IPS Journal of Basic and Clinical Medicine
ISSN: 3115-5731
IPS J Basic & Clin Med, 2(4): 122-132 (2025)
DOI: https://doi.org/10.54117/ijbcm.v2i4.22

Mousepox Virus (Ectromelia Virus), Molecular Mechanisms, Clinical Manifestations, and Control Strategies

Iheukwumere, I. H.[1], Iheukwumere, C. M.[2], Unaeze, B. C.[3], Ike, V. E.[4], Nnadozie, H. C.[1] and Onyema, S. O.[1]

[1]Department of Microbiology, Faculty of Natural Sciences, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.
[2]Department of Applied Microbiology & Brewing, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[3]Department of Medical Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[4]Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.

*Corresponding author email: ik.iheukwumere@coou.edu.ng./ ikpower2007@yahoo.com

Abstract

Mousepox virus or *Ectromelia virus* (ECTV) is a member of rodent-specific virus belonging to the family of the *Poxviridae* and the genus *Orthopoxvirus*. ECTV is the etiological agent of mousepox a severe and often lethal disease in Mice that closely mimics the progression of small pox. *Ectromelia virus* can be transmitted through direct contact, fecal oral route, aerosolize inhalation and bites or scratches from infected mice. The replication cycle of Ectromelia virus (ECTV) begins with attachment, entry, and uncoating, followed by early transcription and translation of proteins necessary for immune evasion and genome replication within the host cytoplasm. Subsequently, late gene expression leads to the assembly, maturation, and release of infectious virions, allowing further spread of the virus. The pathogenesis of Ectromelia virus (ECTV) involves sequential stages beginning with viral entry and primary replication in skin and lymphoid tissues, followed by primary viremia that enables dissemination to organs such as the spleen and liver. Subsequent secondary replication leads to a secondary viremia, resulting in systemic spread and the development of characteristic skin lesions, marking the clinical onset of mousepox. The clinical presentations of ECTV includes fever, lethargy, skin-rash or lesions, systemic organ damage, swelling around the eyes and nose and respiratory problems. Mousepox, caused by Ectromelia virus, is a rodent-specific disease with no human cases, thus it lacks distribution patterns based on human demographics such as age, sex, or occupation. ECTV can be diagnosed using physical examination, viral culture, serological tests such as Enzyme-linked Immunosorbent Assay, viral neutralization assay, western blotting and immunofluorescence assay. Treatment of mousepox virus involves the use of antiviral drugs such as cidofovir, tecovirimat, and medicinal plants with antiviral properties such as *Sarracenia purpurea, Azadirachta indica, Euphoria hirta*. ECTV can be prevented using enhanced biosecurity, regular health monitoring, quarantine procedures and vaccination.

Keywords: Ectromelia virus, Mousepox, Orthopoxvirus, Pathogenesis, Antiviral therapy

Article History
Received: 10 Sept 2025
Accepted: 26 Sept 2025
Published: 07 Oct 2025

Scan QR Code to view[1]

How to cite this paper: Iheukwumere, I. H., Iheukwumere, C. M., Unaeze, B. C., Ike, V. E., Nnadozie, H. C., & Onyema, S. O. (2023). Mousepox Virus (Ectromelia Virus), Molecular Mechanisms, Clinical Manifestations, and Control Strategies. *IPS Journal of Basic and Clinical Medicine*, *2*(4), 122–132. https://doi.org/10.54117/ijbcm.v2i4.22

INTRODUCTION

Mousepox virus, or *Ectromelia virus* (ECTV), is a rodent-specific member of the *Orthopoxvirus* genus, which also includes significant human pathogens such as *Variola virus* (the causative agent of smallpox) and *Vaccinia virus* (used in smallpox vaccines). ECTV is the etiological agent of mousepox, a severe and often lethal disease in mice that closely mimics the progression of human smallpox. Because of these similarities in disease progression, viral structure, and immune evasion strategies, ECTV is widely regarded as an important model for understanding the biology of orthopoxviruses and their interactions with the host immune system (Melo-Silva et al., 2011).

One of the key attributes that makes ECTV valuable as a research model is its ability to manipulate and evade the host immune response. Among the many immune-modulatory proteins encoded by ECTV, serine protease inhibitor 2 (SPI-2) is particularly noteworthy. SPI-2 is a serpin (serine protease inhibitor) that functions not by directly degrading proteins but by binding and inhibiting key enzymes in immune pathways. It is highly conserved among orthopoxviruses, indicating its essential role in virulence.

