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By considering the notion of sustainability in relation to heritage, performance and education through the prism of Complexity and Emergence, science-sourced theories that explain dynamic self-organising systems and their patterns, we are considering three interconnected components of an organic culture.

Performance is ephemeral, suspended in space and time, it resonates deeply at many levels in creative learning, and therefore moulding heritage. Whilst it is created out of identifiable parts, whether instruments or voices, bodies or elements of stagecraft, the performance itself is more than the sum of these parts. By considering performance as a complex system we understand that each time these parts interact together the resulting performance is different yet its pattern is familiar, like shifting sands.

By evoking 'Shifting Sands', a dune type landscape, I reference the natural or physical world, usually studied from a scientific basis. A flow of communication between scientific ideas and artistic production is core in my dance-based praxis, just as the development of computing power and the digital is key to the development of theories of Complexity and Emergence. The digital is also key to my developing discussion here as it enables my referencing of performance works, both of my own creation and of other significant choreographers. These can be accessed easily on-line, and exist semi-permanently in cyber space, which points to a consideration of heritage, performance and education as essentially digitised.

In exploring these interconnections I will entwine my argument to the image of the spiral. The spiral pattern is an essential shaping pattern of dynamic systems as seen in nature and culture across the universe from the spiralling strands of DNA within the body, to ancient carvings on religious sites across cultures, to water going down a plughole. It is a shape that forces continual change extending from micro to macro levels, and by referencing both Nature and Culture, it is also an emblem that binds science and art, the two main arteries of discovery.

By conjuring the spiral as a metaphor for the interconnectedness of things, I enjoin the imagination with the intellect, appropriately perhaps because as a practice-led researcher, I come to theory through tacit knowledge developed out of creative doing. This doing is essentially interdisciplinary and therefore concerned with an interconnectedness that Paul Cilliers argues is a characteristic of both complexity and postmodernism (Cilliers 1998) and that I seek to reinforce in this writing. Complexity describes a system whereby a collection of elements (dancers or musicians improvising following choreographic/compositional rules/equations), interact at a local level, share information, respond to feedback and their environment, and thus form patterns – becoming a self-organising system that is greater than the sum of its parts – perhaps a performance.

I approach this task from my foundations as dancer and performer who has developed her practice as part of a postmodern environment, as teacher and choreographer and latterly, additionally, academic and researcher. In that spiralling I have strayed from the arts into the sciences, and in doing so have found the contemporary theories of Chaos, Complexity and Emergence profoundly and pragmatically enlightening in my pursuits of creating new performance with people, with all the expectations that this engenders. For us, working in the arts, "although we cannot consciously seek the new, since by definition the new cannot be known in advance" (Bolt 2007:31) we seek structures and systems that we hope will foster new learning and creation for ourselves and our communities at local and global levels. Whilst complex systems indicate that everything changes all the time, in doing so, as with the image of shifting sands, the patterns created resonate long after on many levels.

Postmodern or New Dance
When American postmodern choreographer Kenneth King announced, "I think improvising is a science" (King in Banes 1987:177) he made a connection between postmodern dance and science. King also makes intrinsic connections between practical doing, reflection, formal theory and analysis. My own practice-led choreographic research substantiates King's pronouncement and continues the interpollination of science-based theory and improvisation-based contemporary dance through practice-led explorations of the theories of complexity and emergence. In this, I link contemporary postmodern dance practice and these contemporary scientific theories and situate this dialectic as part of a growing interdisciplinary community that is concerned with science, arts, learning-by-doing and new technologies.

King was one of the artists aligned to New York's Judson Church innovators of dance art. Part of the questioning, liberational movement of the 60's these dance and performance makers rejected traditional forms and notions of the professional or expert, towards finding new ways to make live events using chance and improvisation practices that could include a released body, non-western approaches, contact improvisation, an understanding of the relationship between body and mind and therefore the use of self as subject. These postmodern developments informed the British Dance culture within which I was involved and were referred to as the New Dance scene (Adair 1992:191).

These influences were layered onto my roots as a dancer forged through childhood training in the traditional western theatre dance styles of ballet, jazz and tap before being introduced to the contemporary or modern dance techniques developed by Martha Graham, Merce Cunningham and particularly Doris Humphrey and José Limón at university. Recognising the variegated strands of my dance praxis enables establishing a range of links useful to my thesis.

The American modern dance pioneers developed formal and distinct dance techniques which whilst rejecting some of the principles of ballet, such as the use of the turned out leg, and instead variously embraced a recognition and use of gravity, the weight of the limbs, the use of breath, and looked to contemporary and abstract themes as serious subjects for choreography. As ever they also worked closely with composers and artists from other disciplines, such as that between choreographer Merce Cunningham and John Cage, which led to radical innovations in both dance and music and contemporary understandings of culture.

