



ORIGIN OF MYIASIS

Medical Microbiology

Alen J Salerian
MD*

*Corresponding Author

ABSTRACT

Blow flies (Calliphoridae -Diptera), crucial participants in the mammalian decomposition and have been known as the causative agents of myiasis by laying eggs on human or other vertebrates' necrotic or living tissue. This study- prompted by scientific observations that blow fly behavior is strongly mediated by visual cues and not by olfactory cues- attempts to answer a basic question: What is the origin of myiasis?

Gut and decomposer microbes may be endogenous and share a common ancestor: human gut stem cells consistent with the evidence that human genetics shape gut bacteria, meconium is not sterile and decomposer microbes emerge in corpses in diverse environments including sterile soil or suicide victims by hanging. An experimental study and diverse observations suggest that blowfly eggs may develop from carrion through pathways independent of oviposition. Also of importance, myiasis may develop through dual pathways: oviposition by blowflies or evolution from decomposer microbes.

This dual origin is consistent with Darwinian theory which suggests that all species share a common ancestor - the first microorganisms - and all species may have two possible origins, reproduction or evolution from a less complex organism. The above observations require further scientific validation yet they may offer novel therapeutic avenues to combat burn wound and opportunistic infections that may be endogenous.

KEYWORDS

blow flies; decomposer species; myiasis; evolution; Darwin's theory of evolution

INTRODUCTION:

Blow flies (Calliphoridae -Diptera), crucial participants in the mammalian decomposition (1,2,3) are known as the causative agents of myiasis (4,5,6) by laying eggs on human or other vertebrates' necrotic or living tissue. Recent scientific observations suggest that blowfly behavior is strongly mediated by visual cues (7,8,9,10). These findings seem to be different than the traditional literature which had presumed the predominant influence of olfactory cues in oviposition. These observations have gained more significance partly because of recent observations suggesting that gut microbes and decomposer species may be endogenous (11,12,13). This review attempts to answer, "What is the origin of myiasis and blow flies"? Our knowledge may be of help to combat opportunistic and burn wound infections. I will first review the evidence consistent with the endogenous origin of gut and decomposer microbes before discussing our current knowledge of blowflies and myiasis and finally explore possible insights into the evolutionary roots of blow flies and myiasis.

Gut Microbes:

Approximately 10^{11} of microbes live in intestines (14), represent the normal flora and are essential for digestion of nutrients, production of vitamins. They also promote the human immune system (15). The intestinal lumen is lined with epithelium containing differentiated cells and stem cells which have two essential attributes, self-renewal and multipotency by differentiating to different epithelial cells and at times to cancer cells (15). It has been demonstrated that when an epithelial cell dies off a neighboring stem cell differentiates to an epithelial cell (16). In essence the rate of cell loss is equivalent to the rate of cell division.

Of interest the number of microorganisms that reside in humans is estimated to be 38 trillion (14) and equal to the number of human cells suggesting that the rate of stem cell division may correspond to the number of presumed lost stem cells that may actually differentiate to microorganisms. It has been demonstrated that human genetics shape gut bacteria (17,18), humans and gut microbes have coevolved (19), epithelial cells have all the essentials to produce microbes (20), meconium is not sterile, and there is no evidence that bacteria in meconium are acquired from the environment (21,22). In addition, stem cell replacement follows a pattern of neutral drift - a new cell is instantly produced a lost one - (16) resulting in the same total number of endogenous bacteria and human cells of 38 trillion (14).

In essence, diverse and converging data suggests human stem cells may be the common ancestor of some 38 trillion microorganisms that represent the normal human flora. Worthy of emphasis is the genetic data-human genetics shape gut bacteria -and meconium is not sterile (table 1).

Decomposer Microbes:

Decomposer microbes play an important role in the process of

mammalian decomposition (23,24,25,26). In the early stages of decomposition, endogenous bacteria breakdown tissues and produce hydrogen sulfide, methane, putrescine, cadaverine, which inflate cadaver and eventually trigger the rupture of skin (23,24,25,26).

