Dissertation Title: Can studying social insects help medicine?

Contents

Abstract

Social insects are numerous species of insects that live in clusters and manifest in three characteristics, which are division of labor, group integration and overlap of generations. Examples of the social insects are the bees (apidae), wasps (vespidae), ants (formicidae) and termites (Turillazzi, 2012). The social insects are differentiated in function, behavior and structure into castes. The two parameters used to define the social insects are eusocial and pre-social. Eusocial insects share a common living place, have a distribution of the work force, care for the young ones and the offspring work for the community while the parent are still living (Brian 1983, p. 42). The pre-social insects, on the other hand, lack one or more characteristics of the eusocial insects. The eusocial insect is distinct because of its limited occurrence in nature. It also has the most compelling social life. The major caste is the reproductive which is the queen and the other caste is the sterile which comprises of the soldiers and the workers. In addition to reproduction, the queen's other function is to excavate the first galleries and select a site for the new colony. The function of the workers is to care for the larvae and eggs, construct and repair the nest, and collect the colony member's food. The social insect complex social life has made it possible for researchers to carry out experiments on various biological aspects influenced by the social life (Brian 1983, p. 45). According to Hermann (1979), being social is the tendency to form interdependent and cooperative relations with others. Human beings resemble the social insects as they are in constant vigilance against predators, got a wide spread exploration of food and construction of the lining space not forgetting herd immunity. In this paper, we examine how the study of social

insects can be of help in medicine by looking at how the bees can help humans understand their traits. In addition, the paper aims at looking at the identifiable social genes that affect one's character trait, aging in insects and finally, the evolution of altruism through social insects.

How the Bee Helps Us Understand Human Traits

There are several classifications of the various stages of the social insects. Digger bees use similar composite nests without teamwork in brood care; hence, fall under the communal stage of social insects. Euglossine bees use the same nest and also show cooperative brood care, thus is classified under the quasi-social stage of social insects. The halictid bees, which fall under the semi-social stage of insects, use similar nests, demonstrate teamwork in brood care and have the worker caste. The eusocial insects have the characteristics of the semi- social stage of insect and also have an overlap in their generation. The distinction in the duties of these insects helps in explaining the character traits of the varied species of kingdom mammalian (Howse & Clement 1981, p. 32).

The sterile bees are known to transmit their duties to the next generation despite the fact that they are unable to transmit their genes, thus representing a challenge to the natural theory of selection. William Hamilton introduced a new concept, inclusive fitness that could help explain how one can have reproductive fitness without a direct offspring. The inclusive fitness takes account of all the other animals and people who share genes. The inclusion of anyone else's fitness who shares common genes by descent which is factored out by the coefficient of relatedness is the inclusive fitness. This implies that although the workers do not reproduce, their genes would be transmitted to the next generation through sharing the genes of the queen and raising the future queens (Jeanne 1988, p. 75).

The relatedness among the future queens is higher in the honey bees and other hymenoptera than in other animals. This is explained by the haplodipoloidy sex determination where the drone develops from the unfertilized egg and carries one copy of the chromosomes, haploid from their mother only. Haploid drones do not possess the complimentary replica of genes to exchange across the alleles. Therefore, each and every sperm formed by a solitary drone is identical to the other. The females carry two copies of chromosomes and are fertilized, diploid (Michener & Michener 1951, p. 51).

The Social Genes That Can Be Identifiable

Genes do not directly specify behavior, but rather encode molecular products that govern and build the brain's functioning in which conduct is expressed. Behavior, brain activity and development depend on both, the environmental and the inherited influences. Social information can impact brain gene behavior and expression. The complex relationship connects the brain, genes and social behavior. The relationship operate on three time scales, which are the physiological time that impacts the brain activity, developmental time, which impacts the brain development and genome modification slowly, and evolutionary time, which impacts the behavior development through natural selection (Richards 1953, p.82).

A fundamental of social life is communication. Reception, production and interpretation of signals are a common denominator across diverse social behaviors depending on the social context. The biological needs that drive the behaviors are deeply shared despite the fact that behavioral outcomes differ from species to species. The social behavior systems share some common features; among them is that they are acutely sensitive and responsive to the environmental and social information. The information is trans-induced within an individual organism through one or more primary sensory of pathways. The neural signals trans-induced are integrated in specific circuits of the brain through neuromodulatory systems and conserved signal transduction, and the ultimate control of behavioral activity is as a result of internal state of the animal (*Environmental Influences On The Development Of The Female Honeybee Brain Apis Mellifera* 2005, p.46).

