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Silkworm: An Auspicious Model Organism in Biological Science

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INTRODUCTION

In life science and other disciplines, animal models are frequently utilized to gain a better and more comprehensive understanding of certain scientific issues. Higher organisms, such as mammals, are often used in these investigations. On the other hand, the widespread usage of animals may give rise to concerns about animal rights, opinions, and many other bioethical issues in addition to biosafety (Levy 2012). Therefore, an issue with modern life science research is finding an appropriate model animal to limit or replace the use of mammals.

The silkworm, *Bombyx mori* (L.) (Lepidoptera: Bombycidae), is a significant commercial insect with several benefits for life science. These include low breeding costs, huge offspring sizes, short generation times, and distinct genetic backgrounds. Silkworms also have huge genetic resources associated with it. The silkworm's transformation into an innovative modern organism in life science has been accelerated by the completion of its genome. Based on genomic studies, several genes from silkworms are remarkably similar to genes linked to genetic diseases in humans, making them a good model to study human diseases. In this article, we explored the use of silkworms as an excellent model in several research fields, such as anticancer investigations, environmental safety monitoring, human disease, and antimicrobial compound screening. Furthermore, the silkworm model's potential applications in the biological sciences were explored.

One common lepidopteran insect that is very significant to agriculture and the economy is the silkworm, Bombyx mori. Silkworms are commonly used in many different life science investigations because of their short generation time, distinct genetic background, availability of genetic resources, and a significant number of human identical genes.

China and Japan began working on the silkworm genome project in 2003, and by the time it was finished, the silkworm had three draft maps, a fine map, and a multistrain genome re-sequencing (Xia and Yang 2004, Xia et al. 2009). This tremendously accelerated the advancement of sericulture science and made the silkworm an excellent model organism for scientific study. According to Nwibo et al. (2015), the use of silkworm models is currently being applied to a variety of life science applications, including environmental safety monitoring, antipathogenic drug screening, and treatment evaluation.

Silkworm as a Model Organism in Life Science

Over the past ten years, the field of studying human microbial toxicology and pathology using silkworms as model animals has advanced quickly. Research revealed that silkworms were extremely vulnerable to pesticides, antibiotics, pathogenic fungus, and germs that are harmful to humans. There are established silkworm models for viral infection, bacterial infection, fungal infection, and natural immunological activation (Kaito and Sekimizu 2007, Ishii et al. 2015a). As a result, in the current context, using silkworms as model organisms to research human tumors, degenerative diseases, and metabolic diseases has focused.

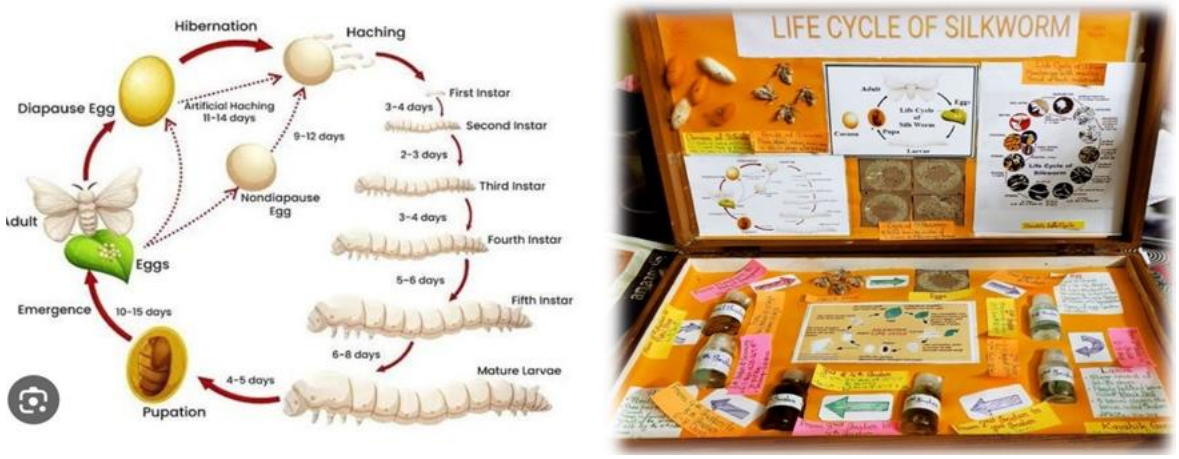

Fig: . Generation cycle pattern of the silkworm (*Bombyx mori*).

The Application of Silkworm in the Screening of Antimicrobial Drugs

The silkworm has drawn a lot of interest as a model organism for human antimicrobial drug screening. In their investigation of antimicrobial medicines, Kaito et al. (2002) demonstrated that silkworms might take the place of mammals in bacterial pathogenicity trials. Consequently, studying silkworm defense mechanisms against harmful microorganisms could be a workable way to produce antimicrobial medications. Research has shown that latrogenic infections, including Aspergillus, and Staphylococcus aureus (Hanada et al. 2011), can kill silkworms. Using the silkworm model, Hamamoto et al. (2004) assessed the toxicity and effectiveness of several antibiotics, including vancomycin, tetracycline, flucloxacillin, and linezolid. Usui et al. (2016) confirmed that evaluating a compound's toxicity in mammals may be done effectively using an acute oral toxicity test conducted on silkworms. To evaluate the therapeutic efficacy of different microbial culture broths, Panthee et al. (2017) used a silkworm bacterial infection model. They were able to identify lysocin E, a novel antibiotic with a novel mode of action that involves

binding to menaquinone, a crucial membrane molecule for the bacterial electron transport chain, causing membrane damage and bactericidal activity.

