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# entgrenzung: transcending boundaries across scientific disciplines

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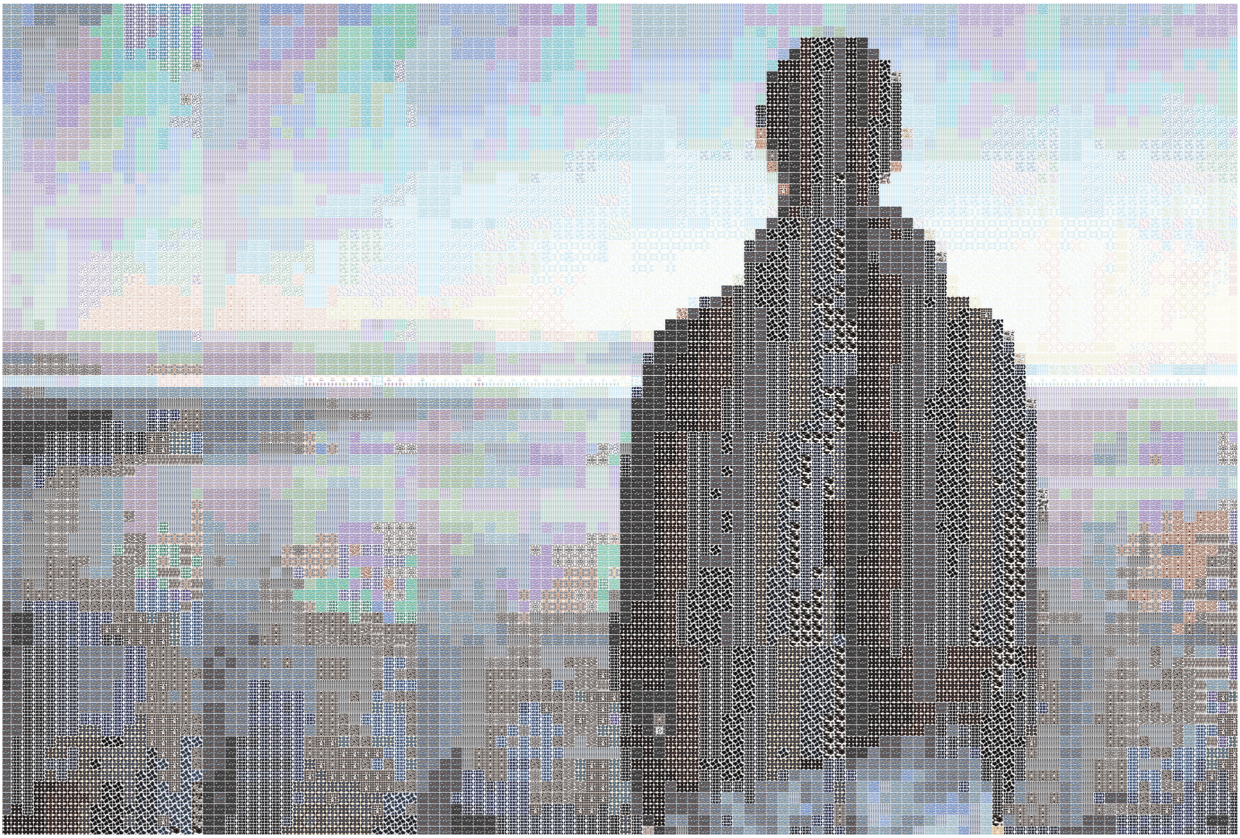
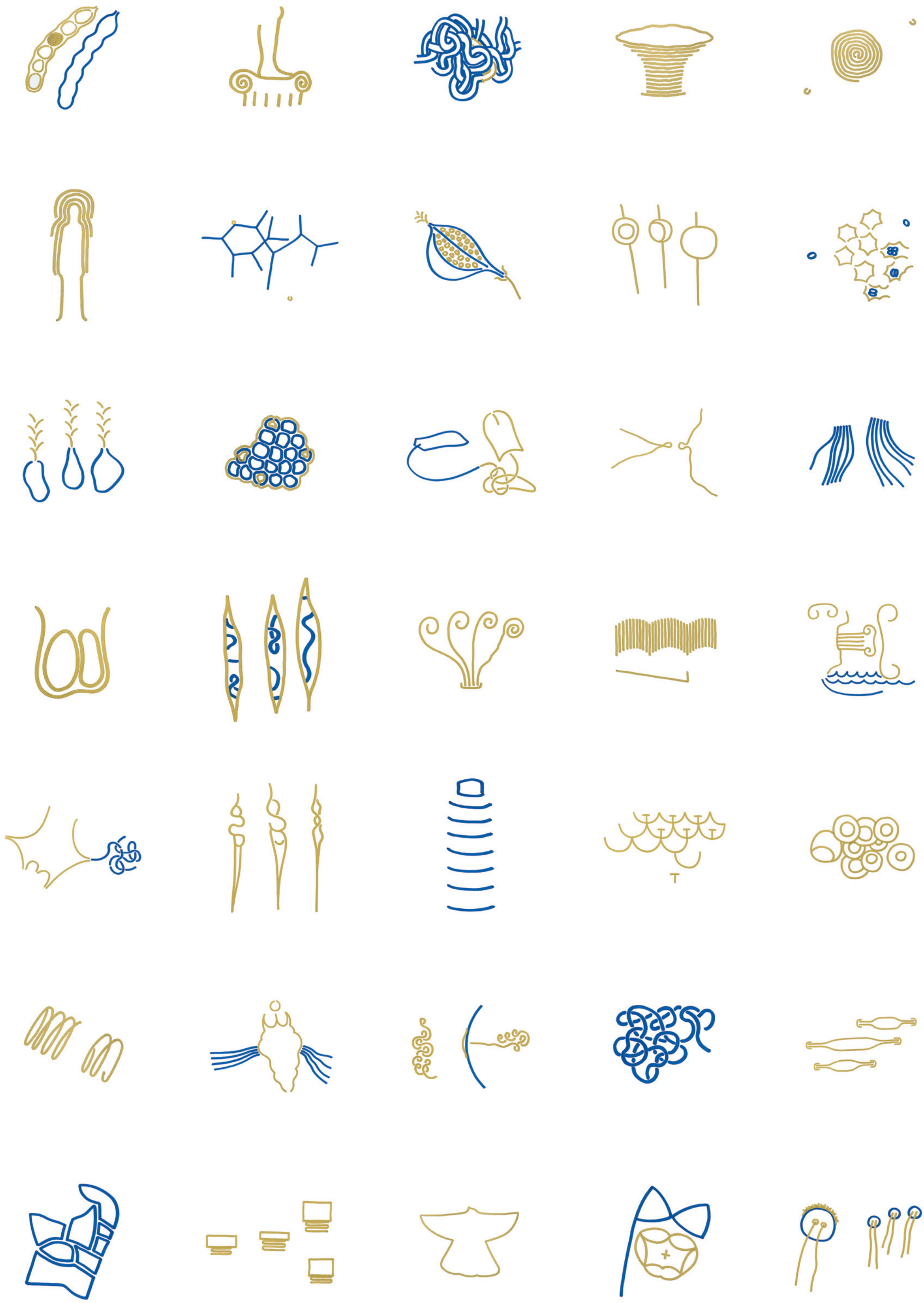


