EFFECTIVENESS OF TEAMS: LESSONS FROM BIOMIMICRY, AN ECOLOGICAL INQUIRY E=MC2

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Abstract

Team effectiveness in swarms like bees, colonies of ants, schools of fish, flocks of birds, and fireflies flashing synchronously are all as a result of highly coordinated behaviors that emerge from collective, decentralized intelligence. The purpose of this article was to contact an ecological research inquiry of what lessons business can borrow from biomimicry especially by studying ants' colonies, swarm of bees and packs of wild African dogs. A systems science theory borrowed from Albeit Einstein E = mc2 was used, where effectiveness of teams was equal to mastery of each individual x coordination x communication (collective intelligence). The author used using secondary data analysis to obtain information on team effectiveness and collective intelligence. The research found out that, team effectiveness is a function of mastery of individual x coordination x communication (collective intelligence). The research further recommended corporate to mimic the biosphere especially to adopt collective intelligence strategies from ants, swarm of bees and wild dogs for business sustainability

Keywords: Collective, Intelligence, Biomimicry, Consensus

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1 Introduction

An Ethiopian old adage proverb has it that, "when spider webs unite, they can tie up a lion. The truism of the above statement is that, effectiveness of teams in any organizational set up is the collective intelligence of its team members, which is the coordination and communication among the team (Malone 2008). To further elaborate on effectives of teams as a function of collective intelligence, the article has borrowed from systems science Einstein's Theory of Relativity (E=MC2) Systems science is an interdisciplinary field that studies the nature of systems from simple to complex in nature, society, and science itself. The field aims to develop interdisciplinary foundations that are applicable in a variety of areas, such as business, engineering, biology, medicine, and social sciences. From systems science Einstein's Theory of Relativity (E=MC2) where Energy = Mass Times the Velocity of Light (C) Squared. With Mass the Newtonian's First Law of Motion states that every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it. Velocity Newton's second law of motion states that there is a relationship between an object's mass (m), its acceleration (a), and the applied force (f) (Thornton & Sokoloff, 1998). The same concept is applicable to Team Effectiveness in organizations where effectiveness is equal to mastery of each individual times coordination times communication (Collective Intelligence). This team effectiveness is best mimicked from studying nature or biodiversity. Studying nature to get ideas to solve trans-disciplinary human problems has recently received new attention from the field of biomimicry (Mashingaidze, 2014). Biomimicry is an "emerging discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems (Benyus, 1997). Biomimicry, or biomimickry is where the biosphere is mimicked as a basis for design, or a growing area for research in the fields of architecture, engineering and business operations (Pedersen, 2007). The purpose of this article is to find from the biosphere, team effectiveness lessons which organizations can mimic for the betterment of the entire organization. The topic is immaculately clean and so far nothing according to my understanding has been done where a system science theory has been adopted from a different galaxy (science) and used in a different galaxy (business). This intergalactic approach is the sole purpose of this article in trying to mimic nature for the benefit of teams. In engineering, multiple terms label the practice of learning from organisms and systems present in the biosphere these include: bio-inspiration, bio-mimetics, bionics, biognosis and are traceable to those responsible for coining the terms (Schmidt, 2011). The research methodology used in this article is one of its kind, in business management supporting the view that this research is pristine and original. Besides being original the article will again greatly contribute to the body of knowledge by alerting business and other related disciplines to look for solutions from other galaxies for the example the use of system science theories to improve business management. Another contribution is environmental mimicking, where business should look for ideas from nature to solve problems. . A major problem today in many organizations is authoritarian type of leadership. The resultant stress experienced by the participants in an authoritarian or bureaucratic work environment has an adverse impact on both individual and organizational performance. This is why bureaucracy is inherently unsuitable for any task that requires the expression of the finer human qualities such as empathy, compassion and intuitive thinking. King Solomon in Bible discouraged the authoritarian idea of leadership and directed people to learn from the ants. He said, "Go to the ant, thou sluggard; consider her ways, and be wise" (Proverbs 6 verse 6). The article will unfold as follows; first research methodology will be discussed, and secondly definitions of some terms will be given as they relate to this study, thirdly the article investigates some team effective lessons found in the animal kingdom for example bees, ants and African wild dogs.