A modern, or contemporary, dance technique yields to and works with the pull of the earth, the drum, inner-dynamics and poly-rhythmic patterns of the body. Such characteristics associate the technique with ancient, non-Western cultures as American dance scholar Dixon-Gottschild here elaborates:

Rather than the classical, Europeanist, linear logic of cause, effect, and resolution, we have irony, paradox, and double entendre — indeed, *radical juxtapositions* — as basic premises of the African-ist aesthetic, and where do we find them? In our postmodern lifestyles (Dixon-Gottschild 2008).

Such radical juxtapositions call to mind our ancestral African beginnings and their cultures and, if we keep spiralling backwards, to the Big Bang, a moment of fusion where the microscopic became infinity and our universe was created. Such rapid evolution from small beginnings is repeated in the making of ourselves. We are conceived, cells split and multiply in rapid accumulation, genetic coding combines with environmental factors and the self and its cultures is formed. These are 'quantum'[1] dimensions, which explain a universe that seems to be based on paradox, matter is also energy, just as chaos and order co-exist and are essentially part of each other.

Through immersion in the improvisational and interdisciplinary culture that continues to defines the contemporary or independent dance and live art making scene in Britain, the expansive processes of discovery - improvisation and choreography – opened up to different, 'other' cultures and narratives to mainstream culture and the academic community. Thus the western creative and academic community increasingly identifies itself as both inter-disciplinary and inter-cultural.

For myself, such understandings have evolved through practice, and it is through a practice-led-research model that I have come to the theories I discuss here. For the improvisational postmodern dance methodologies, essentially identified by inclusive, feminist, interdisciplinary processes that seek to explore the spaces between things, body-mind, the self and other, the personal and political, focused as a "training in perception" (Tufnell & Crickmay 1990:45), that finds synergy with the science of self-organising systems, complexity and emergence. In improvising we work towards awakening the senses, releasing ourselves form forced or fixed ways of doing and knowing, trusting and therefore discovering through making contact and connection. Improvisational postmodern dance forms recognise process as important as product. Quantum physics, the culture that spawned new understandings about science and the universe, similarly points to the sameness of material and energy.

Improvisational forms for discovery are found across disciplines and cultures. For example, Argentine Tango, a form I have worked with often in creating new dance theatre performance with its essential themes of power, desire, intimacy, gender. An orchestration of life's wanderings, of meetings and partings, Argentinean tango is a partner dance and a social dance, an urban dance. Whilst having basic step patterns, the direction, phrasing and tempo of the duet unfolds out of the relationship between the dancers. As with postmodern or New Dance where movement language is 'found' through exploration, Argentine Tango is essentially a dance that is evolved from walking.

Argentine political theorist and anthropologist Marta E Savigliano states that "tangos are expressions of the private, personal world, addressed to the public world" (1995 on-line) demonstrating their essentially theatrical intentions. Similarly contemporary improvisational forms in dance and music, that underpin contemporary avant-garde performance and therefore higher education arts culture, evolve from the act of looking inward and listening to the personal.

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[1] My current choreographic dance project is entitled *Quantum* and explores the essential notions drawn from quantum mechanics.

As a complex modern art form that is interpretative and improvisational, tango is an exemplar of how 'local' cultures, expressions spiral out and interconnect with global currents and patterns.

Dance Performance: Spirals of Complexity

When making my first professional contemporary choreography *"a still point in the turning world"* (1990) I was in pursuit of moving patterns that express and represent a sense of the dynamics and forms that are intrinsic to our universe. And in positing the question "does the world turn us or do we turn the world?"[2] I was perhaps asking a practical question, not a philosophical one. Complexity theory suggests that we do play a part in 'turning the world', as it recognises that all parts of a complex system feedback and *affect* the whole: the dancer affects the dance, that affects the audience, that affects their society, and culture and so on.

A dance where the performers use improvisational structures to create the raw material and key images from which the final work will be derived, can provide a tangible model of emergence at work and in so doing "model[s] the world" (Holland 1998:115). In analyses of complexity and emergence there are different linguistic descriptions of the two terms. I address emergence as the *behavioural outcome* or activity (the performance) that emerges from a complex system.

I refer to this first professional contemporary choreography to highlight that a correspondence between the scientific and the artistic is long been embedded in creative endeavours such as my own, albeit often in a non-defined, intuitive way. In my early years as an dance-maker I described this interest as one concerned with 'how the world works', a curiosity recognised by mathematician and pioneer of emergence theory, John Holland; "Both the poet and the physicist strive to get beneath the surface of events"(ibid:219) whilst acknowledging that "their disciplines seem *very* different" (ibid.:218)

I created *"a still point in the turning world"* with a group of dancers using improvisational practices and it was therefore, in part, a collective exercise and a process that accords with Wendy Wheeler's assertion in her exploration of complexity, bio semiotics and the evolution of culture, that "[c]reativity – the means by which human cultures evolve – is a social affair" (Wheeler 2006:141). Working in this way enables dances to be created from the 'bottom up' and this is a signifier of emergent activity.