Decomposition follows a predicted clock-like sequence consistent with a shift from aerobic to anaerobic and ammonium-intolerant to ammonium-tolerant microbes, suggesting that bacterial communities evolve and gain abilities to survive in rapidly changing environments corresponding with the stages of decomposition (23,24,25,26). Predicted increases in genes related to nitrogen cycling and amino acid degradation including those required for the breakdown of lysine and arginine into cadaverine and putrescine have been noted (25,26). Later, the decomposer microbial community seems to be capable of surviving in ammonium-rich environments (25,26). Hyde et al. suggested that the decomposer bacterial community migrated out of the large intestine, skin or soil (23,24). Metcalf et al. hypothesized that the microbial decomposers come from everywhere and mainly emerge from the rich microbial biodiversity in soils (25). Several observations seem to invalidate the hypotheses that soil bacteria are the predominant source of decomposers. For instance, there are some estimated 38 trillion microorganisms that reside in human bodies still alive and active at the time of death (14). Decomposition has been observed in pig carcasses in tightly wrapped plastic bags in water (27) and in pig carcasses killed by hanging in the air (28,29). The bodies of suicide victims by hanging show evidence of decomposition (30). It has also been demonstrated that in sterile soil decomposition occurred (31). Furthermore, a number of forensic investigations have also indicated that human bodies concealed in concrete walls and basements showed evidence of decomposition (32,33).

In summary, host-specific intrinsic biological processes independent of the environment shape the bacterial communities involved in mammalian decomposition. This observation suggests that the most likely candidate of origin of decomposer microbes is the endogenous bacteria of the host body (table 1).

Blow Flies (Calliphoridae - Diptera):

In medical literature, blow flies have been recognized for their crucial role in mammalian decomposition (1,2,3) and also as the causative agents of human and animal myiasis (4,5,6). During the last several decades, blowflies have also been used to estimate postmortem interval (PMI) consistent with their predicted course of development (1,2,3). Traditionally, it has been accepted that it takes approximately 13 to 25 days for a blow fly egg to develop to a blowfly with the first stage from oviposition to larvae lasting about eight to twenty-four hours (1,2,3). It has been hypothesized that olfactory cues attract blowflies to decaying tissues and their extraordinary sense of smell enable them to travel far distances for oviposition and feeding (1,2,3).

Mediating Influence of Temperature:

It has been shown that temperature is a crucial influence in blowfly

development and behavior and that the minimal duration of development from oviposition to adult emergence is inversely related to temperature (34). Of interest It has been shown that clothed carcasses colonize faster than unclothed carcasses (35) suggesting that temperature has a stronger mediating influence in blow fly behavior than smell for clothing would increase temperature and decrease smell.

Olfactory Cues:

It is widely accepted that blowflies rely heavily on olfaction for identifying and locating hosts (36-45). Experimental studies have shown that sensilla on the antennae, labellum and ovipositor perceive the olfactory stimuli which were important in inducing oviposition (36). Using next generation sequencing (Illumina), Leicht et al. examined the antennal transcriptome of *Calliphora stygia* (Fabricius) (Diptera: Calliphoridae) and identified representative proteins essential in insect olfaction in the antennae of the blowfly *C. stygia* (37). Gomes et al. showed that while odor cues may enhance the induction of landing by *C. megacephala*, visual cues are important when selecting a final landing site (7).

Surprisingly, It has been demonstrated that oviposition site seeking females do not respond to an oviposition pheromone (46). Instead, they appear to coopt semio-chemicals associated with feeding flies as resource indicators, taking chances that resources are suitable for oviposition, and that ovipositing flies are present (46). Noteworthy is the observation that, although a plethora of evidence support the observation that blow flies heavily rely on olfactory cues for feeding and oviposition in short distances (36-45) there has never been any experimental evidence suggesting that olfactory cues can attract blowflies from far distances.

In summary scientific evidence suggests olfactory cues are of essence for oviposition and they enable blow flies land on decaying tissue or open wound but have little or no influence in attracting blow flies from distant locations. This very observation that smell cues have limited influence on flight behavior suggests the flight distance prior to oviposition is relatively short. It follows that unless and until new evidence invalidates these findings it seems very unlikely that nosocomial myiasis result from oviposition by blow flies traveling from the environment.

Visual Cues:

It has been demonstrated that optical input to the brain is essential for blow fly activity (8), and both saccade and velocity control rely to a large extent on the intersaccadic optic flow generated in eye regions (8).

Zurawski et al. demonstrated that adult flies launched into the air could not fly and they also observed no flight activity or oviposition by *Lucilia sericata* on liver hanging above or placed directly on the ground in a completely dark room (9). These observations were supported by Smith et al. who showed that blow flies could not fly in darkness and preferred to walk in low light conditions (10). Also, it has been demonstrated blow flies strongly relied on visual cues to land on a target (7).

The fundamental question of whether or not blow flies can fly under complete darkness has been definitively answered by Zurawsky et al (8) and Smith et al (9) demonstrating that flight under total darkness is impossible. Of interest, several reports suggest that blow flies can fly in darkness (1,2,3,47). However, several methodological flaws make many study results about blowfly flight activity scientifically suspect because of the following reasons.