Eusocial insects have the most compelling social life. It is unfortunate that the experimental genetics have not been developed for the animal species like the social insects, in order to assist in studying the relationship between genes and social behavior. Looking at the social influence on the brain gene expression, it is clear that the genome was at one time assumed to be a passive blueprint guide to the organism development. On the contrary, the genome remains extremely receptive throughout life to a range of stimuli that are linked with social behavior. Effects on the genome by social information can lead to the change in behavior and brain (Gadau, Fewell & Wilson 2009, p. 94).

Microarrays have been used to measure the brain gene expression pattern in the honey bees at their distinct life stages. In the study, there were expression differences in thousands of genes. As the honey bees age, they change their roles and spend their first 2-3 weeks of their adulthood working in the hive and caring for the brood, maintaining the nest among other activities. They then shift to collecting nectar and pollen grains outside the hive within the 4-6th week of adulthood. The perception of the colonies needs as communicated by the pheromones is what the bee depends on to redirect its energies from working in the hive to foraging (Gotwald, 1995). An example is when the bee colony loses a large number of foraging force, and then the young bees can speed up their maturation to become foragers. The onset age of foraging in bees is; therefore, subject to strong social influence. The bee pheromones' perception changes the expression of the hundreds of bee brain's genes in a period ranging from days to weeks (Larson, & Larson, 1968 p. 48).

The major altered areas are the metabolic proteins and the genes of encoding transcription factors. This observation indicates that the social information has a global effect on the shifts in the nuerogenomic states. An example of the concept of the nuerogenomic states in the brain is the daily sleep-waking cycle which involves changes in the expression of genes in the brain as a behavioral state function (Larson, & Larson, 1968 p. 53).

The epigenetic effects are as a result of the social influence on the brain gene expression. Study indicates that initiating state changes, in addition to social signals, can trigger epigenetic modification of the genome, where the heritable changes in the expression of genes are not because of the changes in the DNA sequence. The epigenetic effects associated with the social behavior are similar in all animals and, thus the study on the effects has been done on few genetic loci. Generally, the young ones that do not receive the attention from their mothers, in this case, the queen determine their response to stress even in their future. The differences in responsiveness of top stress can be passed on from one generation to another. The assumption is that the trait is inherited through traditional genetics. It is discovered that the mothers trigger at least two epigenetic changes in the DNA methylation (Mader 1998, p. 32).

In regard to the genotype –environment interaction and their effect on social behavior and brain function, the difference among individuals is notable. This is because the genes vary from one individual to another. In medicine, a study on the interaction between the genotype and environment are used to explain and understand a wide spectrum of psychiatric disorders.

Depression and autism involve the social behavior gone awry (Mader 1998, p. 42).

A study on fire ants who live in colonies with thousands of workers, just like bees gives a clear evidence of genotype-environment interaction impact on social behavior and gene expression. The fire ants have more than one queen, which is a genetic basis. In fire ants, the general protein is involved in regulating the key aspects like the social organization (Venn 2000, 101).

The homozygous BB queens are more fecund and larger than the Bb queens. The BB workers only accept one BB queen, thus resulting to one queen colony. On the other hand, the Bb workers accept more Bb queens, thus resulting to a more ecologically and larger invasive colonies of multi-queen than one queen colony (*Fitness and the level of homozygosity in a social insect*, 2006). In cross- fostering, the BB workers in the Bb colonies tend to become tolerant to the multiple queen colonies and take on the Bb gene expression profile. The study indicates that the worker gene expression was strongly influenced by the colony genotype than their own genotype. The gene and behavioral variation within the population of the same species helps the medicine faculty to understand how the genetic information influences the function and development of the brain circuits, which mediate the social behavior (Free, 1997). The genome detection and analysis of the genomic variation has become common kin to the genome sequencing of the species. For a better behavioral study, it is good to incorporate direct experimental manipulation of genes and the molecular pathways (Larson & Larson 1968, p.67).

Regulatory polymorphism is implicated in the inter-individual differences, in the foraging behavior. The bees with a higher level of brain for expression are more active during foraging than the in hive bees, which have a lower level brain of expression. The precocious foragers that are socially induced demonstrate an advanced increase in their brain expression. Study signifies that the pharmacological treatment threat activates for pathway causes precocious foraging whose role is widespread in the eusocial insects (Larson & Larson 1968, p.90).

Similarly, the study of the variation of the fork head box p2, foxp2 genes influence have vital social roles in numerous species among them human speech. Important transcription factors are encoded by the foxyp2. The nfoxp2 functions as an element in development of the brain circuits, and thus the systems of the underlying diverse socially embedded behaviors even if they do not encode any social behavior in the mechanistic sense. Even if, the mechanistic role of the gene in the neural expression is subtle and indirect, foxp2 evolves according to their effects on the social behavior (Larson & Larson 1968, p.107).