It is common in contemporary dance that the choreographer and her dancers create a social community from which the work emerges. From a post-modern perspective a series of fragmented worlds collide, through deconstruction, parody and pastiche they invent a shared movement language from differences, from which a collage of performance expressions emerge:
The postmodern body is not a fixed, immutable entity, but a living structure which continually adapts and transforms itself. It is a body available to the play of many discourses. Postmodern dance directs attention away from any specific image of the body and towards the process of constructing all bodies (Dempster 1994:32-3).

Referring to the postmodern body as a living structure acknowledges the ever evolving, changing nature of performance works as both biological, of the body/all bodies, and of the shared imaginations of its creators and performers. Through the act of dancing, the body expands to more than itself, echoing the ever-expanding nature of the universe of which it is part. That every-

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[2] Quoted from the publicity for this work.

expanding universe, with its planets, stars, black holes, its known and unknowness, can be visualised as a place of dynamic spiralling as the spiral is essentially a dynamic form, a theory in practice that accords with a postmodern dance aesthetic, "a discourse defined not by a choreographer's specific language, its permanence, canon or category, but by its practice of process' (Claid 2006:128). Within such an aesthetic the *"a still point in the turning world"* choreography evolved through experimentation on my own and other dancers' bodies in the making of spirals and exploring how are they initiated in the body and where they lead. Thus, those bodies are the subjects and objects of the work and the embodiment of a theoretical exploration situating such a choreography as a practice-as-research and postmodern activity.

My route to exploring complexity and emergence came through the recognition that many of the dance patterns that were emerging from dance improvisations I initiated as being similar to fractals. Fractals[3] show self-similar geometrical patterns emerging from an endlessly re- iterated equation in a feedback loop. Such self-similarity and iteration on many scales can be seen in the vein pattern of a leaf in relation to the root pattern of a tree, or in the similarity between a cauliflower floret shape and the cauliflower itself. Mandelbrot was able to show that this 'new geometry', through the rapidly evolving computing power of the 1970s, whilst irregular, contained order. Fractals are the patterns of Chaos (Briggs 2002) a theory that helps understand the extraordinary dynamics where *tiny interferences to systems can wreak huge* changes such as the now famously understood descriptor that a butterfly flapping its wings can tip a system to a critical state where chaos ensues in, for example, a tornado. Whilst sharing the dictum that all parts feed back and affect the whole, chaos and complexity are essentially different in that "[c]haotic systems are exquisitely sensitive to initial conditions, and their future behaviour can only be reliably predicted over a short time period" (Coveney & Highfield 1995:39). By contrast "Complexity refers to the phenomenon of order emerging from complex interactions among the components of a system *influenced* by one or more simple guiding principles" (Gatrell 2005) and is therefore an open system.[4]

In performance we would consider open systems as improvisational. Improvising dancers or musicians might explore particular themes, compositional structures or rules towards building a new collective pattern that whilst unpredictable in some aspects, has a collective shape and is built from shared understandings, or feedback. While these rules may be quite simple, the behaviour which emerges for the entire system is intriguingly complex. In most cases it is rhythmic and fascinating to observe, providing "perpetual novelty" (Holland1998:4) for both the beholder and the elements (dancers, musicians, performers, collaborators) through who flows the information that creates this autopoeitic happening.

In nature emergence is possibly the key to understanding many mysteries concerning the behaviour of the whole (for example a neural network or a biological cell), which depends on the function of its parts (neurons or genes). Increasing numbers of scientific minds are now exploring complexity and emergence for

[a]lthough we may not be able to precisely forecast the long-term behaviour of a complex system, non-linear dynamics shows that we can gain some insights into its global behaviour...

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[3] A term coined by Benoit Mandelbrot when an IBM worker in the late 1970s. "Mandelbrot set up a mathematical equation on a computer which through colour coding its different values shows itself as an evolving intricate swirling pattern that demonstrates self-similarity on many scales" (Hofstadter 2007:69).
[4] Being a new field of research in open systems there are interlinking relationships and common understandings between: systems research, complexity, networks, adaptive systems and emergence.

These insights may provide the bedrock of understanding for future decision-making (Coveney & Highfield 1995:331).

