to be taught about knowledge systems separately. This is not necessary in scientific disciplines, since the horizontal and vertical integration of knowledge into a consilient system is already there. But the discipline of architecture does not have any such framework; making it impossible to build up a knowledge system from discovered information. A new type of theory course — “Architectural Knowledge” — must be added to the curriculum to broaden the preparation of future architects.

As the persons who construct our environment are conditioned to interpret reality in an unnatural manner, re-training them to design adaptively is a major challenge. The goal of architectural education is to contribute to the health of society, not to perpetuate discredited myths and contaminate discovered knowledge. Transforming the current obsolete system begins by evaluating its components to judge how far each helps towards creating a healing environment. This process will be successful only when a shared vision links expectations across disciplines and stakeholders.

In conclusion, it is recommended that the architecture profession embrace all the topics discussed here in a new approach to adaptive design. The educational system will have to jettison much of its present curriculum, including a parochial studio culture, to make place for this new material. Yet the tools making new foundational knowledge possible also serve to judge whether a particular teaching method is useful or not. Topics based on experiment and verification should be included in the new curriculum. If a topic is based on belief, then it must be tested and probably revised or rejected. Such drastic change is the only means of fixing a deficient system.

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