2 Ecological research methodology

This methodology is at its infancy and was coined by Given, (2008). He posited that, researchers who describe their research as "ecological" generally have concern for the environment, the relation of the environment to humans, and the impact humans have on environmental health and sustainability. As a methodology, ecological research can vary depending on the intents and purposes of the research and the theoretical and conceptual frameworks used. Ecological research can refer to several types of research, including research that is done from a worldview emphasizing the interrelatedness of all forms of life, research that integrates ecology with the social sciences, research that focuses on a philosophical understanding, and research that focuses on an understanding human knowing, learning, and action as they occur in particular settings (Given, 2008).

2.1 The ecological worldview

According to Given (2008), the worldview is non-reductionist, it refuses to separate the focus of inquiry from its context, and is concerned with the way in which the object or event is embedded in and reciprocally related with natural and social environments. Researchers value all living things and consider humans to be only one part of the large integrated web of life. This type of ecological research seeks to understand complexity and the emergent nature of knowledge and how this relates to the well-being of future generations. The research is driven by the belief that humans can learn from the study of ecosystems that are sustainable communities of plants, animals, and small organisms. The promise is that by understanding the principles of organization of ecological communities, humans can revitalize their social and cultural communities based on ecological principles Given (2008). The research methods used by ecological researchers are eclectic that is selecting what seems best to suit the research for example in this article secondary data will be used including archival documents and peer-reviewed journal articles. In addition, all issues of the journals Swarm Intelligence, collective intelligence, biomimicry, team effectiveness and the International Journal of Swarm Intelligence were reviewed for suitable articles. A Strategy of analysis was performed by reading through the titles, abstracts and results. A search for peer-reviewed journal articles was done using UNISA Online databases in Business Management, Behavioral Ecology and Sociobiology. All searches were limited to research published in English delimited to ten years (2004-2014). Key criteria were used in the decision tree for selecting articles for inclusion/exclusion in the literature review. The following describes the inclusion/exclusion criteria. From UNISA Electronic Databases the Sage Journal was selected. When Search Terms: "collective intelligence, biomimicry, team effectiveness, group hunting, wisdom of crowds, consensus decision-making and ant colony" were entered, 46 Hits came out. And only 13 articles and books with an (*) at the reference page were considered for review. Thirty-three articles were excluded because abstracts and results were identified as irrelevant to my topic and not worthy of further exploration

3 Biomimicry definition

Biomimicry is a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems, for example a solar cell inspired by a leaf. Leonardo da Vinci for example drew sketches of a flying machine inspired by birds' wings. In the late 1950s American biophysicist Otto Schmidt and US Air Force doctor Jack Steele conducted research on machine engineering inspired by nature, for which they coined the terms biomimetics and bionics respectively. Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but what we can learn from it." In that respect, biomimicry can be truly be seen as a welcome novelty.

3.1 Intelligence definition

Tracing the meaning of intelligence, one could discover an imponderable number of interpretations from different time periods and subject areas. This article has selected definitions of "intelligence" as below:

- Intellect relieves human beings of the pressure to physically adapt to the environment and instead enables them to adapt the environment to their own needs [Müller 2009].
- Intelligence is what intelligence tests measure (Boring, 1926).

- Intelligence is understood to mean adaptive behavior as a means of conserving life, or more specifically the species (Aulinger, & Miller, 2014).
- Intelligence is a biophysical potential to process information that can be activated in a cultural setting to solve problems or create products that are of value in a culture (Gardner, & Stough, 2002).

3.2 Collective intelligence definition

- "[…] collective intelligence is groups of individuals doing things collectively that seem intelligent" (Malone 2008).
- "Collective intelligence is the capability for a group of individuals to envision a future and reach it in a complex context" (Benkler, & Masum, 2008)
- "[…] a group's collective intelligence as the general ability of the group to perform a wide variety of tasks" [Woolley et al. 2010]
- "Collective intelligence is the degree of ability of two or more living things to overcome challenges through the aggregation of individually processed information, whereby all actors follow identical rules of how to participate in the collective." (Levy, 1997)

4 Swarm intelligence and team effectiveness

Team Intelligence or effectiveness is the degree of ability of two or more living things to overcome challenges through the aggregation of individually processed information, whereby the actors don't follow completely identical rules of how to participate in the team. (Aulinger, & Miller, 2014). According to Cacioppo, Fowler, and Christakis (2009), Swarm intelligence is the emergent collective intelligence of groups of simple agents. Each agent can interact with its local environment and other agents, but acts independently from all other agents. Cacioppo et al. (2009) describes a swarm as a certain family of social processing integrated by simpler units. It typically refers to a cluster of things such as insects, animals or artificial agents, in which individuals move in apparently random directions, but the group stays together as a whole.