In understanding the key characteristics of a complex system, might we be able to identify them in local-level practice in performance and pedagogy, whilst also seeing how the long-term sustainability of performance as part of cultural heritage may evolve. Indeed Cilliers ties the embrace of complexity as important to humankind's progression;

We need to come to grips with complexity in order to ensure our survival. At the same time, complexity is the fount of liberty. In both science and politics, therefore, the acknowledgement of complexity is a vital step (Cilliers1998:127).

The Characteristics of a Complex System
In his analysis he defines the ten characteristics of a complex system which I use here as a template for understanding, and becoming participant with, complex dynamic cultures in performance making contexts.

1. Complex systems consist of a large number of elements
2. These elements interact
 3. These interactions are rich
 4. These interactions are non-linear
5. The interactions are with local neighbours
 6. The effect of the activity can feed back on itself
 7. Complex systems are usually open systems
 8. Complex systems operate far from equilibrium
 9. Complex systems have a history
 10. Each element is ignorant of the behaviour of the system as a whole

Consist of a large number of elements

In my practice as a choreographer and dance teacher I often work in situations with **a** large number of elements, the first characteristic of a Complex system as defined by Cilliers, where the participants are the elements. Dance offers many examples where dynamic patterning between large numbers of 'elements' is the core aesthetic effect of the style, from folk dances to a ballet chorus.[5] However, in these dance examples the dancers are not asked to process information and feedback into the work. It is only with the democratic political intentions of the postmodern dance innovators that art-making dancers started to see themselves as equal active agents in a creative process that is essentially collaborative. Emilyn Claid, key innovator of the British New Dance scene, speaks here with a voice resonant with emergent notions;

A collective dynamic is more than the sum of its parts. The power of the collective to change cultural movements does not emerge through the voice of a single author. Neither does it emerge from the unity of the group. The outcomes of collective working occur in the weaving of a connecting web of processes between people and things. The web creates its own patterns of change that are invisible to established systems of production (Claid 2006:124).

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[5] Many artists' works have used such an effect where small changes amongst many elements are the work. Such as painter Jackson Pollock, composers Steve Reich and Phillip Glass.

These elements have to interact

An improvisational dancer is a creative artist motivated to explore creative paths for their own sake. They choose a journey of independent exploration and discovery which, whilst responding to 'rules' of enquiry, of their discipline, of their environment, leads them to new interactions. Their personal uniqueness will be expressed in their actions. Rosemary Butcher refers positively to improvisational dancers she collaborates with as 'intelligent rebels' (Foster in Butcher and Melrose 2005). Working collaboratively is a key methodology in education and in arts pedagogy in Higher Educational contexts.

Paradoxically, it was a computer scientist, Joe Faith, who I worked with on an early project looking at emergence and performance improvisation (*Emergence* 2002, who contributed an exercise that always shows unique emergent patterns forming through movement interactions involving a large number of elements.

The shoe exercise. Rule 1: All players remove their shoes and scatter them in the space (this gives quite a lot of shoes).

Rule 2: Set up a continuous movement system such as 'walk on an imaginary grid' or 'walk into and out of the space following your own image of a spiral'.

Rule 3: If you pass a shoe pick it up.

Rule 4: If you pass another shoe on the floor put the one you are holding down next to it.

The outcome of this exercise is emergent. Piles of shoes form but the patterns made by the size and spacing of those piles can never be predicted. I have worked with variants of this exercise as part of previous performance works *e-Merge* (2004), and in *Baby* (2003/6) where, instead of shoes, we used about 90 small pink beanbag pigs.[6] Examples of such complex performance systems where different elements interact can be seen in the video document *Herd film* (2009 on-line) paradoxically creating a permanent construct from strategies for impermanence.

These interactions are rich

In the context of scientific research that asks "how does a persistent, flexible organization emerge from relatively inflexible components" (Holland1998:82), both ant colonies and neural nets (Johnson 2001, Holland 1998) have been examined to provide insights into the way such a system operates. Ant colonies are an excellent example of complex systems that are made up of large numbers of same elements, where the ants, which interact and respond only to local information, generate a complex society. Ant colonies are self-generating systems where the crucial behaviours that define them as complex systems are clearly demonstrated by the ants' emergent behaviour. The colony's activity is based on ant genetic programming in response to local environmental conditions. Each of the ants has a set of behaviours that are triggered by certain environmental situations and pheromones (scent) left by other ants. The community is "typically possessing only ten or twenty signs" (Johnson 2001:75) such as: follow that pathway, forage for food, enemy nearby. Ants, in picking up scents that trigger different actions, are richly connected readers of

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[6] In my performance making I usually work with other media: music, projected still and moving visual images, text, props, costumes and increasingly new technologies.

signs, as we are, and these semiotic interactions contribute to "a form of collective memory" (Bloom 2000:38).