Peloponnes / Griechenland, Blick über den Golf von Argos, IOCYÀN-Pixelbild

Transdisciplinarity can be understood as an integrative form of research and as a principle for unifying knowledge. This term was first introduced in 1970 by Jean Piaget (1896-1980), who wished «to see a higher stage succeeding the stage of interdisciplinary relationships […], which would not only cover interactions or reciprocities between specialized research projects, but would place these relationships within a total system without any firm boundaries between disciplines» [1]. More recently, Basarab Nicolescu published a manifesto in 1996, which, in turn, is based on Stéphane Lupasco's work (1900-1988); in this manifesto, he proposed a methodology with principles rooted in quantum physics for use in transdisciplinarity [2]. Transdisciplinarity has since become a widely-used word, particularly in sociology and ecology. However, it remains unclear if it is a research area or a methodology. The main problem we encounter is the lack of consistency between the different meanings of transdisciplinary. Here, we attempt to provide a principle for transdisciplinarity, with which we hope to clarify its status.

*Disciplina*, in Latin, refers to the training of a *discipulus*, someone who follows the teaching of a master. Hence, *uni* or *multi*disciplinarity refers to the transfer of knowledge from one or multiple areas of human understanding to a disciple. In comparison, *inter* signifies «between» or «among», i.e. it suggests connection; nevertheless, it implies that the interconnected entities are different. *Trans*, in contrast, means «across», and is associated with efforts to access and bridge what is shared by two distinct entities. In contrast to interdisciplinarity, which tends to combine disciplines by transferring methods or ideas between them, transdisciplinarity tries to find coherence among phenomena at different levels of organization. In this sense, the meaning of *trans* is closer to the prefix *meta*, which denotes «beyond». Disciplinary research has since been used to understand reality; transdisciplinarity then aims to identify common patterns across these disciplines, which appear unrelated under the current framework of scientific inquiry (see figure 1). The end of identifying these common patterns is a more coherent understanding of the world.

IOCYÀN ist ein Kunstwort. IOCYÀN ist ein Zeichnungszyklus vom Frühjahr 2000, entstanden in zweimonatiger Arbeit auf einer Athener Dachterrasse, 240 Handzeichnungen in Blau und Gold auf A4 Karton, thematisch kreisend um die Poesie vorsokratischer Fragmente, Antikentourismus und die Auswüchse modernen Lebens. IOCYÀN ist auch ein Buch, das enzyklopädisch die Umstände und Hintergründe des zeichnerischen Prozesses darzustellen versucht. Die Zeichnungen stenographieren die Welt, als hätte man 240 mal den permanenten Gedanken- und Bilderstrom im Kopf willkürlich angehalten und als Filmstill abgespeichert. So ist ein neuer Ordner mit Bildern entstanden, die formal und inhaltlich zusammen zu gehören scheinen, sich aber einer eindeutigen Zuordnung entziehen.



Since the industrial revolution, individual disciplines have become highly specialized due to technological developments and the complexity unveiled by these technologies. The result of this over-specialization is a fragmentation of knowledge, which remains clearly visible among intellectuals; for instance, scientists, humanists, and artists have immense difficulties in communicating with each other. In this context, transdisciplinary research serves as a tentative approach to address the fragmentation of knowledge at its source. In contrast to the specialized disciplines that attempt to answer questions about a specific aspect of nature, transdisciplinarity aims to capture both the common structure behind these observed systems, and the logic that drives their evolution. As opposed to the reductionist approach, this strategy does not aim to decompose a system into individual components, but rather tries to capture a common principle inherent in all phenomena that can be perceived by the human mind.