SPI-2 plays a crucial role in evading the innate immune response, particularly by targeting Natural Killer (NK) cells. NK cells are a vital component of the early immune defense against viral infections. They patrol tissues for signs of infection and kill virus-infected cells before the adaptive immune system is fully activated. NK cells exert their effects through cytotoxic activity and cytokine production, including interferon-gamma (IFN-γ), which is critical for antiviral defense.

Research by Melo-Silva and colleagues (2011) revealed that SPI-2 interferes with the function of NK cells, impairing their ability to recognize and eliminate infected cells. This allows the virus to establish infection more efficiently, replicate rapidly, and spread throughout the host before a robust immune response can be mounted. Although the exact molecular targets of SPI-2 in NK cells are still being elucidated, evidence suggests that SPI-2 may interfere with signalling pathways essential for NK cell activation and cytotoxicity.

Moreover, the findings from ECTV studies have broader implications for understanding human orthopoxviruses. Since many of these viruses, including *Variola* and *Monkeypox virus*, encode homologous immune-modulatory proteins, the insights gained from ECTV can be translated to other poxvirus infections. This knowledge is especially relevant given the re-emergence of zoonotic poxviruses like *Monkeypox* and the potential for bioterrorism involving engineered orthopoxviruses.

Understanding how ECTV—and by extension, other orthopoxviruses—evades NK cell responses is crucial not only for comprehending viral pathogenesis but also for developing targeted antiviral therapies and vaccines. By blocking or neutralizing immune evasion factors like SPI-2, it may be possible to enhance host immunity and improve outcomes during poxvirus infections.

HISTORY AND ORIGIN OF MOUSEPOX VIRUS

The mousepox virus, known scientifically as ectromelia virus , is a member of the Orthopoxvirus genus within the poxviridae family. It was first identified in the early 20th century when researchers noticed a highly contagious disease affecting laboratory mice in Europe. This discovery was significant, as it led to the classification of ECTV as a close relative of the poxviruses, such as variola virus, which causes small pox in humans (Fenner, 1981).

The first documented outbreak of mousepox occurred in 1930, reported by Marchal, who observed the disease in laboratory mice colonies (Marchal, 1930). The virus was named "ectromelia", derived from the Greek word, ektroma, meaning "abortion" or "malformation", due to limb deformities seen in infected mice. The disease quickly gained attention due to its high mortality rate, severe skin lesions, and systemic infection in susceptible mouse strains (Fenner and Buller, 1997).

Early research into mousepox focused on understanding its transmission and immune response interactions. Scientists determined that ECTV spreads through direct contact, contaminated bedding, and occasionally aerosol transmission, particularly in crowded environments (Parker and Plowright, 1968). Further studies revealed that certain mouse strains, such as C57BL/6, are naturally resistant to the virus, while others like BALB/c, are highly susceptible, making it an excellent model for studying genetic immunity to viral infections (Buller and Palumbo, 1991).

Over time, ECTV research contributed significantly to the broader understanding of poxvirus evolution and immune evasion strategies. The virus shares genetic and structural similarities with vaccinia virus, which was used in the development of small pox vaccines. As a result, mousepox has been widely studied as a model for poxvirus infections, offering insights into how viruses evade the immune system and cause disease in mammals (Moss, 2013).

In recent years, advances in genomic sequencing and molecular biology have provided further clarity on the evolutionary origins of ECTV. Studies suggest that it likely diverged from a common ancestor shared with another orthopoxvirus, adapting specifically to murine hosts over time (Melo-Silva *et al.*, 2011).

Viral structure and Genomic structure

Ectromelia virus (ECTV), the causative agent of mousepox, is a member of the *Orthopoxvirus* genus within the *Poxviridae* family. Like other poxviruses, ECTV is a large, enveloped, double-stranded DNA virus with a complex structure and distinctive replication strategy.

Viral Structure

ECTV virions are brick-shaped particles measuring approximately 220–300 nm in length and 140–260 nm in width, featuring a dumbbell-shaped core flanked by lateral bodies and enclosed within a lipoprotein envelope (Moss, 2013). The envelope is acquired during viral morphogenesis in the host cytoplasm. Mature virions (MV) and extracellular enveloped virions (EV) represent two infectious forms of the virus, with EVs possessing an additional membrane that aids in dissemination within the host (Parker, Siddiqui, & Emerson, 2013).