In performing a dancer similarly performs not only their own parts or roles but also connects and presents this 'collective memory', which might be considered as the essence of the whole work, or indeed even something more universal. Contemporary dance maker Siobhan Davies talks of making structuring decisions "in the moment", aiming for an audience to see both the simplicity and the complexity (Davies in Butterworth & Clarke 1998:57) inherent within it. The dual identity displayed by task-based ants/dancers as integral part of ant colonies/dance performance systems that are able to move "between the abstract and the figurative" (ibid:63) echo the paradoxical nature of matter itself. As Coveney & Highfield state "all physical objects are intrinsically ghostly" in the sense that

Particles of matter are waves of energy, and waves are particles, appearing as one or the other depending on what sort of measurement is being performed in any experiment (1995:81).

And working with paradox is something that that feels very familiar when creating performance from improvisational starting points.

The [improvising] performer refers to a map of possible choices determined by the structure of the form. The map must be recognized by a community of participants in order for the improvisation to make sense, but the map doesn't definitely mark the entire terrain. Here is the paradox of improvisation: it is neither truly spontaneous nor fully choreographed (Cooper-Albright & Gere 2003:106).

These interactions are non-linear
One of the key factors regarding complex systems is their non-linearity. They 'do not obey the simple rules of addition' (Coveney & Highfield 2006:9). When working with complexity, a scientific theory that might be considered as an equation for producing emergent outcomes, we are not confronted by absolutes and exactness. In the performed arts it is the differentiation of presentation of known material or texts (scores, choreographies, etc.) that may get called artistry. And for system creators such as choreographers and composers, it is perhaps a requirement that the innovator of a discipline changes fundamentals of that known genre or language. Wendy Wheeler in her exploration of complexity, bio semiotics and the evolution of culture, articulates this as

when a person has become so familiar with an area that they are able to 'tweak' it with confidence in order to explore the bending of its rules. Transformational creativity occurs when rule-bending gives way to an entirely new formulation of the dominant rules of the field (2006:140).

For arts disciplines to evolve and find new audiences and therefore to remain meaningful as part of a wider evolving culture they must mutate and change. Such mutation and change results fundamentally from rich interactions.

The interactions are with local neighbours
In my practice I have observed that by encouraging interaction between dancers and ideas through improvisation at a local level, new unexpected outcomes arise, which in turn may become symbolic theatrical images/ideas that are central to a new performance work. Birringer perceives this in Pina Bausch's choreographic approach "thirty dancers and their diverse personalities

constitute the dynamics of the improvisation" (1998:91) underscoring that the interaction between the company members, 'local neighbours', as they explore certain choreographic 'rules', create, in some large part, the textural quality of an emerging performance work. Similarly, in the opening minutes of my *Herdfilm* (http://www.vimeo.com/7641806), local interactions between individuals can be seen starting to transform into a group dance work. For example, in the upper oblong window of film footage, as it opens, the dancers can be seen in rehearsal clothes, individually walking spirals in shared space. After a short while you can perceive a transition from five dancers walking their own spirallic pathways, to five dancers interacting with each other in a spiral informed, self-organising *group dynamic.*[7]

As stated earlier New Dance and postmodern dance practices had at their core the breaking of boundaries between art and everyday experience, the opening of routes to the high art experience to non-dancers and non-western disciplines in an attempt to invigorate the art experience beyond the traditional frames of reference. This is particularly evident in the work of Pina Bausch, recognized as a major figure in the world of 'high art' dance, in her restaging of her 1978 work *Kontakthof* in 2000. She remade this work using male and female performers aged over 65, who were not professional dancers. In this version the change in the age of the cast rewrote the themes underscoring the work: the interrogation of male/female relationships, the offering of self to others for validation and acceptance. In restaging it thus with 'non- dancers' who are clearly in a stage of life where the conventional demands of dance performance are very difficult, the work creates a new and powerful resonance. As with so much postmodern work, performances of *Kontakthof* are founded on a complex network of local relationships between performers, images, and questions about how we deal with our bodies and relationships, and, I would argue, the performative outcomes of *Kontakthof* are emergent. Such emergent performance, demonstrated by this latter version of *Kontakthof,* is understood as a live event that results from the play of relationships between the elements (the older performers, the music, the set, the music, the audience) on stage in time.

The effect of the activity can feed back on itself
Yvonne Rainer was also one of the postmodern dance innovators associated with the New York based Judson Church group. Demonstrating synergy between the development of the science of complexity and postmodernism, her 1970 project *Continuous Project - Altered Daily* created a system of rules that were given to the dancers to
Interpret, thus integrating into the performance their own feedback and the environmental circumstances pertaining at that time. Rainer, through the contrasting rules and possibilities for performing material given to the dancers

set in motion a mechanism for producing change, for promising and pursuing development and variation and at the same time deferring and displacing possible conclusions. .... In this way, and like that performance which is ostensibly 'minimalist', the *Project* puts into question the possibility of separating the 'work' from its immediate circumstances, and so of identifying those properties which it is in possession of and by which it is defined (Kaye 1994:116-117).