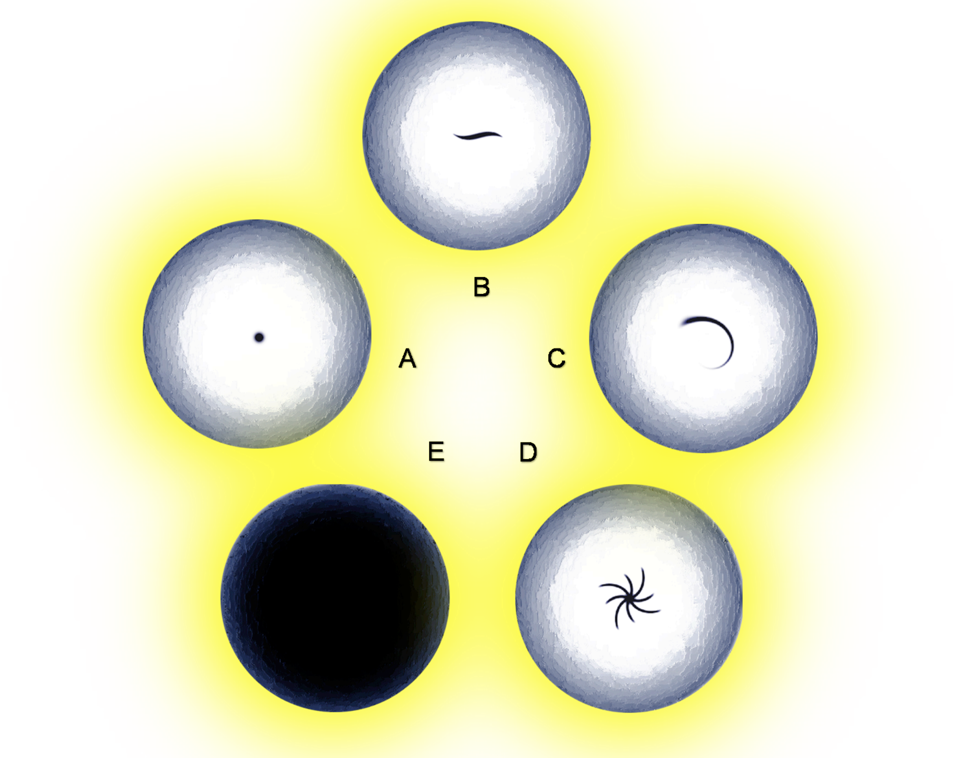
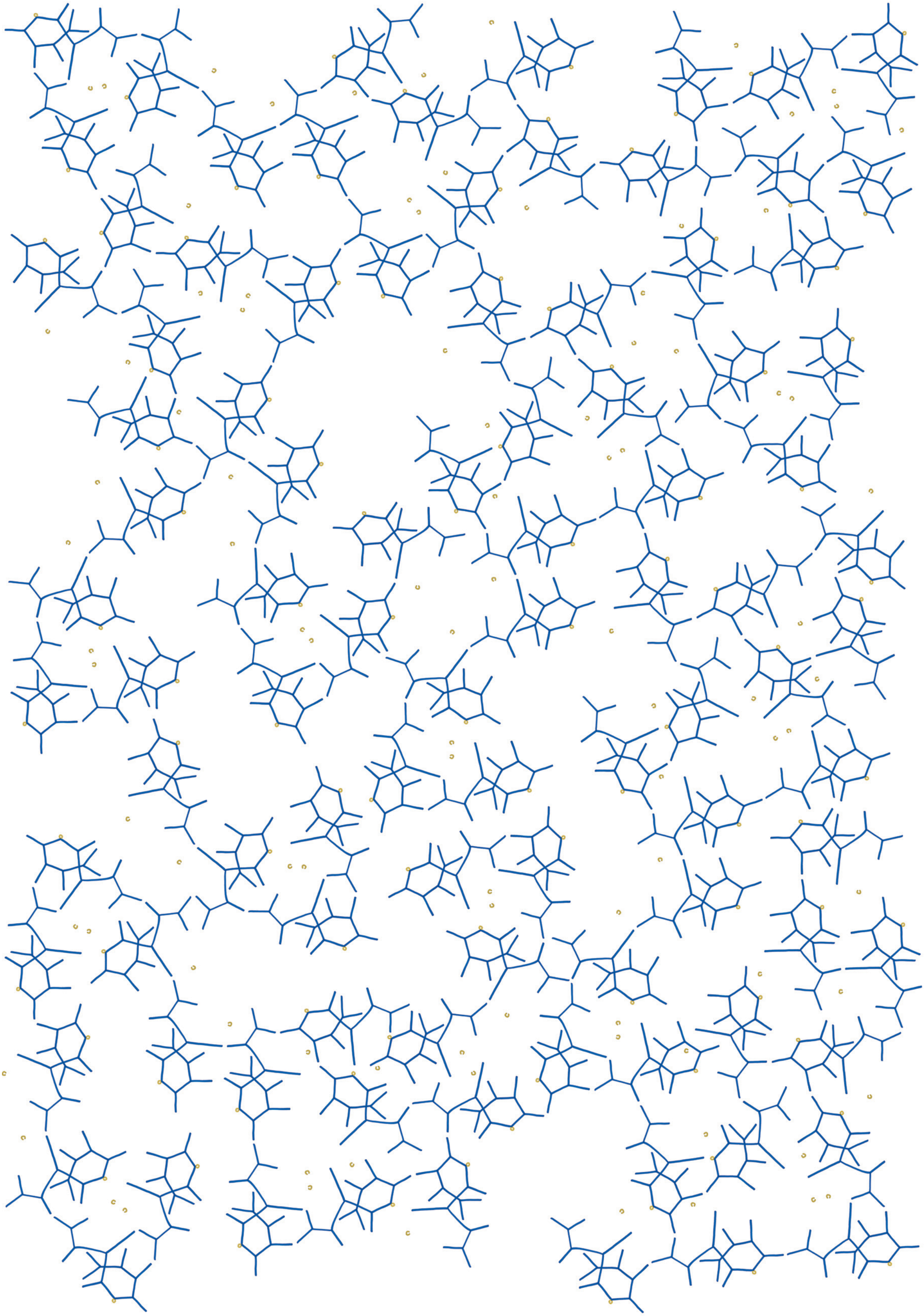