The surface of the virion is decorated with numerous surface tubules and proteins that facilitate attachment and entry into host cells. These proteins interact with host cell receptors, mediating membrane fusion and allowing the virus to deliver its core into the cytoplasm, where replication occurs.

Genome Organization

The genome of ECTV is a linear double-stranded DNA molecule approximately 209 kilobase pairs (kbp) in length (Chen et al., 2003). It contains over 190 open reading frames (ORFs), which are highly conserved among orthopoxviruses. The genome exhibits a characteristic terminal hairpin loop at each end, along with inverted terminal repeats (ITRs) that contain regulatory sequences and genes involved in host immune evasion.

The central region of the genome encodes essential genes for viral replication, transcription, and morphogenesis. In contrast, the terminal regions are more variable and contain genes involved in host range determination, immune modulation, and virulence, such as *SPI-2* (serine protease inhibitor-2), which plays a key role in evading host natural killer (NK) cell responses (Melo-Silva et al., 2011).

Unlike many DNA viruses, poxviruses—including ECTV—replicate entirely within the cytoplasm of infected cells. The virus carries its own transcriptional machinery, including RNA polymerase, transcription factors, and capping enzymes, enabling it to transcribe and process its mRNAs independently of the host nucleus (Moss, 2013).

STRUCTURAL PROTEINS AND THEIR FUNCTIONS

ECTV encodes several structural proteins integral to its virion architecture and infectivity. Key structural proteins include:

1. A10 protein: This protein forms trimers that contribute to the virion's core structure, playing a crucial role in maintaining the integrity of the viral particle
2. Profilin Homolog: An ectromelia profilin homolog interacts with cellular actin, affecting the formation and spatial organization of the host cell cytoskeleton.
3. EVM1 Protein: A chemokine-binding protein that interferes with the host immune surveillance processes. EVM1 is abundantly expressed early during mousepox infection and can selectively bind CC chemokines and inhibit their interactions with host receptors.

ACCESSORY PROTEINS AND THEIR FUNCTIONS

ECTV encodes accessory proteins that modulate host immune responses, enhancing viral survival and replication. Notable accessory proteins include:

1. E163 protein: This protein binds chemokines through their glycosaminoglycan binding domain and interacts with GAGs to anchor at the cell surface, modulating chemokine activity and interfering with host immune responses
2. F-Box Proteins: ECTV encodes a novel family of these proteins that interacts with the host's ubiquitin-proteasome system, potentially targeting specific cellular proteins for degradation to benefit viral replication.
3. A41 protein: An immunomodulatory protein with an amino acid sequence similar to the 35-kDa chemokine-binding protein, targeting host immune molecules to modulate the immune response.

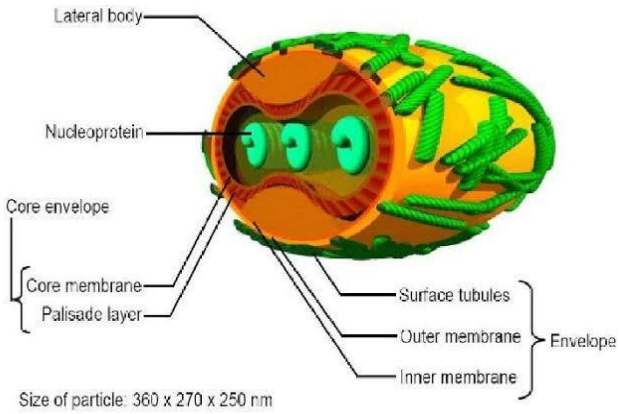

Figure 1: Structures of Mousepox virus
Source : Melo-Silva *et al.* (2011)

CLASSIFICATION OF MOUSEPOX VIRUS

Taxonomic Classification:

- Kingdom: Bamfordvirae
- Phylum: Nucleocytoviricota
- Class: Pokkesviricetes
- Order: Chitovirales
- Family: Poxviridae
- Subfamily: Chordopoxvirinae
- Genus: Orthopoxvirus
- Species: Ectromelia virus
- Common name: Mousepox virus

ROUTE OF INFECTION

In natural settings, ECTV primarily infects mice through cutaneous routes, often via abrasions or wounds in the skin. This transmission mode facilitates direct contact spread among individuals or through contaminated materials (fomites).