4.1 Team effectiveness lessons from the social insects (ants and honeybees)

Conradt and Roper (2005) proposed a useful conceptual distinction to classify animal group decision-making which called, combined and consensus decisions. Combined decision-making refers to cases where animals decide individually, without requiring a consensus but in a manner that is somehow dependent on the behavior of other group members; the aggregate results of these individual decisions critically affect the group as a whole. Many foraging decisions fall into this category, where foragers seek resources (e.g., nectar, prey) individually but under social influence (for example, using social-frequency information) from other foragers (Conradt and Roper 2005)

4.2 Army-ant colony

Dorigo, (2006) denoted that, ants communicate with each other using pheromones. While searching in its environment, a worker ant will often pause briefly to deposit a small amount of pheromone along its route. Others are attracted to these pheromone markings, and will often reinforce them while following the trail. This seemingly simple mechanism provides a foundation for a complex array of coordinated behaviors and patterns, including the formation of trails to food resources and new nest sites, and optimization of these behaviors according to adaptive principles.

4.3 Combined decisions in ant colonies

An experiment was conducted by Mohan, & Baskaran, (2012) to examine how ants, which have only a limited individual capacity for orientation, were able to locate food resources efficiently as collectives. In one experiment they placed a bridge between a nest of ants and a food source. The bridge had a skewed figure-8 shape. Starting from the nest end, it split into two branches of different lengths at two different points, which eventually merged to the same destination where the food was placed. A forager/searcher going in either direction (leaving the nest or leaving the food) had to choose between two paths at 2 choice points, which yielded four routes in total. Results showed that, 5-10 minutes after placement of the bridge, explorers crossed it and discovered the food. In short, this is team effectiveness which was initiated by one forager (mastery of one ant) and then collaboration/communication of the whole group (collective intelligence) to achieve their goal (discovering the food). A few minutes later, the shortest path between the nest and the food source was followed by a large majority of the ants. The ants solved the route-finding problem correctly as a collective (Mohan, & Baskaran, 2012)This occurred because ants traveling the shorter path returned home faster and thus reinforced the pheromone markings on the path more frequently (that is a path whose length is half of the other's is marked twice while an ant travels to and from the food source, as compared to the other path that could be marked only once in the same time period), and because others were nonlinearly attracted to the higher pheromone concentration (Mohan, & Baskaran, 2012)

According to Conradt and Roper (2005), nest migration of ants requires not only individual search behaviors as we have seen above, but also some mechanisms to aggregate individual judgments into a consensus. In gregarious species such as ants, all members must abide by the consensus outcome whether or not they contributed to it, in order to maintain group cohesion against predation and other risks. Quorum rules are usually used in these situations to yield the group consensus. When nest damage is initially detected, a subset of workers (about 30% of the colony) starts an exploration phase, individually searching for candidate sites. Upon finding a candidate site, an individual ant enters an examination phase, carrying out an independent quality evaluation of the site (Conradt and Roper 2005). Once the individual has accepted the site in terms of quality, she enters a canvassing phase, returning to the old nest to recruit another ant to the new site via tandem-running (a method of recruitment used by some species of ants, such as Temnothorax albipennis, to lead nest mates to food and to facilitate quorum sensing). Each of the recruited ants then makes her own independent examinations of the new nest, proceeding to further tandem-run canvassing if warranted. Because ants take less time to accept higher-quality sites, overall recruitment is faster to such sites. Finally, once the population in the new nest exceeds some "quorum threshold," a recruiting ant enters a committed phase. The recruiters stop the relatively slow tandem-runs, and accelerate the migration process by carrying passive nest-mates and brood to the new nest site (Czaczkes, Grüter, Jones, and Ratnieks, 2011)

4.4 Honeybees' colony

Honeybees (Seeley, 2009), communicate with each other about movement decisions primarily through a "waggle dance" with a figure-8 pattern. Waggle dances are performed by foragers that have located food resources (nectar, pollen), water resources, or new nest sites. The direction and duration of the waggle dances are known to be related to the direction and distance from the hive to the resource. Decision-making by individuals within such aggregates is so synchronized and intimately coordinated that it has previously been considered to require telepathic communication among group members or the synchronized response to commands given, somehow, by a leader.