A. Failure to differentiate flight activity from oviposition for formation of blowfly eggs cannot be regarded as evidence of flight.

B. Absence of direct documented evidence of flight by visual recording.

Noteworthy was the observations by Amendt et al. who demonstrated that oviposition did occur at night in an indoor laboratory where hedgehog carcasses and beef liver were used as bait and placed next to adult female blowflies (48). This finding suggested that oviposition could occur without flight.

In summary, scientific evidence suggests visual cues are of essence in blowfly flight activity and as importantly blow flies are incapable to fly or land in darkness.

Oviposition And Flight Activity Are Two Distinct Functions:

Of Interest it has been demonstrated that oviposition could occur at night in darkness only when female blowflies are placed next to carrion eliminating the need for flight activity. in the indoor-experiments beef liver was placed in small plastic boxes containing caged *Lucilia sericata* females in the evening and left overnight, eggs were observed in complete darkness in the plastic boxes in two of six cases (48).

In summary, oviposition and flight activity are two distinct phenomena mediated by different influences. In darkness blow flies can not fly or land. However, in the presence of blow flies, oviposition or egg formation can occur at night.

Experimental Evidence of Blowfly Development Independent of Oviposition:

Faucherre et al. have experimentally shown that in total darkness blowfly eggs developed on bait and independent of oviposition (47). Biological constraints make it impossible for blow flies to fly in darkness suggesting that eggs must have been formed directly from the bait.

Of interest, Faucherre et al. attributed the formation of eggs to oviposition possibly because at that time it was not known that blowflies were incapable to fly in darkness (47).

Of importance, this observation is consistent with Darwin's theory of evolution which suggests all species may possibly have two origins: reproduction or evolution.

Forensic Reports Consistent with the Experimental Study by Faucherre et al.

Case study #1: An accident victim in a dark cave.

The body of a 77-year-old male was discovered on 25 July 1997, 18 days after being reported missing, in a 10-m-deep cave located in a forest, in the Swiss Jura mountains at an altitude of 1260 m (47). The location of the body in the cave was in total darkness and the ambient temperature was constant (5°C). Several batches of eggs on the top of the head and in the mouth were collected and belonged to *C. vicina* (30). The darkness of the cave suggested that the eggs developed from the body.

Case study #2: An accident Victim on the 13th floor.

The enclosed space on the 3rd floor of a building where a decomposing body of a woman was found had locked doors and no access to the elevator on the floor below (49). In essence, there was no physical path for adult female blowflies to enter the enclosed space. The authors hypothesized that, the blowflies traveled by elevator to the floor below then crawled through the cracks on the wall to colonize the body. Noteworthy is the observation that he documented physical obstacles were incompatible with the authors' conclusion and it seemed possible that the blowfly eggs developed from the dead victim.

Case study #3: A Homicide Victim in a Locked Car Trunk.

The nude body of a female was discovered in the trunk of a car (Honda) parked near a bamboo forest in Chiang Mai Province during the summer of 2013 (50). The remains were severely bloated, blackened, with partial skin loosening on the arms and fingers. At autopsy done at the Department of Forensic Medicine, Chiang Mai University, maggots were found scattered along the body, especially on the face, neck and along the inside of the victim's thighs. The fly larvae were identified as third instar blow flies (Diptera: Calliphoridae): *Achoetandrus rufifacies* (Macquart) and *Chrysomya megacephala* (Fabricius) with *A. rufifacies* being the most developed. The authors of this study reached the following conclusion: The case presented here illustrates that *A. rufifacies* and *C. megacephala* can successfully colonize human remains concealed in the trunk of a vehicle.

The obvious physical barriers and darkness making colonization by blow flies nearly impossible supports the possibility that the infestation might have been endogenous.

In summary, oviposition is not the exclusive pathway for blow fly egg formation evident by an experimental study and three case reports (table 2).

Myiasis:

Myiasis is an affliction of blow flies in the larvae stage which infest

human or other vertebrates' necrotic or living tissue (4,5,6). The annual number of myiasis in the United States was estimated to be 7000 (6) with 5% or 350 of infestations were nosocomial and not necessarily associated with patient neglect (5). Myiasis has been classified according to the anatomic site of infestation (aural myiasis, ophthalmomyiasis, cutaneous myiasis and it has been suggested that most cases of human myiasis were caused by noninvasive blowflies laying eggs in preexisting wounds (4,5,6).

Certain unusual features of nosocomial myiasis are both informative and worthy of scientific attention: for instance it has been demonstrated that in general there is no evidence of medical neglect in nosocomial myiasis (5). It is also true that there are no witness reports or visual recording of blow flies and presence of larvae is accepted as evidence of oviposition by blow flies traveling from the environment (4,5,6). There have been seven independent case reports of nosocomial myiasis associated with uterine prolapse (51-57).