PROPERTIES OF MOUSEPOX VIRUS

Biological Properties:

1. Host Specificity: ECTV naturally infects mice, causing mousepox , a disease characterized by high mortality in susceptible strains.
2. Pathogenicity: The virus induces acute, often lethal infections in laboratory mice, making it a valuable model for studying orthopoxvirus pathogenesis.
3. Immune Evasion: ECTV encodes various immuno modulatory proteins that inhibit host immune responses, facilitating viral replication and dissemination.
4. Replication cycle: As a poxvirus, ECTV replicates entirely within the cytoplasm of infected host cells, utilizing its own transcriptional machinery.
5. Transmission: The virus spreads through direct contact between infected and susceptible mice or via contaminated materials, leading to outbreaks in laboratory settings.

Physical Properties:

1. ECTV particles are large, brick shaped virus measuring from 250-300nm in length and 150-200nm in width.
2. The virus is temperature-sensitive; exposure to 55 degree Celsius inactivates the virus after 30 minutes.

3. The virus demonstrates stability under various environmental conditions, contributing to its persistence in contaminated environments.
4. It is an enveloped virus.

Chemical Properties:

1. Lipid Composition: The viral envelope contains host-derived lipids, essential for membrane fusion during the infection process.
2. Protein Content: ECTV encodes numerous structural and non-structural proteins, including enzymes necessary for DNA replication and transcription.
3. Chemical Inactivation: The virus is susceptible to inactivation by detergents and common disinfectants, such as formalin, which disrupt the viral envelope.
4. pH Sensitivity: ECTV maintains stability across a range of pH levels but can be inactivated under extreme acidic or alkaline conditions.
5. Resistance to organic solvents: The virus exhibits resistance to organic solvents like ether and phenol, allowing it to persist in certain environments.

MODE OF TRANSMISSION

Mousepox virus can be transmitted through:

1. Direct contact: The virus is transmitted primarily via aerosol droplets, contact with body fluids, or infected bedding.
2. Fecal-oral transmission and vector transmission: This is also possible but less common.
3. Inhalation of airborne virus particles
4. Contaminated food and water
5. Bites or scratches from infected mice

REPLICATION OF THE VIRUS

The replication cycle of Ectromelia virus involves several stages:

1. Attachment: ECTV binds to the host cell receptors, initiating infection (Iheukwumere *et al*., 2025a).
2. Penetration: Following attachment, the virus enters to the host cell cytoplasm (Iheukwumere *et al*., 2025b).
3. Targeting site of replication: After penetration, ECTV targets specific cytoplasmic regions for replication (Iheukwuemere *et al.*, 2025c).
4. Uncoating: The viral core is released into the cytoplasm, allowing access to the viral genome (Iheukwumere *et al*., 2025d).
5. Early transcription: Early genes are transcribed within the viral core, producing proteins essential for DNA replication and immune evasion (Iheukwumere *et al*., 2025e).
6. Early translation: The early mRNAs are translated into proteins necessary for subsequent replication steps (Iheukwumere *et al*., 2025f).
7. Genome replication: The viral genome is replicated in cytoplasmic structures known as viral proteins (Iheukwumere *et al*., 2025g).
8. Late transcription and translation: Late genes encode structural proteins necessary for virion assembly (Iheukwumere *et al.*, 2025h).
9. Maturation: New virions are assembled and undergo maturation to become infectious particles.
10. Release: Mature virions are released from the host cell, enabling infection of new cells.

PATHOGENESIS OF MOUSEPOX VIRUS

The pathogenesis of *Ectromelia virus* (ECTV), the causative agent of mousepox, occurs through distinct, well-characterized stages:

1. Entry and Primary Replication

ECTV primarily gains entry through skin abrasions, mucosal surfaces (particularly via the oropharyngeal route), or through experimental intraperitoneal or subcutaneous inoculation. Upon entry, the virus infects epidermal cells and local macrophages, initiating its initial replication cycle. Infected dendritic cells subsequently transport the virus to the draining lymph nodes, where further viral amplification occurs (Chen et al., 2003; Iheukwumere *et al*., 2024a).