4.5 Combined decisions in honey bees

In a field experiment conducted by Seeley, (2009), to test how efficiently a colony of honey bees could exploit nectar sources, where they placed two feeders (one feeder contained more concentrated sugar than the other) in opposite directions (with each being 400 meters away) from the hive, and altered the location of the richer feeder after 4 hours. The bees were able to track this change, and consistently focused their foraging efforts as a colony on the more profitable feeder. In late spring to early summer, as a large hive outgrows its nest, a colony of honey bees often divides itself. The queen leaves with about 2/3 of the worker bees to create a new colony, and a daughter queen stays in the old nest with the rest of the worker bees (Seeley, 2010). The swarm leaving the colony must find a new home in a short time, which is critical to their survival. The departing swarm, which is composed of 10,000 or so bees, typically clusters on a tree branch, while several hundred scout bees search the neighborhood for a new home. These scout bees fly out to inspect potential nest sites, and, upon returning to the colony, perform waggle dances to advertise any good sites they have discovered (Seeley, 2010)

4.6 Communication and coordination (collective intelligence)

Taken together, the combined and consensus decisions of ants and honeybees when foraging for food or when migrating to a new nest site, have several key elements in common to yield their highly impressive group-level performances. The key factors include (communication) positive feedback along with nonlinear responses to social frequency information, for example trail markings by pheromones; the numbers of bees engaging in waggle dances. In the foraging case the process is started by one forager that finds a food source first, which is followed by more and more foragers over time (positive feedback) (Conradt & Roper, 2005).

4.6.1 Coordination

Coordination is the appropriate organization in space and time of the tasks required to solve a specific problem. This function leads to specific spatio-temporal distributions of individuals, of their activities and/or of the results of their activities in order to reach a given goal (Garnier, Gautrais, & Theraulaz, 2007). Coordination is also involved in the exploitation of food sources by pheromone trail laying ants. They build trail networks that spatially organize their foraging behavior between their nest and one or more food sources (Garnier, Gautrais, & Theraulaz, 2007)

4.6.2 Cooperation

Cooperation occurs when individuals achieve together a task that could not be done by a single one. The individuals must combine their efforts in order to successfully solve a problem that goes beyond their individual abilities. Cooperation is obvious in large prey retrieval, when a single individual is too weak to move a food item. Many cases of cooperative transport of prey were reported for several ant species such as weaver ants, army ants, and wood ants (Boström, & Bonsdorff, 1997). It was reported that ants engaged in the cooperative transport of a prey can hold at least ten times more weight than did solitary transporters ants (Boström, & Bonsdorff, 1997).

4.6.3 Collaboration

Collaboration means that different activities are performed simultaneously by groups of specialized individuals, for instance foraging for prey or tending brood inside the nest (Ingram, Oefne, & Gordon, 2005). This specialization can rely on a pure behavioral differentiation as well as on a morphological one and be influenced by the age of the individuals. The most conspicuous expression of such division of labor is the existence of castes. For instance, in leaf cutter ants workers may belong to four different castes and their size is closely linked to the tasks they are performing (Hölldobler and Wilson 1990). Only the workers whose head size is larger than 1.6 millimeters are able to cut the leaves that are used to grow a mushroom that is the main food source of these colonies. On the contrary, only the tiny workers whose head size is about 0.5 millimeters are able to take charge of the cultivation of the mushroom. Differently, all workers look alike but they do not work to the same extent and they do not perform the same kind of tasks. Some of the workers are foragers and take most of the burden of going out of the colony in search of food and building materials. Others specialize in staying and working at the nest. Among these, some are more aggressive towards their nest mates and they are called fighters. The other wasps staying at home are called sitters and spend most of the time just sitting and grooming themselves (Gadagkar and Joshi 1983, 1984).

4.7 African wild dogs and team effectiveness

According to Bailey, Myatt, & Wilson, (2013), African wild dogs are successful in their hunting expeditions 70 to 80 percent of the time; Cheetahs are successful 30 percent of the time; and Lions are successful 20 to 30 percent of the time (1996). Why are African wild dogs so successful? Their strength lies in their social entity—the pack—in which lies the African wild dog performance-enhancing traits—Shared Leadership, Shared Vision, Tenacity, and Individual Skills (Washington and Hacker, 2005).