Kaye here in highlights how feedback systems are deeply woven into such performance works, thus ensuring ever-changing outcomes and in addition he draws attention to the term 'minimalist' implying, in my terms, that it is connected with emergence. Minimalist work is foremost

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[7] Scientists define this shift as a 'phase transition'. It occurs because of the flow of energy/information between the elements thus "changing from one defined state to another at a critical juncture" (Johnson 2001:111).

prescribed by repetition of simple phrases that may modulate over long periods of time. The term 'minimalism' is most often used to denote a style of contemporary music composition and includes compositions by artists such as Steve Reich, Philip Glass, John Adams and Gavin Bryars. Music by all of these artists has been used by established contemporary choreographers such as Lucinda Childs, Shobana Jeyasingh, Merce Cunningham and Anna Teresa De Keersmaeker. An example of this genre of music-dance collaboration, which I saw performed in 1999 in London's Queen Elizabeth Hall and excited me by its obvious emergent structuring, was De Keersmaeker's hour-long choreography to Steve Reich's *Drumming* (1970-71)[8]. The choreography for this piece unfolds from a single motion phrase, explored exhaustively for an hour through endless combinations, variations and transformations.

De Keersmaeker manipulates simple gestures and basic movements into drawn out swathes of pulsating dance patterns that heavily use repetition, giving a hypnotic effect that plays in contrast to sections of sensual simplicity and intimacy. At all times one is able to identify the simplicity (the base material, the human dimension) from which the complexity of the dance composition is derived.

It is through repetition that subtle differences can be fore grounded. Indeed, de Keersmaeker defines her own choreographic intention as follows:
I try to bring the "I" and the "you" to the surface. The structures give precisely the sort of freedom that allows individuality to emerge. It's like a machine that starts up and must continue until it winds down by itself, but allowing flavours and colours to stand out more strongly[9].

The use of repetition and feedback entwines dance and music and, for my purposes, also the individual and the group, so closely in *Drumming* that it shows the shape shifting nature of complexity. A dance where the performers use improvisational structures to create the raw material, and therefore are feeding into and contributing to the key images from which a performance work will be derived, can provide a tangible model of emergence at work and in so doing "model[s] the world" (Holland 1998:115).
Birds flocking can similarly be understood as made up of a web of local interactions that whilst invisible to the human eye are a key example of emergent behaviour. The patterns of the flock cannot be described by the behaviour of individual birds, and consequently have been a core inspiration for the computer modelling of complex systems (Waldrop 1993:241).

Complex systems are usually open systems
Artists such as Pina Bausch have created new performance works not by 'choreographing on' dancers but by asking questions her performers. These simple starting points, often concerning "everyday social experiences of the body" are modelled into "objectifying sequences of images and movements" (Servos 1998:38). And these sequences of images are put together in postmodern works as collage or montage. This principle of montage that Bausch established in her work is a methodology has influenced many contemporary performance makers. In the context of my work I was particularly drawn to Servos's notion that

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[8] This composition by Reich is exclusively written for percussion instruments and has been used by many choreographers (e.g. Laura Dean 1975) to accompany new dance performance.
[9] This quotation was taken from an on-line source relating to the Keersmaeker company that is no longer available. The author was Adolphe, Jean-Marc. Translation Duckworth, O. *Drumming*: 'Stripping down complexity' no date.

The linkage of scenes in free association, without the need for continuity of plot, psychology of character, or causality, also refuses to be deciphered in the normal way. It defies interpretation (ibid.).

Servos' analysis of how Bausch's work challenges theorists' or critics' attempts at deconstructing her performance work suggests that, in formal terms, her works could be seen as open systems. Open systems respond to their environments, and in Bausch's performance works we see the use of unusual, challenging and distinct stage settings as a key creative strategy. In *Viktor* (1986) huge earth walls skirting the stage are gradually eroded as individuals throw shovels of the earth down into the performance space throughout the duration of a work which includes: a woman throwing bread gently to feed an origami paper bird; a woman approaching a microphone on a stand but her only utterance is a deep exhalation of tiredness? pain? after which she falls onto the extended arms of a line of men lying in a row next to her. The men pass her prone body across the line of them, she is put back onto her feet, walks back to the microphone and repeats the process; someone walks onto the stage with a sheep on a lead. *Carnations* (1982) has a stage covered in, as you might imagine, carnations, and for *"1980"* (1980) the stage was covered with grass. Such stage settings demand that a major part of the work is the relationship between the individual performer's negotiation of their own material within the challenging environment. In these works we see the use of
systems whose state changes over time. Systems such as these are multifaceted, complex and interdependent. They constantly push and pull at themselves to create the sensuous irregularity and unpredictability that is the signature of our physical environment (Briggs 1992:15).