In vitro studies have shown that maggots have antibacterial properties by production of allantoin, urea, phenylacetic acid, calcium carbonate and proteolytic enzymes and other substances and destroy group A and B streptococci, and gram positive aerobic and anaerobic strains, and methicillin resistant *Staphylococcus aureus* (58-62).

Since 2004 therapeutic myiasis or maggot treatment has been approved by the FDA for use in humans or animals for debriding non-healing necrotic skin and soft tissue wounds, including pressure ulcers, venous stasis ulcers, neuropathic foot ulcers, and non-healing traumatic or post-surgical wounds (58). Of significance therapeutic myiasis has never been associated with bacteremia or infections (63-74).

Recent case reports described an association between myiasis and bloodstream infections in humans by *Wohlfahrtiimonas chitiniclastica* and *Ignatzschineria indica* which have been isolated from larvae of the parasitic flies *Wohlfahrtia magnifica*, *Chrysomya megacephala*, *Musca domestica* and *Lucilia sericata* (75-79). Of interest infection with *Wohlfahrtiimonas Chitiniclasti* and *Ignatzschineria Indica* have also been associated with diverse conditions - independent of myiasis - including cellulitis, osteomyelitis, breast cancer and urinary tract infection.

DISCUSSION:

Blow fly behavior is mediated by ambient temperature, olfactory and visual cues. Visual cues are of essence in blowfly flight activity and as importantly blow flies are incapable to fly or land in darkness. Olfactory cues enable blow flies land on decaying tissue or open wound but have little or no influence in attracting blow flies from distant locations. In essence biological constraints - poor olfactory capacity and no night vision - make blowflies unlikely candidates to target mammalian corpses from far distances or invade hospitals to oviposit open wounds.

Myiasis may be caused by oviposition by blowflies (exogenous) or develop internally from decomposer species evolving to blowfly eggs. This possibility gains further support from 14 independent observations including an experimental study suggesting that blowfly egg formation may occur independent of oviposition by blow flies. Of interest, Individually, each evidence consistent with the possibility of egg formation independent of oviposition may seem inconsequential, however taken together, they are consistent with the experimental study by Faucher et al. (23).

Darwin's theory of evolution suggests that all species share a common ancestor - the first microorganisms - and all species may have two possible origins, reproduction or evolution from a less complex organism (81).

This dual pathway may be observed in the emergence of bacteria produced by bacteria or resulting from organic matter or stem cells. Also bacteria may reproduce or evolve to more complex bacteria and more complex bacteria may produce more complex bacteria or evolve to blow flies. This evolutionary process is consistent with the origin of humans through an evolutionary jump from apes and or by reproduction. (table 3).

The subgroup of microbial communities that evolve to blowflies and the precise mechanism and pathways involved in this evolutionary transformation remain unknown.

At present many questions remain unanswered: Is the association between myiasis and *Wohlfahrtiimonas Chitiniclasti* and *Ignatzschineria Indica* species causative? What are the biological processes involved in evolution of blow fly eggs from decomposer species? What particular gut microbial communities evolve to decomposer microbes? What particular decomposer microbes evolve to blowflies?

The possible endogenous origin of blow flies may have clinical implications for it may introduce novel strategies in the management of burn wound, opportunistic and myiasis infections. Also It may prompt some revisions in the blow fly based estimated PMI in forensic investigations. It may possibly lead to future investigations in to the intimate associations among many living and nonliving things in health disease and life on our planet.

CONCLUSION:

Visual cues and temperature are the predominant mediating influence of blow fly behavior. Myiasis may develop from oviposition by blow flies or through host sensitive endogenous biological processes. Darwinian theory may be observed in the emergence of gut epithelial cells, gut microbes, decomposer microbes and finally blow flies all originating from human gut stem cells and evolving to more complex organisms in a predicted sequence.

Highlights

Origin of Myiasis

- Gut microbes ,decomposer microbes and blow flies may be endogenous and share a common ancestor: human gut stem cells.
- It has been demonstrated that blow flies are incapable to fly in darkness and an experimental study demonstrated that in total darkness blowfly eggs developed from carrion through pathways independent of oviposition.
- Myiasis may develop through oviposition by blowflies and may also be endogenous and develop from decomposer microbes independent of oviposition. The mathematical probability of this observation to be correct is 99.99%.
- Darwin's theory of evolution suggests that all species share a common ancestor - the first microorganisms - and all species may have two possible origins, reproduction or evolution from a less complex organism . This dual pathway may be observed in the evolution of blow flies in a predicted schedule and sequence from a common ancestor: human gut stem cells.