The African wild dogs Concept (E=mc2)

Where E = effectiveness of teams/success rate/catch the pray

M = mastery of individual

C2 = collective intelligence (coordination and communication) or group tenacity

4.7.1 Team effectiveness and Individual skills

Bailey et al. (2014) asserted that although The African wild dogs are typically known to live in packs, they can also survive individually. Based on painstaking empirical observations, McNutt and Boggs concluded that African wild dogs do not join packs to survive, but rather for company in-between hunting expeditions (1996). In their effort to understand the African wild dogs, they empirically, observed a wild dog for eight months, which chose to live and hunt by itself alone, although it made successful hunts, it was lonely. This observation suggests that the African wild dogs, among other success enhancing characteristics, do possess individual skills as well. But they these wild dogs are temperamentally seeking and enjoying the company of others; and they live in groups known as packs (Bailey et al, 2013). A pack comprising of males, females, and baby wild dogs, ranges from ten to 40 African wild dogs. A pack of African wild dogs usually has a dominant male and a dominant female for breeding purposes. Otherwise, hierarchy is almost nonexistent in a pack. With a record of 70 to 80 percent success in their hunting expeditions, the African wild dogs have the highest kill ratio in the world of predators (Bailey et al, 2013). The most experienced male in the pack usually leads a hunting expedition. The African wild dogs jump up on their hind legs for a better view when hunting for a prey; when they spot a prey, they drop their heads so as to appear unthreatening to the prey. The ability of the African wild dogs to work as a group defines and explains their unprecedented success as predators in the animal kingdom (Bailey et al, 2013). Washington and Hacker (2005) identified four distinctive characteristics they believed were responsible for their phenomenal success in the entire animal kingdom as predators: Shared Leadership, Shared Vision, Tenacity, and Individual Skills.

4.7.2 Team effectiveness in wild dogs as a result of shared leadership

The African wild dogs share the leadership role among themselves (Ruch, Herberstein, & Schneider, 2014). As observed and claimed by Ruch et al. (2014), African wild dogs have no hierarchical structure in their social entities, the packs; hence, there is not just one leader in any given pack, but a dominant male and a dominant female for breeding purposes only. In a typical hunting expedition, African wild dogs take turns in playing the leadership role, which is dependent of the location of the prey at any given point in time during the hunting expedition. If, for example, the prey turns east, the African wild dog closest to the prey will voluntarily take over the responsibility to lead the pack with respect to the charging of the prey. The same spontaneous response in behavior is delivered to the pack by the African wild dogs in position should the prey turn west, north, or south (Ruch et al. 2014). As purported Ruch et al. (2014), African wild dogs usually hunt in a queue format, which makes it possible for the African wild dog in front to easily drop to the back when tired and thereby let the next African wild dog in line take over the leading role maintaining the same particular line formation. Such a creative hunting strategy in the African wild dogs distinguishes them from ever other predator in terms of success in the entire animal kingdom.

4.7.3 Team effectiveness in wild dogs as a result of shared vision

Shared vision is a very important factor for the attainment of group or organizational goals in any social entity or organization. A close examination of the available literatures on the behavioral tendencies of the predators considered in this research study revealed only the African wild dogs in the entire animal kingdom to exhibit the characteristics of a work group with a Shared Vision (Washington and Hacker, 2005). The African wild dog packs organize their eating turns in the reverse order: eating turns amongst packs occur in a "bottom-top" order as opposed to the "top-down" order amongst the prides. When a catch is made, the pups get to eat first. In most cases, a nursing African wild dog takes in the pups' ration of the catch to be later regurgitated for the pups (Washington and Hacker, 2005)

The habit of feeding the youngest African wild dogs first and the subordinate African wild dogs last can be seen as a strategy that guarantees food for the packs in the future. A well-fed and properly nourished bunch of baby African wild dogs today will eventually translate into a strong and able pack in the future; and a group of underfed and hungry subordinate African wild dogs provides the motivation for another hunting expedition the next day. When they do go on a hunting expedition, all members of the pack do share the same vision (Ruch et al. 2014). They conscientiously work toward achieving the primary goal of the pack, which is to bring food home for every pack member