Briggs' scientific definition of a dynamical system echoes the 'signature' strokes of Bausch's oeuvre, also created from sensuous, visceral activities between people in relationships of 'irregularity and unpredictability'. Briggs also refers to the 'push and pull' that is inherent within systems.

Complex systems operate far from equilibrium
This tension between the individual and an environment which is evident in Bausch's works is indicative of 'open' work and also illustrates how complex systems operate far from equilibrium as represented by an enormous concrete wall tumbling down at the start of her *"Palermo, Palermo,"* (1990). Such works have risk and change and the unexpected at core in mirroring the chaos and complexity of life. Sadly, the choreographer died in 2009 and so new epic works cannot be expected, but due to the enormous popularity of her work the world over the Bausch company continues to painstakingly reconstruct and tour works internationally for the benefit of current and future generations. Her intangible heritage is further celebrated in film maker Wim Wenders' film PINA (2011), created for her with her legendary company Tanztheatre Wuppertal.

The international popularity of her work beyond just 'dance' audiences shows the humanity in this complexity, that chaos is essential to the human heart here confirmed by Briggs. "Heart attacks and epileptic seizures are, scientists think, a form of self-organised chaos which occurs when the heart or brain suddenly becomes *too* regular" (Briggs 1992:110) and heart attacks often point towards death. The notion of death or complete inactivity and lifelessness is starkly antithetical to the art-form of dance particularly. Cilliers pointing to the importance of chaotic activity to healthy living systems, "Equilibrium is another word for death" (1998:6) makes an urgent case for its recognition which Katherine Lett shows is beginning. In her article 'A Case for Chaos Theory in Nursing' "Strategies such as abandoning false notions of control and acceptance of the uncertainty

of the future are proposed as means by which nurses can apply chaos theory to their practice" (Lett 2001:16).

Complex systems have a history

Embracing the abandonment of 'false notions of control' and accepting paradox in creative states that are far from equilibrium in performance making as a liminal space where "people 'play' with the elements of the familiar and defamiliarize them" (Turner 1982:27).   The work of anthropologist Victor Turner resonates with the multi-directional flow of possibilities of the spiral. A flow of information forwards and backwards through space and time brings us to the penultimate characteristic of complex systems and one that addresses so directly the concern with sustainability of performance and heritage. Whilst complexity states that systems change, unpredictably, they carry with them the histories of both themselves, and the elements that create them. In the arts we refer to the canon of work upon which the present or current sits. In performance, this may be the text – whether choreography, score, narrative – and also the disciplines and languages that the performers draw on in its presentation. Dance improvisation practitioner Juleyn Hamilton conjures the notion of these evolving iterations as an organic process: "Every movement has within it a seed of another movement. It is just like any lifeform. It has within it a living structure" (Hamilton [video 1993]). Parsing movement making with the evolution of live organisms suggests an interdisciplinary culture interested in the creation of hybrid forms made from Nature and Culture.

Performers, like birds flocking, in building a performance through responding to tasks in relation to time and space are part of a spiralling complex system that draws on their own own history of experiences, physicalities, biologies, thus imbuing themselves integrally into the final performed work and it in them.

Such mixing of material accords with neuroanthopologist Paul Howard Mason's observation that "New choreographies are, more often than not, some form of re- ordering of old worlds into new combinations" (2009:29).

This spiralling flow of new and old into unpredictable new patterning enables what is valued in a community's heritage to be up cycled by a, robust, complex system forward into new cultural form. Such sustainability, in terms of complex forms, is understood as clusters or hubs of material, which collectively shared, become new motifs or symbols. Such cultural signatures are sustained into the future because they are increasingly strengthened as they are repeatedly communicated. They are composite outcomes of a number of 'rules' in a system that seem to take hold that become higher level rules for future evolutions and communications. Points of interconnection are weighted and this "Clustering is ubiquitous... a generic property of complex networks (Barabasi 2003:51) ".

In terms of performance, and thus art, and ultimately in understanding cultural heritage through understanding this aspect of complexity, that it evolves higher level, more sophisticated language, reminds us that whilst seemingly impermanent, because dynamic, leaves permanent constructs.

Each element is ignorant of the behaviour of the system as a whole
To grasp the final tenet of a complex systems that demonstrates emergent behaviour is to consider the ant ecosystem as referenced earlier. The whole (the colony) is clearly greater than the sum of its parts in that the removal of one or several ants will not hinder the colony's survival and evolution. Each ant (element) is clearly unaware of what the majority of ants are doing and of the

global shape of the colony it contributes to, instead concerning itself with getting information as to its task from interaction with other elements at a local level.