2. Primary Viremia

Following replication in the regional lymph nodes, the virus enters the bloodstream in what is known as primary viremia. This stage is characterized by:

- Dissemination of the virus to organs such as the spleen, liver, and bone marrow.
- Infection of cells within the reticuloendothelial system (RES).
- Replication within mononuclear phagocytes.

Primary viremia is typically transient and of low magnitude but plays a critical role in seeding secondary lymphoid organs (Esteban and Buller, 2005; Iheukwumere *et al.*, 2024b).

3. Secondary Replication in Target Organs

The spleen and liver are the principal sites for extensive secondary viral replication. Here, hepatocytes and splenocytes undergo necrosis due to a combination of direct viral cytopathic effects, apoptosis, and immune-mediated inflammation. Clinically, this stage may manifest as mild symptoms in infected mice, including lethargy and ruffled fur (Parker et al., 2013; Iheukwumere *et al*., 2024c).

4. Secondary Viremia and Systemic Spread

Following intensive replication in the liver and spleen, ECTV re-enters the circulatory system in a secondary viremia. This facilitates the widespread dissemination of the virus to peripheral tissues, including:

- The skin and extremities, where pock lesions develop.
- Other epithelial surfaces, from which the virus may be shed.

This stage signifies the transition from subclinical to clinically apparent disease, with characteristic cutaneous lesions often observed on the ears, feet, and tail (Chen et al., 2003; Iheukwumere *et al*., 2024d).

DISEASES ASSOCIATED WITH THE VIRUS

Mousepox, also known as **ectromelia**, is a highly contagious viral disease caused by the *Ectromelia virus* (ECTV), a member of the *Orthopoxvirus* genus within the *Poxviridae* family. The disease primarily affects laboratory and wild mice, with significant implications for biomedical research facilities, where outbreaks can compromise experimental outcomes and necessitate colony eradication.

Clinical Forms
Mousepox can present in three major clinical forms, depending on the strain of the virus, route of infection, mouse strain, and immune status:

1. **Peracute Form**
   - Sudden onset with high mortality within 24–48 hours
   - Often occurs without noticeable clinical signs
   - Associated with highly susceptible mouse strains
2. **Acute Form**
   - Characterized by lethargy, ruffled fur, and rapid weight loss
   - Hepatosplenomegaly and internal hemorrhaging may occur
   - Mortality usually occurs within 5–7 days post-infection
3. **Chronic Form**
   - Occurs in partially resistant or immunocompetent mice
   - Presents with classic cutaneous lesions (pocks) on the tail, feet, and ears
   - Mice may survive but remain carriers, posing a risk for future outbreaks

.

CLINICAL MANIFESTATIONS OF THE DISEASE

Signs and symptoms include:

1. Fever
2. Lethargy
3. Skin rash or lesions
4. Systemic organ damage
5. Swelling around the eyes and nose
6. Development of pustules on the skin, which may progress to scabbing and necrosis
7. Loss of appetite
8. Respiratory problems

DISTRIBUTION OF THE DISEASE

People-Based Distribution
Mousepox is a rodent-specific disease and does not affect humans. Therefore, there is no distribution based on sex, age, marital status, occupation, or human demographics.

Note: All cases are restricted to laboratory or wild mice, and occasionally other rodents under experimental settings.

Place-Based Distribution

Continent Level:

- Commonly reported in North America, Europe, and Asia where laboratory mice are used in large numbers.
- Rare or absent in wild mouse populations in most regions due to lack of surveillance.

Tropical vs Temperate Regions:

- More common in temperate regions, especially where there are well-established laboratory animal research facilities.
- Rare in tropical regions, especially due to limited mouse colonies and fewer poxvirus studies.

West African Countries:

- No known reports of natural mousepox outbreaks in West African countries.
- It is not endemic or commonly observed in African wild rodent populations.

Geopolitical Zones (Nigeria Example):

- No documented cases in any Nigerian geopolitical zone—North West, North East, North Central, South West, South East, or South South.
- Nigerian research centers using lab mice may adopt strict biosecurity, preventing outbreaks.

Period-Based Distribution

Seasonal Variation:

- In controlled laboratory settings, outbreaks can occur at any time of year if hygiene lapses or infected animals are introduced.
- However, in rodent colonies, stress due to colder temperatures (e.g., winter) may increase susceptibility.

Climatic Seasons:

- Winter and autumn: Slightly higher chances of outbreaks due to stress in mice.
- Summer and spring: Less frequent but still possible under poor lab conditions.