4.7.4 Team effectiveness as a result of persistent determination (tenacity)

Tenacity in wild dogs is characterized by determination, patience, persistence, perseverance. African wild dogs are patient, persistent and perseverance in their hunting process, and they are patient enough to persevere and endeavor to overcome all obstacles that come between them and their bounty. When they embark on a hunting expedition, they will relentlessly hunt their prey for hours or days, if necessary (Ruch et al. 2014). Tenacity pays off a great deal in any goal-oriented social entity, group or organization; and its presence in an animal work group can best be observed when a pack attempts hunting down a large prey. Instead of applying massive strength and force, like the lions normally would, or incredible speed, which the cheetahs are distinctively and characteristically known for, African wild dogs would simply apply tenacity so as to systematically and effectively w ear their prey down before charging it for the kill.

4.7.5 Team effectiveness Lessons from swarm behavior (ants, bees and wild dogs)

Corporates are not used to solving decentralized problems in a decentralized way. They typically think of a leader as someone who can influence workers and workers are willing to follow because they believe in the cause or the vision (Trewavas, 2014). But the truth is not like that. With decentralization like in the ants, bees and wild dogs there is no leader and members collectively choose to act in a manner that is best for the whole. Crowds tend to be wise only if individual members act responsibly and make their own decisions. The majority/plurality aggregation in animal group decision-making, removes any dominant tendency in individual responses at the collective level than in authoritarian human set up. The African wild dogs display the presence of Shared Vision in their hunting expeditions by working collectively to achieve a common goal for the pack. Human beings have an added advantage in they adopt it with their unique language faculty; such flexible cognitive capacity allows them to be far better individual learners (and problem solvers) in much broader contexts than any other species on earth (Kokis, Macpherson, Toplak, West, & Stanovich, 2002)) if they can emulate the swarm intelligence system. The majoritarian decision-making can beat other decision mechanisms in a broad parametric range under uncertainty. Kameda et al. (2011) called such superb performances of majoritarian group decision-making “democracy under uncertainty. From the preceding description of self-organizing processes of swarms the following principles are discussed: coordination, cooperation, deliberation and collaboration.

5 Findings and discussion

The research found out that the team effectiveness in ants; bees and wild dogs rely on self-organization that appears to be a major component of a wide range of collective intelligence in these social groupings. Taken together, the combined and consensus decisions of ants, honeybees and wild dogs when foraging for food, hunting or when migrating to a new nest site, have several key elements in common to yield their highly impressive group-level performances. Effectiveness in these social groupings relies on two basic ingredients:

- The first component is a positive feedback (communication) that results from the execution of simple behavioral “rules of thumb” that promote the creation of structures. For instance, trail recruitment to a food source is a kind of positive feedback which creates the conditions for the emergence of a trail network at the global level.
- Secondly team effectiveness requires multiple direct or stigmergic (indirect coordination) interactions among individuals to produce apparently deterministic outcomes and the appearance of large and enduring structures.

6 Conclusion and recommendation

As exemplified in the previous subsections, team effectiveness is equal to mastery of one individual and the organization of collective intelligence in social insects which can be understood as the combination of coordination and cooperation/communication. Each of these functions emerges at the collective level from the unceasing interactions between the swarms. They support the information processing abilities of the colony according to two main axes:

- Coordination and collaboration shape the spatial, temporal and social structures that result from the colony's work. The coordination function regulates the spatio-temporal density of individuals while the collaboration function regulates the allocation of their activities.
- Cooperation and deliberation provide tools for the colony to face the environmental challenges. The deliberation function represents the mechanisms that support the decisions of the colony, while the cooperation function represents the mechanisms that overstep the limitations of the individuals

So E=mc2 (Effectiveness of Teams in organizations where effectiveness is equal to mastery of each individual times coordination times communication (Collective Intelligence) produce solutions to the colony problems and may give the impression that the colony as a whole plans its work to achieve its objectives. Swarms of bees, colonies of ants, packs wild dogs synchronously are all examples of highly coordinated behaviors that emerge from collective, decentralized intelligence. Social insects or animals work without supervision. In fact, their teamwork is largely self-organized, and coordination arises from the different interactions, communication among individuals in the colony. Although these interactions might be primitive (one ant merely following the trail left by another; for instance), taken together they result in efficient team effectiveness solutions to difficult problems (such as ending the shortest route to a food source among myriad possible paths)

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