FIGURE 1 | DISCIPLINARY RESEARCH

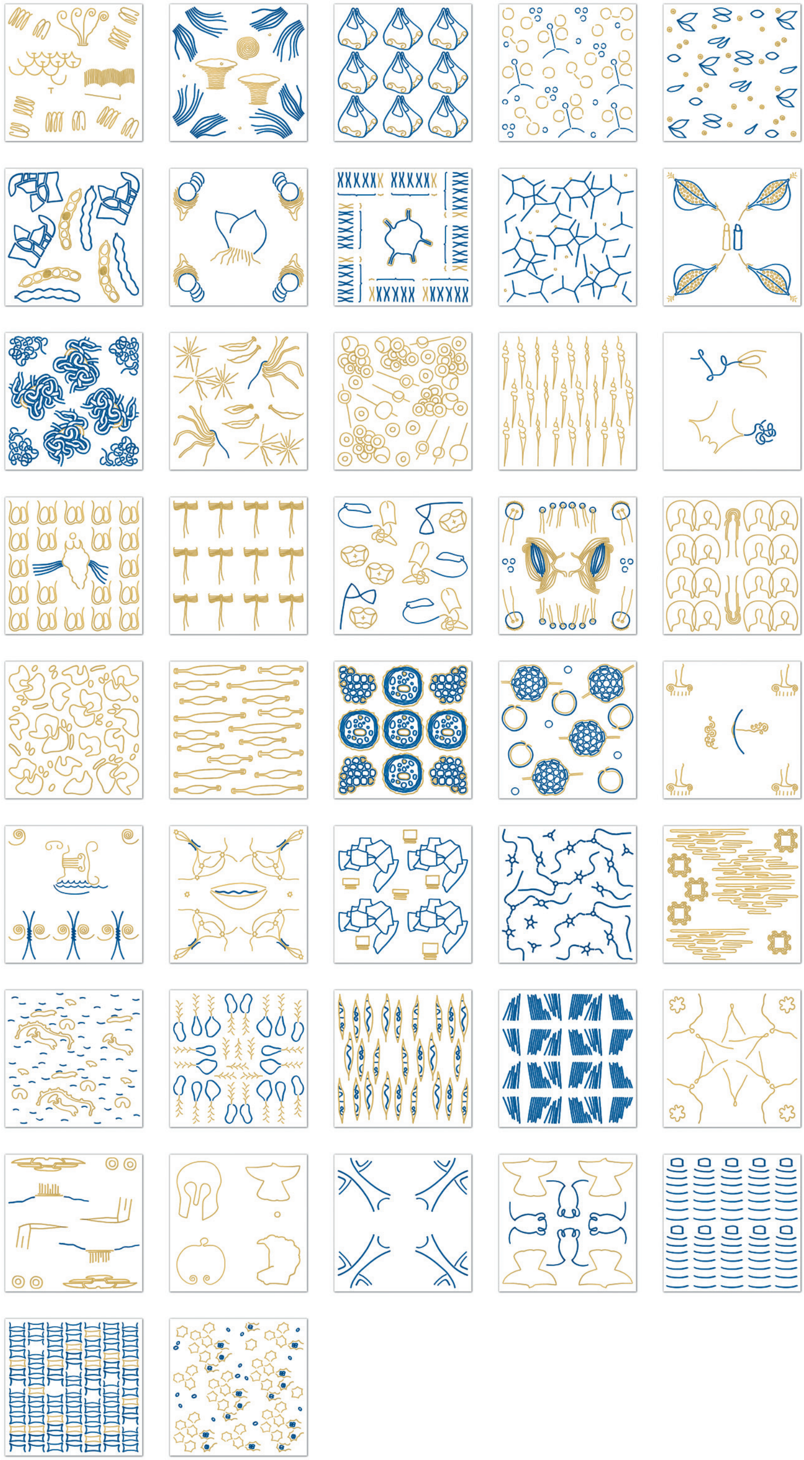
THE REALITY PERCEIVED BY THE HUMAN MIND – THE BLACK SYMBOLS WITHIN THE SPHERES – CAN BE UNDERSTOOD BY THE KNOWLEDGE FOUND IN ONE (A; UNI), MANY (B; MULTI), BETWEEN (C; INTER), ACROSS (D; TRANS), OR BEYOND DISCIPLINES (E; META). NOTE THAT THESE APPROACHES ARE NOT ANTAGONISTIC, BUT COMPLEMENTARY; I.E. META IS ALSO DEPENDENT ON TRANS, TRANS ON INTER, INTER ON MULTI AND MULTI ON UNIDISCIPLINARY RESEARCH.



For instance, if we consider events in the realm of cosmology, physics or biology, we observe that there is a tendency towards differentiation, resulting in the phenomenon of diversification. Diversity can be observed at different levels of organization: in atoms, molecules, cells, tissues, human beings, societies, planets, stars, and even galaxies. Nevertheless, each level of organization underwent the same process (i.e. diversification), which may be a manifestation of common, fundamental design principles. In this case, these principles could be self-organization and natural selection, which drive both the diversification process, as well as its evolution.

The term self-organization was first introduced by Immanuel Kant (1724-1804) to describe a connection between organization and function in living systems. Since then, the concept has evolved to the science of self-organization whose aim is «to identify the principles and mechanisms by which an ensemble of agents in interaction evolves towards a particular dynamical temporal or spatial pattern» [3]. On the other hand, natural selection, which was first popularized by the naturalist Charles Darwin (1809-1882) in his essay *On the Origin of Species* [4], has been under scrutiny for 150 years and has fostered an ongoing debate between evolutionists and creationists until the present, each supporting a diametrically opposite perception of the world. In reality, both sides of the debate rely on the same logical arguments. This logic can be articulated in two steps: 1) natural selection of an entity that manifests itself throughout differentially amplified elements, 2) the potential to transform and evolve.