Wet vs Dry Season (in tropical terms):

- Not strongly seasonal in tropical zones due to lack of endemicity.
- In regions with outbreaks, dry seasons may increase rodent movement and contact, slightly raising risks in wild populations.

Day vs Night:

- Mousepox virus transmission is not time-dependent (diurnal/nocturnal patterns don't apply).
- However, mice are nocturnal, so transmission among mice may be more active at night when they're moving around.

DIAGNOSIS

Physical Examination
A thorough physical examination of the animal is the first step in diagnosing the mousepox virus. The clinical signs of MPV can be non-specific and vary depending on the strain and severity of infection. Key physical signs include:

- Skin Lesions: The most prominent feature of MPV is the presence of skin lesions, which can range from small papules to large, ulcerative lesions.

- Fever: Mice with MPV may exhibit an elevated body temperature (fever), often preceding the appearance of visible skin lesions.
- Weight loss and weakness: Infected animals may show signs of emaciation, lethargy, and decreased activity.
- Enlarged lymph nodes: The lymph nodes of infected mice may be swollen due to the immune response to the infection.
- Respiratory and Gastrointestinal symptoms: Though less common, respiratory distress and gastrointestinal symptoms such as diarrhea may also be observed. Since these signs overlap with other infectious diseases, physical examination alone cannot confirm MPV infection, necessitating further diagnostic tests.

Sample Collection

Sample collection is a critical step for the diagnosis of MPV, as it ensures that the correct tissue or biological material is obtained for analysis (Iheukwumere *et al*., 2024e).

- Lesion Samples: Lesions on the skin, if present, should be sampled. Scraping the surface of the lesion or collecting fluid from the lesion can provide viral particles. The collection site should be disinfected to avoid contamination.
- Blood samples: White blood or serum can be collected to assess for antibodies against MPV and to confirm viral infection.
- Organ saamples: In more severe cases, organs such as the liver, spleen, lungs or kidneys can be collected. These tissues may show evidence of viral replication during necropsy.
- Swabs: Swabs from nasal passages or ocular regions can be taken to detect the virus in mucosal secretions.
- Fecal samples: Though not routinely used, fecal samples may be helpful in some cases if gastrointestinal symptoms are observed.

For the best results, samples should be collected early in the course of the disease when viral load is high.

TRANSPORTATION OF THE SAMPLE

Proper transportation of samples is essential to ensure their viability and to avoid contamination or degradation. The key considerations for transportation include:

- Temperature Control: Samples should be transported under conditions that preserve their integrity. For tissue and organ samples, refrigeration (four degree celsius) is typically required. For viral samples, transport on ice is recommended to slow down potential degradation.
- Transport medium: Samples like blood, swabs, or other fluids should be transported in appropriate viral transport media to maintain virus stability during transit.
- Packaging and handling: To prevent contamination, samples should be securely packaged according to biosafety guidelines (such as those established by the CDC or WHO). If the sample is suspected of being infectious, the sample should be labelled as “biohazard” and transported in compliance with relevant safety protocols.
- Prompt delivery to the diagnostic laboratory is crucial to avoid loss of sample integrity.

Serological Tests

Serological testing plays a key role in diagnosing MPV, especially for identifying infected individuals or animals in the absence of clinical signs. These tests detect antibodies against the virus or viral antigens present in the serum or plasma of the host.

- Enzyme-Linked Immunosorbent Assay (ELISA): This is one of the most widely used serological methods for detecting MPV-specific antibodies. ELISA detects either IgM (indicating recent infection) or IgG (indicating past infection) antibodies. A positive result suggests prior exposure to the virus or an active infection (Iheukwumere *et al*., 2024f).
- Virus Neutralization Assay (VNA): This assay is used to measure the ability of antibodies in the serum to neutralize the virus, providing evidence of immunity or current infection.
- Western Blotting: This method detects viral antigens in the blood or serum. It is particularly useful when looking for specific viral proteins associated with MPV.
- Immunofluorescence Assay (IFA): This method involves using fluorescent-labeled antibodies to detect MPV antigens in tissue samples or cell cultures.

CULTURING OF THE SAMPLE

Virus isolation via culture is another method for diagnosing MPV. Culturing involves growing the virus from a sample, which provides a definitive diagnosis.