Aging In Social Insects to Help Us

The lifespan of the queen is one of the striking features of the social insects. The lifespan can reach up to 30 years in some ant species. There is a tremendous variation in the castes lifespan since the queens might live up to 500 times longer than the males. The queens also live 10 times longer than the workers. The polymorphism of this lifespan has allowed the researchers to investigate the proximate of aging and the evolutionary theory of aging (Bittles & Collins, 1986). The researchers use the naturally evolving system of the social insects to address issues of aging and the lifespan determination. According to biologists, aging is a series of physiological and morphological changes which progressively increase the risk of an organism dying from intrinsic causes and, thus reducing its late-life fecundity process (Walter 2009, p. 73).

The aging process is wide spread among the sexually reproducing organism. The evolutionary theory explains that aging is as a result of natural selection having little power on what happens late in the life of an organism. Extrinsic mortality is the key to understanding. The level of extrinsic mortality explains why the species have different aging rates and lifespan. High level of adult mortality is predicted to select for an increased investment in early reproduction (Wilson, 2012). This results to diverting resources away from the late survival and allows late-acting deleterious mutations to accumulate. As a result, there is the faster rate of aging and a shorter reproductive lifespan. A study on social insects has been used to pin down individual genes, and pathways that are likely to cause the aging or regulate the loss of function of the aging process (Walter 2009, p. 74).

The ant, bee, wasp colonies consist of several phenotypically distinct female castes which arise through differential gene expression from a single genotype. Since the castes differ in the task specialization, reproduction, body size, and the level of extrinsic mortality, this offers the researchers an opportunity to test the direct effect of the extrinsic mortality on the evolution of aging as they control the confounding factors.

The gene expression studies between the genetically identical social insects with the different lifespans might help identify new candidate genes that are involved in lifespan determination and aging (Venn 2000, p. 55).

Furthermore, a comparative study has indicated that evolution of the special life in insects was associated with a 100-fold increase in the adult lifespan. In the weaver ant, the large workers belonging to other significant castes perform all the risky tasks outside the nest among them, terrestrial defense foraging, nest guarding and repairs. On the other hand, the small workers care for the brood. The great difference in the extrinsic mortality risks is brought about by the pronounced division of labor. The evolutionary theory of aging predicts that, minor workers exhibit a longer intrinsic lifespan as compared to the major workers (Venn 2000, p. 67).

The ant colony members are genetic clones that are derived from unfertilized eggs. Although the reproductive and non-reproductive ants are morphologically the same and have the same body sizes, the difference in extrinsic mortality results, in the difference, in their life spans. The reproductive life is three to ten times longer than the non-reproductive. This implies that the pattern of aging is molded by extrinsic mortality rates and not the difference in the reproductive systems, genotypes and body size. According to several comparative analyses, the shorter intrinsic lifespan is associated with the extrinsic mortality risks (Venn 2000, p. 72).

Species with a slow rate of aging and nearly centenarian lifespan have evolved independently and repeatedly in both the reptiles and mammals. The molecular pathways and processes are involved in the lifespan determination and aging of organisms (Gullan & Cranston, 1994). One of them is the insulin or the insulin growth factor signaling pathway. The second one is the oxidative damage to DNA like the physical damage or loss of the methylation. The third is accumulation of the dysfunctional mitochondria, then the loss of irreplaceable cells, and changes to the protein structure. The radical hypothesis of aging states that the organisms senesce because their macromolecules and the cells are damaged by the reactive oxygen species. It is evidenced that oxidative damage indeed contributes to aging. The higher the reactive oxidation rate, the lower the lifespan across the mammalian species (Walter 2009, 69).

In honey bees, the proximate cause of the lifespan differences between worker bees is the specialization in the different tasks. The honey bee workers can be divided into two behavioral groups with different aging trajectories. One of the groups consists of young bees who work inside the hive, and the other group consists of the older bees that that specialize in foraging for honey and pollen (Breed 1982; 1989). After switching to foraging, the foragers age and die faster within two weeks. The in hive bees are protected from switching to foraging, thus can live 8 times longer than the foragers. The proximate mechanism for the difference in the life span is attributed to juvenile hormone and the vitellogenin- mediated shutdown of the forager immune system. Switching to foraging is associated to an increase in the juvenile hormone, which in turn results, in the cessation vitellogenin synthesis. A study on the candidate gene SODI is found to play a role in the longevity of the queen's life (Weiss, & Vergara 2002, p. 65).