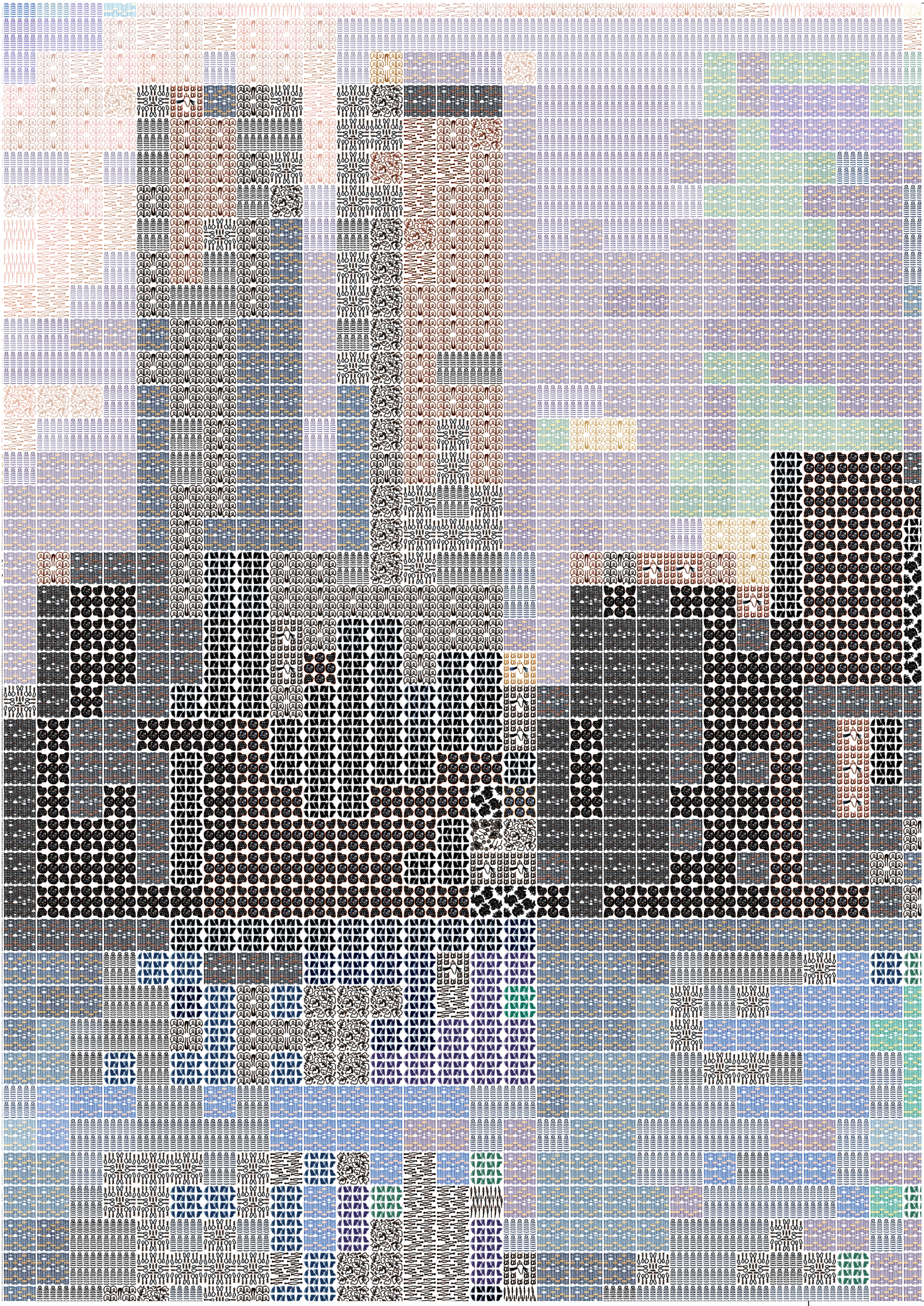
Die Zeichnungen sind Keimzellen für Strukturen, deren weitere Entfaltung von festgelegten Entwicklungsprinzipien abhängt; zügellose Wucherung ist genauso denkbar wie streng geplante Mustergenerierung. Was aus den Zeichnungen wird, welche inhaltlichen Verschiebungen und welche neuen Anforderungen für den Betrachter entstehen, hängt von den Rahmenbedingungen des Experiments ab. Einer mehr oder weniger klassischen symmetrischen Anordnung von Bildelementen entsprechend wurden ausgewählte Zeichnungen zu 42 verschiedenen Zeichnungspixeln zusammengesetzt. Dem Prinzip spannungsvoller Ausgewogenheit folgend entstand aus den Zeichnungspixeln ein neuer Satz von 42 unterschiedlich dichten und farblich variierenden Kompositplatten, die wiederum als Grundelemente von Flächengestaltungen eingesetzt werden können. Dabei tritt die Bedeutung der Einzelzeichnung zugunsten einer abstrakteren Pixelstruktur in den Hintergrund, ohne jedoch ausgelöscht zu werden. Die Grundbausteine bleiben erhalten, auch wenn sie kaum noch sichtbar sind; die Art, wie man betrachtet entscheidet darüber, was man sieht.



In biology, the clonal selection theory introduced by Niels Kaj Jerne (1911-1994) [5] and further developed by Frank Macfarlane Burnet (1899-1985) [6], the Darwinian theory for the origin of cellular differentiation discussed by Jean-Jacques Kupiec [7], the concept of quasispecies developed by Esteban Domingo [8], and the theory of neuronal group selection proposed by Gerald Maurice Edelmann [9] are examples that demonstrate how natural selection can be found at different levels of organization, although the mechanistic details of such evolution remains undefined.

A comparable process is also described in the Old Testament. Natural selection and differential amplification of humanity starts with *Genesis* and persists until the odyssey of Moses. God intervenes with humans in a selective manner. Those who have been selected, from the creation of Adam «out of a stream coming up from the earth and watering the whole surface of the ground» [10] to the election of Moses, are chosen to grow in number. As pointed out previously, it is not out of context to say that the Old Testament assumes the same conceptual framework as modern biology.

We showed that it is possible to overcome the mutual exclusivity of evolutionism and creationism by suggesting a common scheme of development from both theories. We have to elaborate on this if we wish to understand what is across disciplines. To this end, we must first identify elements acting at different levels of organization, which we call **hypersets**. Secondly, we need an extension of the concept of natural selection [11], where the amplification process happens in a differential manner. In the extension, natural selection favours the potential of hypersets to differentiate. For example, in biochemistry, the polymerization of amino acids – the molecules constituting the primary sequence of proteins – leads to the definition of specific functional domains necessary for the determination of the three-dimensional shape of the protein. These domains can be arranged in different ways, leading to a hyperset of proteins that have the ability to engage in cooperative behaviour, which then allows higher-order functions within the cell. The same principle can also be observed in human societies, where individuals tend to be normalized and forced to adopt a defined number of socially-accepted attitudes toward life. However, the actual possibilities naturally given to individuals in terms of behaviour form a much bigger set – a hyperset which should, in return, foster more cooperative behaviours. Whether the hyperset appears in human history as spiritual beliefs; in economy as capitalism or Marxism; or in technology as the automotive or telecommunications industry, we can clearly observe the same pattern underlying the birth and growth of the actual phenomena characterizing our world. Natural selection and differential amplification describe a dynamic equilibrium characteristic of a large spectrum of phenomena ranging from the hyperset of quantum particles to the hyperset of galaxies.



We assume that each observable system is able to transform and differentiate – that is, each system is capable of evolving, or at least, could be externally influenced to evolve. The characteristics of a hyperset can be summarized by its two aspects, namely **stability** and **evolvability**. Stability pertains to the ability to perform a set of self-sustaining functions and the capacity to resist informational inputs. We use the term **information impenetrance** to describe the intrinsic property of a system that resists change, in spite of external informational inputs and internal disturbances. Information impenetrance ensures the stability of a system.

Evolvability refers to the ability of a system to take up a set of new self-sustaining functions that differ from the system's current or original set. This transformation is achieved by introducing external informational input and / or internal disturbances, which cannot be integrated into the current equilibrium of the hyperset. We call this property **information penetrance**. Penetrant information partly destabilises the system. Under such circumstances, a non-evolvable system (e.g. a man-made machine) is likely to lose its stability and break down functionally, or into its separate components. However, an adaptive system is able to go into a disoriented state, whereby the possibility of taking up a new functional set exists. Before any further information penetrates, the system fluctuates between the old and new states [12]. The system breaks its symmetry either randomly, or upon the penetration of additional information. The result of symmetry-breaking is either a new functional set, or a regression to the old functional set.