Cell Culture: MPV can be cultured in specific mammalian cell lines, such as Vero cells (from African green monkey kidney) or BHK-21 cells (baby hamster kidney cells). The virus causes cytopathic effects (CPE) in these cells, such as cell rounding, detachment, or lysis, which are indicative of viral replication (Iheukwumere *et al*., 2025i).

Incubation and Observation: Cultures should be incubated at 37°C and observed for cytopathic effects. Confirmation of MPV can be achieved by visualizing characteristic viral structures using electron microscopy or by performing PCR on the cultured sample.However, culturing MPV is time-consuming and requires specialized facilities, which may not always be available, especially in resource-limited settings.

MOLECULAR ANALYSIS

Molecular techniques are powerful tools for the direct detection of MPV and for providing high specificity and sensitivity.

Polymerase Chain Reaction (PCR): PCR is the gold standard for detecting viral DNA. Specific primers targeting regions of the Ectromelia genome can be used to amplify the virus’s DNA. Real-time PCR can also quantify viral load, helping determine the severity of infection (Iheukwumere *et al*., 2025j).

Quantitative PCR (qPCR): This technique is useful for detecting and quantifying viral DNA in tissue, blood, or organ samples, providing a more accurate picture of viral replication. Reverse Transcription PCR (RT-PCR): In cases where MPV has an RNA intermediate, RT-PCR can be used to convert RNA into DNA and amplify the viral genetic material.

DNA Sequencing: Sequencing PCR products can help confirm the identity of the virus and provide insight into potential genetic mutations or variants.Molecular analysis is particularly advantageous for detecting the virus at an early stage, even before clinical symptoms appear.

OTHER FORMS OF TESTING

In addition to serological and molecular tests, other diagnostic methods may be employed in certain situations:

Electron Microscopy: Direct visualization of the virus in tissue samples or cell cultures can confirm MPV infection. The virus appears as a large, brick-shaped particle typical of poxviruses.

Histopathological Examination: Tissue samples, especially from lesions, can be examined histologically to identify typical changes associated with MPV, such as cell necrosis, inflammation, and inclusion bodies within the cytoplasm of infected cells.

Immunohistochemistry (IHC): IHC can be used to detect viral antigens in tissue sections, providing an additional layer of specificity in the diagnosis.

TREATMENT

Mousepox, caused by the ectromelia virus, serves as a model for studying poxvirus infections in humans. While no specific treatments exist for mousepox, insights from antiviral therapies and traditional medicinal practices offer potential avenues for management.

Antiviral Drugs for Mousepox

1. Cidofovir

Cidofovir is a nucleotide analogue with broad-spectrum activity against DNA viruses, including poxviruses. In murine models, cidofovir has demonstrated efficacy in preventing lethal infections when administered intaperitoneally or intranasally. A single intraperitoneal dose of 100mg/kg, given 24 hours post-infection, significantly improved survival rates in mice infected with vaccinia virus.

Usage: In research settings, cidofovir is administered intraperitoneally at 100 mg/kg, 24 hours after infection. However, due to potential nephrotoxicity, its use requires careful monitoring.

2. Tecovirimat (TPOXX)

Tecovirimat targets the VP37 envelope protein, inhibiting the formation of extracellular virus particles. While effective against orthopoxviruses, the FDA has cautioned about the potential for resistance development in monkeypox, emphasizing judicious use.

Usage: Tecovirimat is administered orally at 600 mg twice daily for 14 days in humans. Its application in mousepox models requires further investigation.

Medicinal Plants with Antiviral Properties

Several medicinal plants have demonstrated antiviral activities against poxviruses or related pathogens.

1. **Sarracenia purpurea (Purple Pitcher Plant)**

arracenia purpurea, commonly known as the **purple pitcher plant**, is a perennial, carnivorous plant native to North America. It belongs to the family *Sarraceniaceae* and is notable for its unique method of obtaining nutrients through insect capture. The plant is widely distributed across the eastern United States, Canada, and parts of the Great Lakes region (Ellison et al., 2003; Schnell, 2002).

The plant forms a rosette of tubular, pitcher-shaped leaves that can range from green to deep red or purple, depending on environmental conditions. These modified leaves function as passive pitfall traps. Unlike some other carnivorous plants that use movement or suction, *S. purpurea* relies on rainwater to fill its pitchers, creating a habitat for prey digestion and microbial symbiosis (Ellison and Gotelli, 2001).