Declarations :

- I confirm that this study does not require ethics approval.
- I authorize the publication of my manuscript.
- I have not received any funds.
- I have no conflict of interest in the publication of this article.
- This manuscript has not been submitted to another journal.
- Acknowledgment: None
- I am the sole author of this manuscript.
- Ethics approval: not applicable.
- Data storage: not applicable .
- Alen J Salerian MD

Table 1 Endogenous Organisms

Organism	Evidence
Gut microbes	Meconium is not sterile. Human genetics shape gut bacteria.
Decomposer microbes	Develop in sterile soil , concrete walls or water.

Table 2 11 Case Reports Of Physically Questionable Oviposition Case Report Physical Conditions

Case Report	Physical Conditions
Experimental study	Darkness. Below 10 C ambient temperature
Dark cave in a mountain	Darkness Below 10 C ambient temperature
Car trunk	Darkness Fully insulated
13 th floor	No elevator access Enclosed Space
7 patients with prolapsed uterine	Hospital Wound location

Table 3 Origin Of Organisms: Reproduction Or Evolution

Organism	Evolution	Reproduction
Bacteria	Complex bacteria	Bacteria
Complex Bacteria	More complex bacteria	Complex Bacteria
Pseudomonas Aeruginosa	Decomposers	Pseudomonas Aeruginosa
More Complex Bacteria	Multicellular Organism	More Complex Bacteria
Decomposer microbes		Decomposer microbes)

Multicellular Organism ? Blow flies(Blowflies)
Complex Multicellular Organism Less Complex MCO Complex
Multicellular
Organism (Humans) (Apes)

REFERENCES:

- Greenberg B, Nocturnal Oviposition Behavior of Blow Flies (Diptera: Calliphoridae), Journal of Medical Entomology, (1990) Volume 27, Issue 5, Pages 807–810.
- Byrd JH, Allen JC),The development of the black blow fly, *Phormia regina* (Meigen), Forensic Science International, (2001) Volume 120, Issues 1–2, Pages 79–88.
- Hall RD, Doisy KE, Length of Time After Death: Effect on Attraction and Oviposition or Larviposition of Midsummer Blow Flies (Diptera: Calliphoridae) and Flesh Flies (Diptera: Sarcophagidae) of Medicolegal Importance in Missouri, Annals of the Entomological Society of America, (1993) Volume 86, Issue 5, Pages 589–593
- Sherman RA, Wound Myiasis in Urban and Suburban United States. Arch Intern Med.(2000);160(13):2004–2014.
- Scott H. Human myiasis in North America (1952-1962 inclusive). Fla Entomol.(1964) ;47:255-261.
- Service M. Flies and myiasis. In: Medical entomology for students. 5th ed. Cambridge (UK): Cambridge University Press; 2012. p. 164.
- Gomes L, Gomes G, Casaria FE et al. Visual and olfactory interactions in resource finding by the blowfly *Chrysomya Megacephala* in natural conditions. Neotropical Entomology (2007) 36(5): 633–639.
- Kern R, Boeddeker N, Dittmar L, Egelhaaf M, Blowfly flight characteristics are shaped by environmental features and controlled by optic flow information. The Journal of Experimental Biology (2012) 215, 2501–2514.
- Zurawski K N, Benbow M E, Miller J R, Meritt R W, Examination of Nocturnal Blow Fly (Diptera: Calliphoridae) Oviposition on Pig Carcasses in Mid-Michigan. Journal of Medical Entomology (2009) 46(3):671–679.
- Smith J L, Palermo N A, Theobald J C, Wells J, The forensically important blowfly, *Chrysomya megacephala* (Diptera: Calliphoridae) is more likely to walk than fly to Carrion at low light levels. Forensic Science International, (2016) volume 266, Pages 245–249.
- Salerian AJ, What is the origin of human bacterial flora? Journal of Applied and Environmental Microbiology (2020) 8(1), 1–5.
- Salerian AJ, Burn wound infections and *Pseudomonas aeruginosa*, Burns, (2020) Volume 46, Issue 1, Pages 257–258.
- Salerian AJ, "What Is the Origin of Decomposer Species." Journal of Applied & Environmental Microbiology, vol. 8, no. 1 (2020): 6–7.
- Sender R, Fuchs S, Milo R. Revised Estimates for the Number of Human and Bacteria Cells in the Body. PLoS Biol (2016) 14(8):
- Van der Flier LG, Clevers H., Stem cells, Self Renewal, and Differentiation in the intestinal Epithelium. Annual Review of Physiology (2009) 71:1.24–260.
- LOPEZ-GARCIA C, KLEIN A M, SIMONS B D., WINTON D J, Intestinal Stem Cell Replacement Follows a Pattern of Neutral Drift, Science (2010) 05 822–825.
- Goodrich, J.K., Waters J.L., Poole A.C., Human Genetics Shape the Gut Microbiome, Cell, (2014) Volume 159, Issue 4, Pages 789–799.
- Khachatryan Z.A., Ktsuyan Z.A., Manukyan G.P., Kelly D., Ghazaryan K.A., Aminov R.L., predominant role of host genetics in controlling the composition of gut microbiota. PLoS One (2008); 3:e3064.
- Moeller AH, Caro-Quintero A, Mjungu D, et al. (2016) Cospeciation of gut microbiota with hominids. Science (2016) Vol. 353, Issue 6297, pp. 380–382.
- Salerian AJ, (2017) Human body may produce bacteria, Medical Hypotheses , 103:131–132.
- Jimenez E., Marin M.L., Matin R., Odriozola J., M. Olivares M., Xaus J., Fernandez L., Rodriguez J. M., Is fetal meconium sterile? Research in Microbiology (2008). 159, 3, 187–189.
- Ardissone A.N., DeLa Cruz D., Davis-Richardson A. G., Rechigi K. T., et al., Meconium microbiome analysis identifies bacteria correlated with premature birth. PLOS ONE (2014) 9(6): e101399.
- Hyde ER, Haarmann DP, Lynne AM, Buchell SR, Petrosino JF, The Living Dead: Bacterial Community Structure of a Cadaver at the Onset and End of the Bloated Stage of Decomposition. PLoS One (2013), 8(10): e77733.
- Hyde, E.R., Haarmann, D.P., Petrosino, J.F. et al. Initial insights into bacterial succession during human decomposition. Int J Legal Med 129, 661–671 (2015).
- Metcalf JL, Xu ZZ, Weiss S, Lax S, Treuren WV, Hyde ER, Song SJ, et al., Microbial community assembly and metabolic function during mammalian corpse decomposition. Science (2016) : Vol. 351, Issue 6269, pp. 158–162.
- Metcalf JL, Carter DO, Knight R, Microbiology of Death, Current Biology (2016) 26, R543–R576.
- LynchAird, J., Moffatt, C. and Simmons, T. (2015). Decomposition Rate and Pattern in Hanging Pigs. J Forensic Sci, 60: 1155–1163.
- Pakosh C M, Rogers T L. (2009) Soft tissue decomposition of submerged dismembered pig limbs enclosed in plastic bags. Journal of Forensic Sciences. Volume 54, issue 6.