The Application of Silkworm in HumanDisease Model

Numerous models of silkworm diseases have been developed due to the great degree of similarity between the genes of silkworms and several human genetic diseases. Although the adenylate protein kinase signaling pathway also controls hemolymph glucose in silkworms, it is crucial for the regulation of human blood glucose (Yusuf et al. 2011). About 40% of the insulin-like peptide generated by the silkworm gene is identical to human insulin, according to Zhang et al. (2015). Based on this, transgenic silkworms were used to express the human insulin receptor (hIR), creating a silkworm diabetes model. Transgenic silkworms expressing human insulin were given human insulin to lower hemolymph glucose levels and increase Akt phosphorylation in the adipose tissue. Wortmannin, a phosphatidylinositol 3-kinase inhibitor, was co-injected to prevent the transgenic silk worm expressing hIR from inhibiting human insulin-induced hypoglycemia. Applying the hIR ligand bovine insu-lin also successfully lowers the sugar content of transgenic silkworms. This study created a transgenic strain of silkworms expressing the hIR utilizing the GAL4/UAS system, and the results show that functional hIRs that react to human insulin were successfully induced in the transgenic silkworms (Matsumoto et al. 2014).

Table 2. ED_{50} of antifungal agents in a silkworm model with *Candida tropicalis* or *Candida albicans* (Hamamoto et al. 2004, Ishii et al. 2017)

Antifungal agent	True fungus	ED_{50} in silkworm (μg/g)	MIC μg/ml	ED50/MIC in ratio	
				Silkworm	Mouse
Amphotericin B	*C. tropicalis*	1.8	3.2	0.6	0.2
	C. albicans	4.1	1.6	2.6	1.3
Fluconazole	*C. tropicalis*	1.8	1.6	1.1	7.4
	C. albicans	1.8	0.4	4.5	8.6

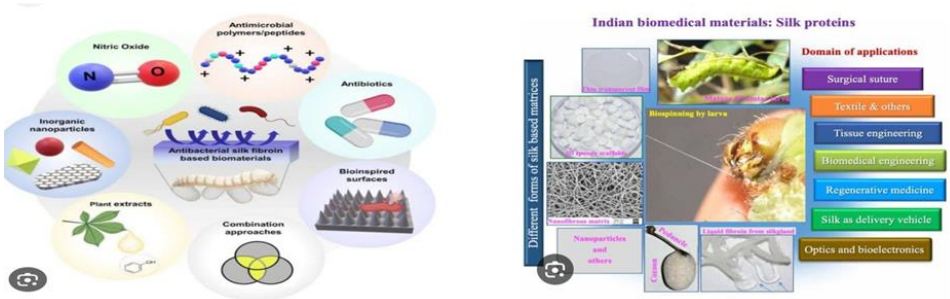

Fig:

The Application of Silkworm in EnvironmentalMonitoring

Environmental issues including pesticide residues and heavy metal pollution have been brought on by rapid economic expansion. Selecting a model animal for environmental monitoring is essential to the evaluation of ecological environment safety. According to Sekimura (2005) and Hamamoto et al. (2009), silkworms are particularly vulnerable to pesticides, heavy metals, and other dangerous chemicals found in the environment. When the

amount of Cd2+ in silkworm artificial diet increased to 10 ppm, it was discovered that the silkworm survival rate dropped significantly (Sekimura 2005). According to a different study (Li et al. 2016), adding low concentration nano-TiO2 to the silkworm feed enhanced the weight of the insects, while detoxifying genes such BmCYP6ae22, BmGSTol, and Bmcce were expressed more often at the transcriptional level (Tian et al. 2016). Tian et al. also noted that Ag nanoparticles (AgNPs) had harmful and growth-inhibiting effects on silkworms on an individual basis. The metabolic cycle, apoptosis, signal transduction, and ion transport have all been impacted by AgNP exposure. The silkworm is a model organism used to evaluate the possible risks associated with nanoparticles (Meng et al. 2017). Furthermore, even after being diluted 5,000 times, the organophosphorus pesticide MEP emulsion could still poison silkworms (Sugiyama and Emori 1980). Consequently, harmful compounds that negatively impact soil, water quality, the medical environment, and other areas can be monitored using the silkworm model.

The Application of Silkworm in Pest Control

A silkworm larvae virus infection model was first created by Kodama et al. (1972) for use in medication therapy and insect defense studies. After injecting the virus into the silkworm's hemolymph, the findings demonstrated that nalidixic acid might stop the nuclear polyhedrosis virus (BmNPV) and flacherie virus from proliferating and shield silkworms from other viral infections. When dissolved in acetone and added to the larvae's food, the insect growth regulator flufenoxuron enhanced BmNPV infection in fifth-instar B. mori larvae. Furthermore, as flufenoxuron concentration rose, the LD50 of BmNPV dropped. But when undissolved flufenoxuron was added to the diet in the form of powder, it had no such impact (Arakawa et al. 2002).

CONCLUSION

The silkworm model has been effectively used to many facets of life science study and has significantly aided in the advancement of science in this area. But there are still a lot of obstacles to overcome, and the use of the silkworm model is still in its infancy in many fields due to a lack of adequate animal research and data from clinical trials. Shortly, silkworms may be utilized instead of mammals to investigate the efficacy of drugs. However, there are several drawbacks to the silkworm approach. Because silkworms are immune to human genetic diseases such as neurological disorders and neurological conditions, utilizing them as models for genetic disease research is inappropriate. Furthermore, psychological disorders like anxiety or depression are not present in silkworms. Silkworms can provide a complementary and additional role to mammals, even though they cannot entirely replace them. In conclusion, encouraging the use of silkworm models in scientific research will considerably advance both science and society by offering fresh perspectives on old approaches to problem-solving.

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