Durch einfache Farb- und Helligkeitsmanipulationen wurden aus den ursprünglich 42 Zeichnungspixeln über 800 Modifikationen entwickelt, mit denen die programmgesteuerte Mosaikerzeugung nach Fotovorlagen möglich wird. Die Ergebnisse der automatischen Generierung wurden anschließend einer Auswahl und in Teilbereichen einer manuellen Überarbeitung unterzogen. Das Programm prägt so die Gesamterscheinung des Pixelbildes, ohne sie allein zu beherrschen. Die Serie der Pixelbilder widmet sich inhaltlich der Darstellung bestimmter Erinnerungsorte, die im kulturellen Gedächtnis Zeichenhaftigkeit erlangt haben. Es kommt zu Rückkopplungen zwischen dem Fotodokument und den universell anmutenden Erinnerungsskizzen, aus denen das Pixelbild zusammengefügt wird.

Bisher realisierte Motive: Aralsk (Schiffswrack), Arktis (Eisberg), Bamiyan (gesprengte Buddha-Statuen), Cottbus (Tagebau), Dresden (Elbschlösschenbrücke), Hasankeyf (Staudammprojekt), Jerusalem (Grenzmauer), Loekken (Westwall-Bunker), Mostar (Bücke), New York (WTC), Peleponnes (Golf von Argos), Potsdam (Glienicker Brücke), Sakkara (Pyramide), Tschernobyl (Atomkraftwerk), Weimar (KZ Buchenwald), Yucca Mountain (Atomendlager)

New York City, Blick auf das WTC, IOCYÀN-Pixelbild

Evolution thus defines the ability of hypersets to cooperate, integrate, and express informational inputs (see figure 2). We illustrate this in more detailed by taking cell biology and behavioural psychology as examples.

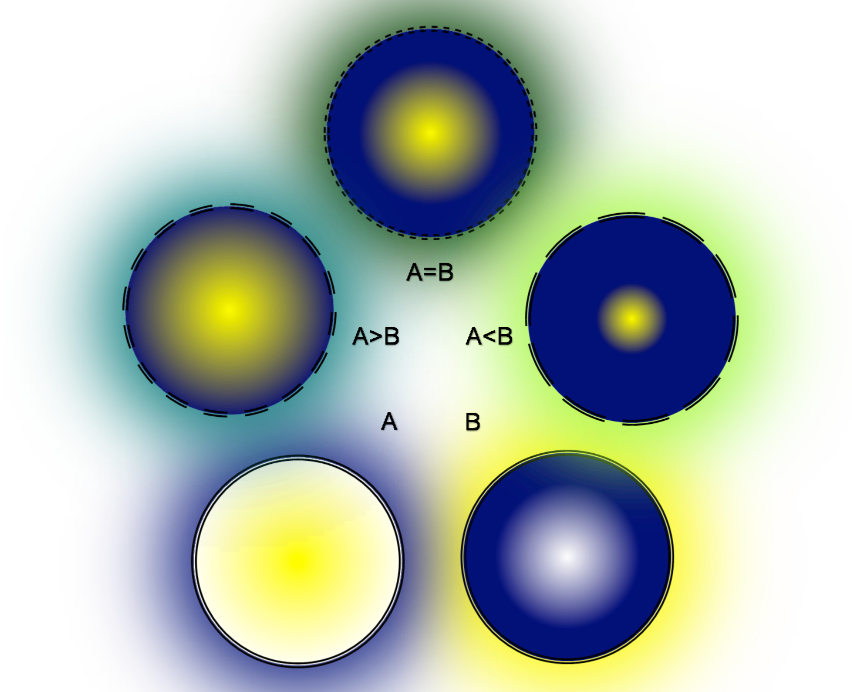
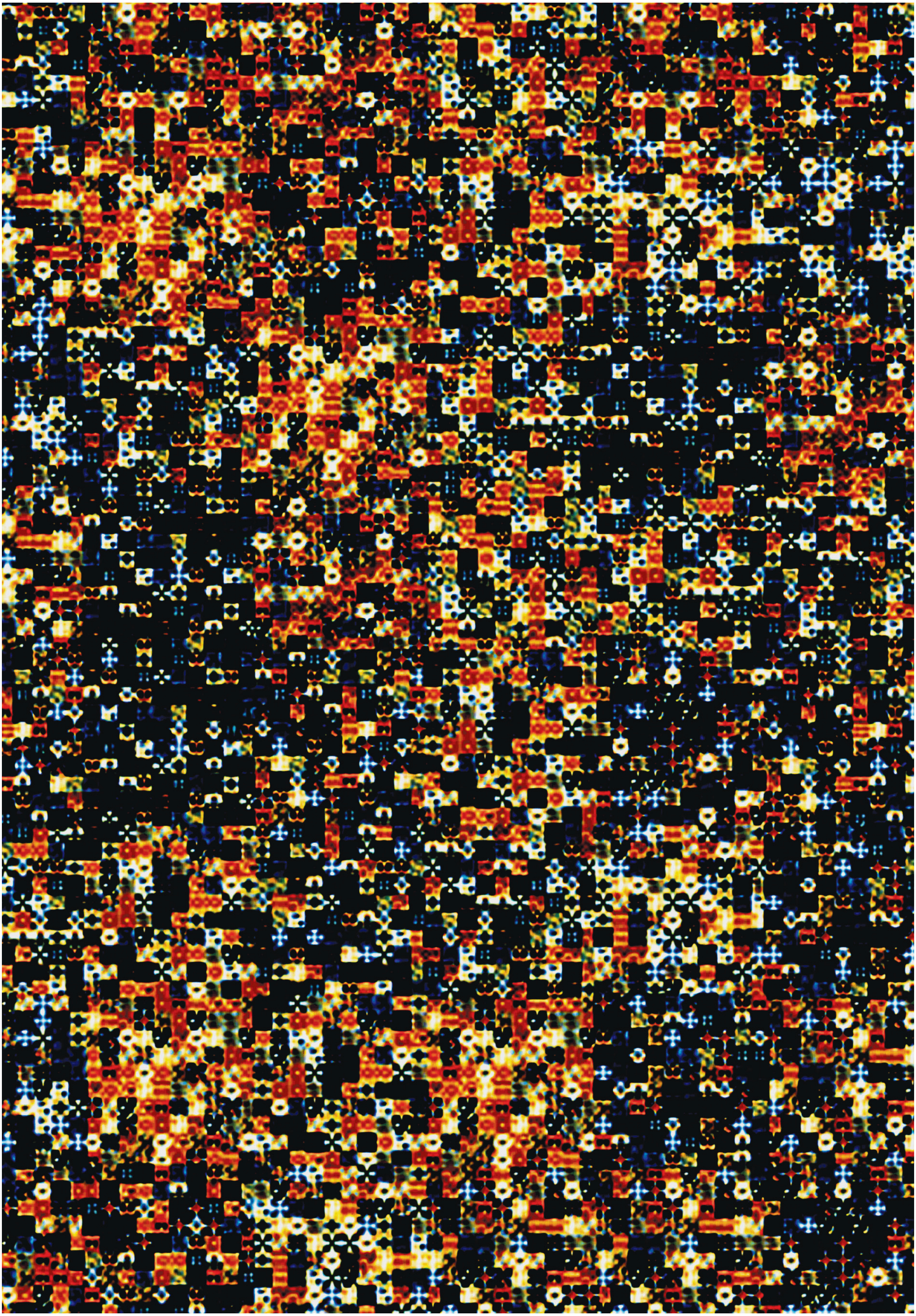
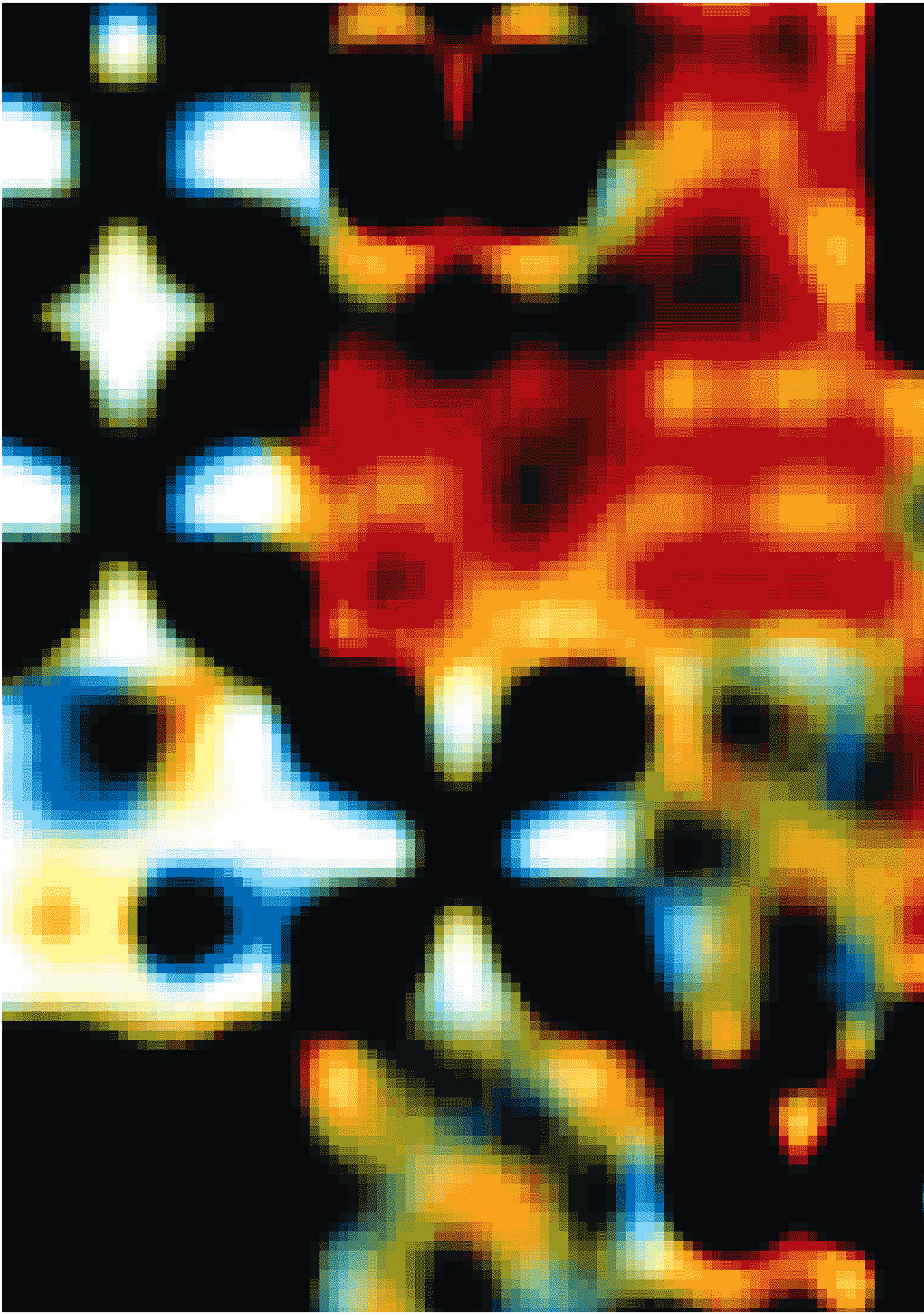