And towards conclusion, making a micro macro leap from the tiny ant to "one of the greatest figures of twentieth-century mathematics and, from the perspective of complexity, also of science" (Coveney & Highfield 1995:29) whose work and life perfectly demonstrates this principle. Traced to one of his last published papers by British mathematician Alan Turing, famous for his work breaking the German Enigma codes at Bletchley Park during the Second World War[10] which "demonstrated using mathematical tools how a complex organism could assemble itself without any master planner calling the shots." (Johnson 2001:14). Turing has been acknowledged by those engaged in the study of emergence as its progenitor for he created the first blueprint of the computer which has subsequently "provided a tool for measuring complexity" (ibid.:30) and therefore enabled the scientific community to identify emergent phenomena.

The use of the term *universal* computer underlined a vital shift in mathematics, for Turing's abstract notion of a machine was designed to tackle *any* mathematical problem "in the sense that a modern computer can carry out any program" (Coveney & Highfield 1995:30). The computer, being capable of processing many different types of equations, languages and softwares to a considerable degree of complexity consequently opened the potential of cross-disciplinary dialogue on many levels, significantly contributing to a digital art-science culture which I consider myself part. Turing's *universal* machine has particular relevance to artists as it started "as a purely imaginary device, a "thought experiment" (Gribbin 2004:114). Such imagining/inventing constructions before knowing that they are feasible is one of the traditional routes of the artist.

To my mind an analogy can be found between the use of the computer and postmodern dance, for just as the modern computer is able to take on the physical computational activity of a mathematical problem, a group of improvising dancers can take on a choreographic problem through detailed physical activity, turning ideas into movement and then performed dance. Just as it is the computer programs and systems that are the heart of a computer as a creative tool, it is the performance making *system* that can work with any number of ideas, or styles, or participants, and is, perhaps, the most important part in such a creative process.

Conclusion

In this writing I have addressed manifestations of complexity and emergence in different fields of activity demonstrating that emergence theory can be applied across disciplines, and are therefore as relevant to computer scientists and choreographers as to philosophers and biologists.
The themes permeating my practice-theory research infuse, in a micro-macro fashion, across my various teaching and choreographic activities.

This research is practice-led and is defined by these theories and by the work of influential and highly respected dance artists, highlighting the interplay between my choreographic research and a broader dance context. And like Wayne McGregor, Artistic Director Random Dance, Resident Company at Sadler's Wells, and Resident Choreographer of The Royal Ballet

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[10] A number of documentaries have been made about his work and life. In October 2014 a new film about his work and impact will be released and an orchestral work by the Pet Shop Boys had its world premier at the Royal Albert Hall as part of the 2014 BBC proms.

as a choreographer committed to change, there has always been a seamless relationship for me between the investigation of process in professional work and that undertaken in an educational context (McGregor 2000).

McGregor, whose interests in the art-science-digital interface have particular affinities for me, underlines how all parts of his practice interconnect, from the local to the global, and points to change being an implicit focus in his work. He reminds us also that a dynamic of change or transformation is essential to creative activity echoing that in scientific terms, emergent behaviour self-organises as unique non-linear dynamic patterning from the bottom up and is subject to neighbour interaction, pattern recognition, feedback and indirect control (Johnson 2001). For, in proposing complexity as a methodology for ensuring the 'new' in performance, we surrender complete control and embrace collaboration and interconnection. Just as Barthes posited the death of the author (1977) in his now classic *Image-Music-Text* linking to a gestalt where the self is activated by relations to others/the environment, so too John Holland ruminates in *Emergence* on "the end of science" (1998:234). Whilst an *actual* end to either artistic or scientific activity doesn't appear to have come about as yet, these statements do point to a synergy in both scientific and artistic thought and therefore the end of fixed disciplinary boundaries. This writing references interdisciplinarity as central to a 21st century understanding that moves beyond traditional dualistic tension; that the sciences produce knowledge and the humanities address meaning. I propose that in practicing complexity we move away from polarity, which is so evidenced by conflict, towards different modes of knowing, shifting sands, that ripple across many fields.

What I aim to have achieved in connecting my choreographic activity, embedded in its postmodern dance context, to a growing cross-disciplinary field of emergent research with a sci-art interest in a digitally empowered global culture. In analysing and articulating my own history as a complex system dance-based practice-led research I have embedded my work within an interconnected dynamic of artistic and scientific activity that is working towards an understanding of how systems operate across our universe. Such interconnections will, I trust, trigger further understandings.

End Notes

6947

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