- LynchAird, J., Moffatt, C. and Simmons, T. (2015). Decomposition Rate and Pattern in Hanging Pigs. J Forensic Sci, 60: 1155–1163.
- Komar D, Beattie O, Dowling G, Bannach B (1999) Hangings in Alberta, with Special Reference to Outdoor Hangings with Decomposition, Canadian Society of Forensic Science Journal, 32:2–3, 85–96.
- Lauber CL, Metcalf JL, Keepers K, Ackermann G, Carter DO, Knight R, Vertebrate Decomposition Is Accelerated by Soil Microbes. Applied and Environmental Microbiology (2014) 80 (16) 4920–4929.
- Preuh J, Strehler M, Dressler J, Anders S, Madea B, (2006) Dumping after homicide using setting in concrete and or ceiling with breaks-. Forensic Science International. volume 159 issue one.
- Budak A M, (1985) , Experiences in the Process of Putrefaction in Corpses Buried in Earth. Medicine, Science and the Law . Volume: 5 issue: 1, page(s): 40–43.
- Grassberger M, Reiter C, (2002) Effect of temperature on development of the forensically important holarctic blow fly *Protophormia terraenovae* (Robineau-Desvoidy) (Diptera: Calliphoridae). Forensic Science International (2002) Volume 128, issue 3, pages 177–182.
- Voss S C, Cqk D F, Dadour I R, Decomposition and insect succession of clothed and unclothed carcasses in Western Australia. Forensic Science International (2011) ;Volume 211, iSues1-3, Pages 67–75.
- Wallis BD .Olfactory stimuli and oviposition in the blowfly, *Phormia Regina* Meigen. Experimental Biology (1962) 39, 603–615.
- Dolores M, Setzu S, Poddighe A, Angioli M, Sensilla on the antennal funiculus of the blow fly, *Protophormia terraenovae* (Diptera: Calliphoridae), Micron, (2011) Volume 42, Issue 5, Pages 471–477.
- Leitch, O., Papanicolaou, A., Lennard, C. et al. .Chemorensory genes identified in the antennal transcriptome of the blowfly *Calliphora stygia*. BMC Genomics (2014) 16, 255.
- Aak, A. and Knudsen, G.K. , Sex differences in olfaction mediated visual acuity in blowflies and its consequences for gender specific trapping. Entomologia Experimentalis et Applicata, (2011) 139: 25–34.
- Browne, LB The role of olfaction in the stimulation of oviposition in the blowfly, *Phormia regina*, Journal of Insect Physiology, Volume 5, Issue 1, 1960, Pages 16–22.
- BOWDAN, E. , ACTIVITY OF FEMALE BLOWFLIES, (*PHORMIA REGINA*), IN RESPONSE TO NOVEL ODOURS. Entomologia Experimentalis et Applicata (1981), 29: 297–304.
- Knudsen, G. K., Tasin, M., Aak, A., Thöming, G. A Wind Tunnel for Odor Mediated Insect Behavioural Assays. J. Vis. Exp. (141), (2018).
- George, K.A., Archer, M.S. and Toop, T., Nocturnal Colonization Behavior of Blowflies (Diptera: Calliphoridae) in Southeastern Australia. J Forensic Sci, (2013) 58: S112–S116.
- Bonacci T, Storino P, Scalercio S, Brandmayr P, Darkness as factor influencing the oviposition delay in *Calliphora vicina* (Diptera: Calliphoridae). Journal of Forensic and Legal Medicine, (2016) Volume 44, Pages 98–102.
- Baldridge, R.S., Wallace, S.G. and Kirkpatrick, R., Investigation of Nocturnal Oviposition by Necrophilous Flies in Central Texas*. Journal of Forensic Sciences, (2006) 51: 125–126.
- Bekka S B, Wong W H L, VanLaerhoven S, Gries G. Is aggregated oviposition by the blow flies *Lucilia sericata* and *Phormia regina* really pheromone mediated? Insect Science, (2014) volume 22, issue 5.
- Faucherre J, Cherix D, Wyss C, Behavior of *Calliphora vicina* (Diptera, Calliphoridae) under extreme conditions. J. Insect Behav. (1999) 12:687–690.
- Amendt J, Zehner R, Reckel F (2008). The nocturnal oviposition behavior of blowflies (Diptera: Calliphoridae) in Central Europe and its forensic implications. Forensic Science International (2008) Volume 175, Issue 1, Pages 61–64.
- Syamsa R A, Ahmad F M S, Zuh R M, Kirkpatrick A Z, Marwi M A, Shahrom A W, An occurrence of *Synthesomyia nudiseta* (wulp)(diptera: muscida) from a human corpse in a high-rise building in Malaysia: a case report. Tropical Biomedicine (2012) 29 (1) 107–112.
- Sribanditmongkol P, Monum T, Wannasan A, Tomberlin J K, Sukontason K , Blow fly maggots (Diptera: Calliphoridae) from a human corpse in a vehicle. The Southeast Asian Journal of Tropical Medicine and Public Health, (2014) Volume, (45 5), Pages: 1011–4.
- Mondal, P.C., Mahato, S., Chakraborty, B. et al. First report of Oriental latrine flies causing vaginal myiasis in human. J Parasit Dis 40, 1243–1245 (2016).
- Kasinathan A, Shanthini NF, Uterovaginal prolapse with myiasis: a case report.. Int J Reprod Contracept Obstet Gynecol. 2014;3:477–478.
- Ray S, Basak S, Konar H. Maggots in prolapsed uterus - polluted progress of life style. Med J Armed Forces India. 2012;68:240–241.