Altruism Evolution through Social Insects

Kin selection is a theory that proposes that an animal might pass on its gene by helping the relatives to reproduce since they share common genes rather than reproducing by itself. Charles Darwin explained using an example of the sterile workers, who evolve in social insect groups and how the honeybee can sacrifice its life for the sake of protecting the colony. This behavior can evolve since it still drives to pass on genes, but through the relatives. The relatedness within the social insects is increased when the ancestral females were found to be monogamous and decreased when the female was found in polygamous colonies. It is evident that kin selection is fundamental in the evolution of social insects (Paul, Miller& Paul 1993, p.76).

In conclusion, the biological needs that drive the behaviors are deeply shared despite the behavioral outcome which differs from species to species. The sterile bees are known to transmit their duties to the next generation despite their inability to transmit their genes. This has been explained by the inclusive fitness theory. The relatedness among the future queens and the other hymenoptera tend to be higher than any other animal. Genes encode molecular products which govern and build the brain functioning, thus resulting in behavior expression. The microarrays have been used to measure the brain gene expression pattern in the honey bees at their distinct life stage. In medicine, the relationship that exists between an individual's genotype and factors of the environment are used to study and understand the psychiatric disorders in people. The high extrinsic mortality tends to reduce the lifespan of an organism

(Kanal, 1956). The proximate cause of lifespan difference in the honey bees is attributed to the specialization of the bee’s tasks. According to altruism, the kin selection is where the animal might pass on its gene by helping the relatives to reproduce (Scott & Seglow, 2007). The complexity and variability in the social life of the social insects has made it possible for researchers to conduct studies and experiments on various aspects of life such as transmitting behavior, aging and altruism.

Bibliography

Bittles, A. H., & Collins, K. J., 1986. *The Biology of human ageing*. Cambridge: Cambridge University Press.

Blum, L. A., 1980. *Friendship, Altruism, and Morality*. London: Routledge & Kegan Paul.

Breed, M. D., 1982. *The biology of social insects*. Boulder, Colo: Westview Press.

Breed, M. D., 1989. *The Genetics of social evolution*. Boulder: Westview Press.

Brian, M. V., 1983. *Social Insects: Ecology and Behavioural Biology*. London: Chapman and Hall.

Environmental influences on the development of the female honeybee brain Apis mellifera., 2005. Stanford, Calif.: Universität Würzburg.

Fitness and the level of homozygosity in a social insect. (2006). Eugene, Or.: Routledge.

Free, J. B., 1977. *The social organization of honeybees*. London: E. Arnold.

Gadau, J., Fewell, J., & Wilson, E. O., 2009. *Organization of insect societies: from genome to sociocomplexity*. Cambridge, Mass.: Harvard University Press.

Gotwald, W. H., 1995. *Army ants: the biology of social predation*. Ithaca: Comstock Pub. Associates.

Gullan, P. J., & Cranston, P. S., 1994. *The insects: an outline of entomology*. London: Chapman & Hall.

Hermann, H. R., 1979. *Social Insects*. New York: Academic Press.
Howse, P. E., & Clement, J., 1981. *Biosystematics of Social Insects*. London: Published for the Systematics Association by Academic Press.
Jeanne, R. L., 1988. *Interindividual Behavioral Variability in Social Insects*. Boulder: Westview Press.
Kanal, P. V. 1956. *Altruism*. Moga: Dev Samaj Book Depot.
Larson, P. P., & Larson, M. W., 1968. *Lives of social insects*. New York: World Pub. Co..
Mader, S. S., 1998. *Biology* (6th ed.). Boston: WCB/McGraw-Hill.
Michener, C. D., & Michener, M. H., 1951. *American Social Insects; A Book About Bees, Ants, Wasps, And Termites,*. New York: Van Nostrand.
Paul, E. F., Miller, F. D., & Paul, J., 1993. *Altruism*. Cambridge [England: Cambridge University Press.
Richards, O. W., 1953. *The Social Insects*. London: Macdonald;.
Scott, N., & Seglow, J., 2007. *Altruism*. Maidenhead, England: Open University Press.
Turillazzi, S., 2012. *The Biology of Hover Wasps*. Berlin: Springer.
Venn, C., 2000. *Ants and Other Social Insects*. Chicago: World Book.
Walter, B. J., 2009. *Aging and Social Homeostasis in Social Insects*. Minneapolis, Minn.: Greenhaven Press.
Weiss, K., & Vergara, C. H., 2002. *The Little Book of Bees*. New York: Copernicus Books.

Wilson, E. O., 2012. *The Social Conquest of Earth*. New York: Liveright Pub. Corp..