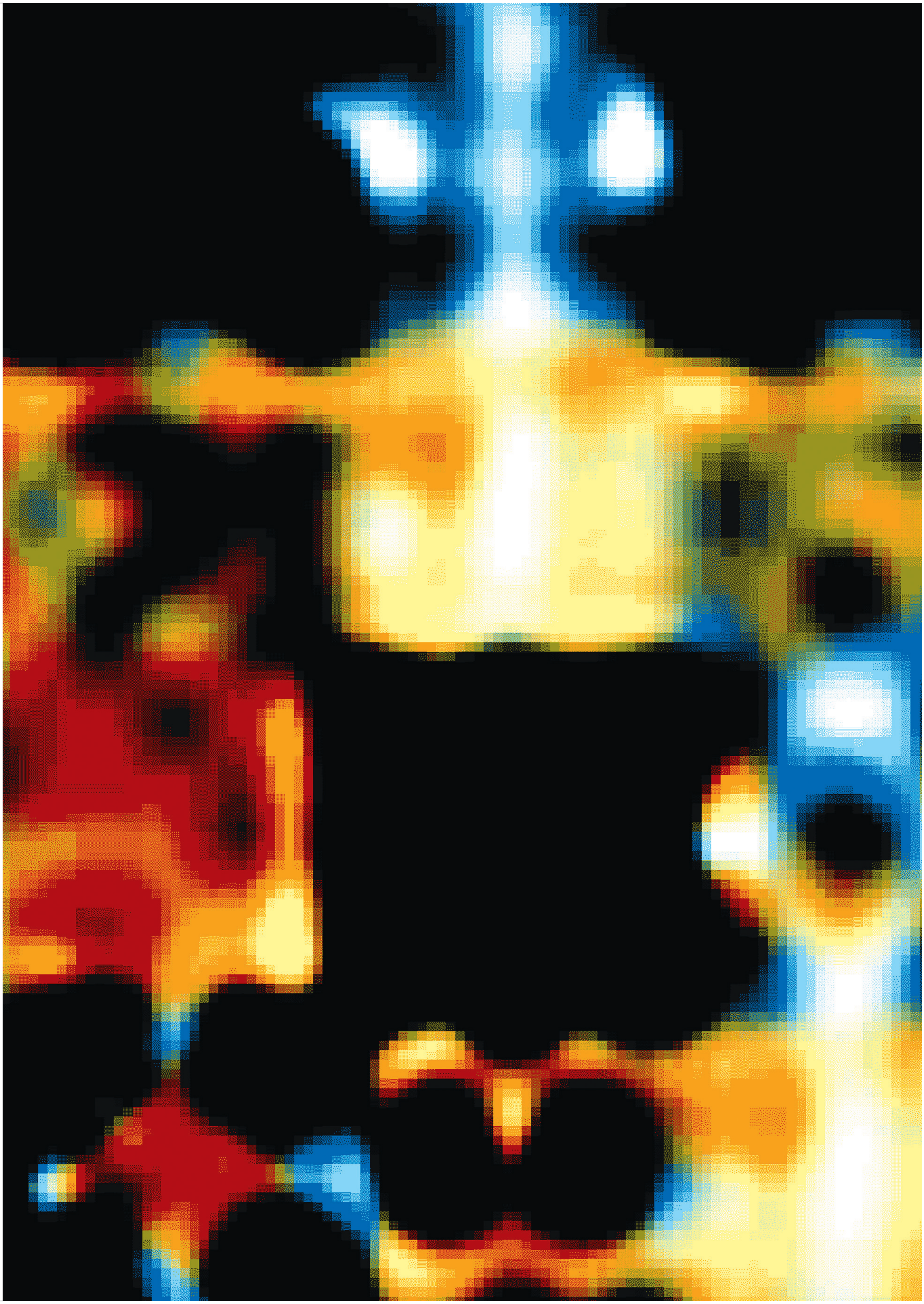

FIGURE 2 | A PRINCIPLE FOR TRANSDISCIPLINARY RESEARCH

A STABLE SYSTEM (A) IS ABLE TO EVOLVE (B) IF THE HYPERSETS ARE ABLE TO INTEGRATE INFORMATIONAL INPUTS OR OUTPUTS (A>B; INFORMATION PENTRANCE OR A<B; INFORMATION IMPENETRACE) WHEN THERE IS A CRISIS, AN UNCERTAINTY OR A FLUCTUATING STATE (A=B).

A well-characterized model for an evolvable hyperset is the cell polarization machinery. Under normal conditions, the mechanism of cell polarization is robust, with multiple redundancies among its individual components [13]. High information impenetrance is secured by these apparent redundancies, responsible for regulating cell morphology, cytoskeletal dynamics, and intracellular molecular diffusion. However, information penetrance can be achieved by different techniques. One example is the morphogenetic mutants of the yeast *Schizosaccharomyces pombe*. The polarization machinery can cause the cells to enter into a *completely* disoriented state when the morphogenetic pathways are *partially* disrupted through mutagenesis. Despite the lack of physical polarity, these cells nevertheless break symmetry spontaneously and carry out an abortive cell division [14, 15]. Another example could be found in mammalian cells, where a mitotic cell is forced into a disoriented state through a combination







of epigenetic and chemical manipulations [16]. These cells also break their symmetry in a random orientation, without any further information input. In both examples, the cell division machinery duly performs its function. Up to now, it is unclear whether a fluctuating state between several possible morphological outputs exists at this level. Nevertheless, studies done on spontaneous polarization of the yeast *Saccharomyces cerevisiae* show that the presence of such a state is imminent [17, 18]. Further experiments using high-resolution microscopy are likely to clarify this situation.

In psychology or behavioural psychotherapy, a neurotic disorder can also be considered an adaptive hyperset, because it is defined by a self-sustaining chain of destructive mental and behavioural patterns. These patterns are developed through a patient's previous personal experiences; consequently, it may be considered an adapted system of mental / behavioural patterns, resulting from personal development. Personal development, in turn, is induced by previously *penetrant* informational inputs. Due to its adaptive nature, the system is refractory against old information, and is thus information-impenetrant. In a non-therapeutic setting, hyperset destabilisation can only happen through drastic external changes (e.g. social turmoils or an accident) or by strong internal disturbances (e.g. physical sickness or aging). Under such circumstances, the neurotic structure becomes destabilised, and the person experiences a crisis, which is essentially a state of mental / behavioural fluctuations.

Therapeutic intervention is appropriate at the stage in which fluctuations occur. Here, we use a paradigm extracted from the neo-Freudian school of psychoanalysis as an example [19, 20]. The ability of the therapist to bring up relevant information in the course of treatment is of vital importance. This can be achieved only if the therapist 1) understands the neurotic structure holistically, 2) is able to keep possible internal disturbances of the patient in view, since these may be potentially used to further destabilise his neurotic habits, and 3) is already experienced in terms of the transformation intended to replace the neurotic structure with a higher psychological function. In other words, one can say that it is essential for the therapist to have a corresponding hyperset that is already highly *evolved*. These preconditions allow the therapist to engage the problem both externally and internally. Penetrant inputs are given in a regulated way to help the patient realize and integrate the possibility of a higher functional hyperset. This higher functional set allows the patient to handle daily situations with better self-control, compassion, and clarity, resulting in an improved quality of life. The treatment is considered successful when the new, higher functioning set replaces the old one. The higher functioning set is in itself an adaptive system, and is therefore impenetrant to the information that induced the transformation.

Accordingly, we propose a new principle called **hyperset cooperation**, based on natural selection and differential amplification (see figure 2). Hypersets are stable, are able to change through multiple recombinations and are able to evolve through cooperation in the presence of informational inputs across different levels of organization. This principle assumes that a common logic lies beyond the observed coherence in phenomena, which only differ when these phenomena are expressed at different scales. In such a case, transdisciplinarity can be considered to an integrative form of research complementary to interdisciplinarity. Its aim is to unify knowledge and bring new paradigm shifts to bridge natural, social, and human sciences.

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