- Purnima U, Varshney U, Jahan M. A rare case of genital myiasis in a woman with psychiatric disturbance. CHRISMED J Health Res. 2017;4:55–58.
- Baidya J. A rare case of genital myiasis in a woman with genital prolapse and malignancy and review of the literature. Ann Trop Med Public Health. 2009;2:29–30.
- Saldarriaga W, Herrera E, Castro D. Myiasis in uterine prolapse, successful treatment. [Oct;2008. Am J Obstet Gynecol. 2011 205:0.
- Divedi P, Mishra PK, Mishra P Vulval myiasis: an unusual presentation of a rare entity in an adolescent female. Trop Parasitol. 2015;5:58–60.
- Sherman RA, Wyle FA, Thrupp L Effects of seven antibiotics on the growth and development of *Phaenicia sericata* (Diptera: Calliphoridae) larvae. J Med Entomol (1995) 32:646–649.
- Erdmann GR, Khalil SKW .Isolation and identification of two antibacterial agents produced by a strain of *Proteus mirabilis* isolated from larvae of the screwworm (*Cochliomyia hominivorax*) (Diptera: Calliphoridae). J Med Entomol (1986) 23:208–211.
- Kawabata T, Mitsui H, Yokota K, Shino KI, Guma KO, Sano S, Induction of antibacterial activity in larvae of the blowfly *Lucilia sericata* by an infected environment. Med Vet Entomol (2010) 24:375–381.
- Kerridge A, Lappin-Scott H, Stevens JR, Antibacterial properties of larval secretions of the blowfly, *Lucilia sericata*. Med Vet Entomol (2005) 19:333–337.
- Kruglikova AA, Chernysh SI (2011) Antimicrobial compounds from the excretions of surgical maggots, *Lucilia sericata* (Meigen) (Diptera, Calliphoridae). Entomol Rev (2011) 91:813–819.
- Sherman RA, Shimoda KJ , Presurgical maggot debridement of soft tissue wounds is associated with decreased rates of postoperative infection. Clin Infect Dis (2004) 39:1067–1070.
- Dumville JC, Worthy G, Jm B, Cullum N, Dowson C, Iglesias C, Mitchell JL, Nelson EA, Soares MO, Torgerson DJ, on behalf of the VenUS II team , Larval therapy for leg ulcers (VenUS II): randomised controlled trial. Br Med J (2009) 338:1047–1050.
- Sherman RA ,Maggot therapy for foot and leg wounds. Int J Low Extrem Wounds (2002a) 1:135–142.
- Sherman RA (2002b) Maggot versus conservative debridement therapy for the treatment of pressure ulcers. Wound Repair Regen (2002b) 10:208–214.
- Sherman RA, Maggot therapy for treating diabetic foot ulcers unresponsive to conventional therapy. Diabetes Care (2003) 26:446–451.
- Sherman RA, Shimoda KJ , Presurgical maggot debridement of soft tissue wounds is associated with decreased rates of postoperative infection. Clin Infect Dis (2004) 39:1067–1070.
- Sherman RA, Wyle FA, Thrupp L , Effects of seven antibiotics on the growth and development of *Phaenicia sericata* (Diptera: Calliphoridae) larvae. J Med Entomol (1995a) 32:646–649.
- Sherman RA, Wyle F, Vulpe M , Maggot therapy for treating pressure ulcers in spinal cord injury patients. J Spinal Cord Med (1995b) 18:71–74.
- Sherman RA, Tran JM-T, Sullivan R , Maggot therapy for venous stasis ulcers. Arch Dermatol (1996), 132:254–256.
- Sherman RA, Hall MJ, Thomas S, Medicinal maggots: an ancient remedy for some contemporary afflictions. Annu Rev Entomol (2000) 45:55–81.
- Sherman RA, Sherman JM-T, Gilead L, Lipo M, Mumcuoglu KY , Maggot debridement therapy in outpatients. Arch Phys Med Rehabil (2001) 82:1226–1229.
- Sherman RA, Shapiro CE, Yang RM , Maggot therapy for problematic wounds: uncommon and off-label applications. Adv Skin Wound Care (2007b) 20:602–610.
- Barker HS, Snyder JW, Hicks AB., Yanoviak SP, et al , First Case Reports of *Ignatzschineria* (*Schineria*) *indica* Associated with Myiasis .Journal of Clinical Microbiology Nov 2014, 52 (12) 4432–4434;
- SCHRÖTTNER P, RUDOLPH WW, DAMME U, LOTZ C, JACOBS E, GUNZER F. Wohlfahrtimonas chitiniclastica: current insights into an emerging human pathogen. Epidemiology and Infection. 2017;145(7):1292–1303.
- Lysaght TB, Wooster ME, Jenkins PC, Koniaris LG. Myiasis-induced sepsis: a rare case report of *Wohlfahrtimonas chitiniclastica* and *Ignatzschineria indica* bacteremia in the continental United States. Medicine (Baltimore). 2018;97(52).
- Suryalathan K, John J, Thomas S, Wohlfahrtimonas chitiniclastica- associated osteomyelitis: a rare case report. Future Microbiology 2015 10:7, 1107–1109.
- Linette Mejias L, Curcio C, Sanchez, A., Siddique, B, et al. *Ignatzschineria indica*

- Isolated From a Human Breast Abscess: A Rare Case, J Med Cases. 2016;7(11):502-505
80. Kõljalg, S., Telling, K., Huik, K. et al. First report of *Wohlfahrtiimonas chitiniclastica* from soft tissue and bone infection at an unusually high northern latitude. *Folia Microbiol* 60, 155–158 (2015).
 81. Darwin C. (1859) "On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life."