Insects are attracted to the pitcher by nectar secreted along its rim. Once inside, the slippery surface and downward-facing hairs prevent escape, leading the prey to drown in the fluid within. Unlike other *Sarracenia* species, *S. purpurea* lacks digestive enzymes and instead depends on a **microbial community** within the fluid to break down the captured prey. These microorganisms convert organic materials into nutrients that the plant can absorb, particularly nitrogen and phosphorus, which are scarce in the acidic, nutrient-poor soils where it typically grows (Bradshaw and Creelman, 1984; Butler and Ellison, 2007).

Sarracenia purpurea is an important species in **bog and fen ecosystems**, contributing to biodiversity and nutrient cycling. The plant supports a miniature aquatic ecosystem within its pitchers, housing organisms like protozoa, mosquito larvae, and midge larvae that assist in decomposition. Due to its symbiotic relationships and adaptation to nutrient-poor environments, it is also the subject of ecological and evolutionary studies (Peterson et al., 2008; Bledzki and Ellison, 2003).

While *S. purpurea* is not globally threatened, some populations are vulnerable due to habitat destruction, peat harvesting, and pollution. Conservation efforts focus on preserving its wetland habitats and promoting awareness of its ecological significance (NatureServe, 2023).

Historically, Native American groups used *Sarracenia purpurea* extracts to treat smallpox and other ailments (Moerman, 2009). Modern research has explored its antimicrobial and anti-inflammatory properties, though more scientific evidence is needed to confirm clinical applications (Gray et al., 2005).

Figure 2: Sarracenia purpurea (Purple Pitcher Plant)
Source: Peterson et al. (2008)

2. **Azadirachta indica (Neem)**
Azadirachta indica, commonly known as Neem, is a highly valued tree in traditional and modern medicine due to its diverse therapeutic and ecological properties. Native to the Indian subcontinent and now widely cultivated in tropical and subtropical regions, Neem belongs to the Meliaceae family and is often referred to as the "village pharmacy" in rural India for its extensive medicinal applications (Subapriya and Nagini, 2005). Over the centuries, it has earned global recognition for its contributions to health care, agriculture, and environmental sustainability.

Botanically, the Neem tree is a fast-growing, evergreen species that can reach heights of up to 20 meters. It features compound pinnate leaves, small fragrant white flowers, and a smooth olive-like fruit containing a single seed. This seed is particularly rich in bioactive compounds, most notably azadirachtin, which plays a vital role in its insecticidal properties (Koul et al., 2004).

The phytochemical composition of Neem is remarkably diverse. More than 140 compounds have been identified in various parts of the plant, including leaves, bark, seeds, and oil. These compounds—such as azadirachtin, nimbin, nimbidin, salannin, and quercetin—confer a broad spectrum of pharmacological effects. Azadirachtin, in particular, has gained attention for its potent antifeedant and insect-repellent properties, making Neem a key resource in organic agriculture (Biswas et al., 2002; Isman, 2006).

Neem's medicinal utility spans across systems of traditional medicine such as Ayurveda, Unani, and Siddha. It is used to treat a variety of ailments ranging from skin disorders, gastrointestinal diseases, and diabetes to parasitic infections and inflammatory conditions (Subapriya and Nagini, 2005). Neem oil and leaf extracts are frequently employed in the treatment of skin conditions like acne, eczema, and psoriasis due to their antimicrobial and anti-inflammatory effects. Furthermore, Neem twigs are traditionally used as natural toothbrushes, offering antibacterial benefits for oral hygiene (Alzohairy, 2016).
Beyond its therapeutic roles, Neem has significant environmental and agricultural benefits. Neem oil and cake are used as natural pesticides and soil enhancers in sustainable farming practices. These bio-pesticides are known to disrupt the hormonal systems of insect pests, inhibiting their reproduction without harming beneficial organisms or pollinators (Isman, 2006). Moreover, Neem trees are drought-resistant and can grow in nutrient-poor soils, making them valuable for reforestation and erosion control projects (NRC, 1992).

While Neem is generally considered safe, certain parts of the plant—particularly Neem oil—should be used cautiously. Excessive consumption, especially in children, has been associated with toxic effects including vomiting, drowsiness, seizures, and in rare cases, coma (Sundaravalli, et al., 2010). Therefore, proper dosage and formulation are critical when incorporating Neem into therapeutic regimens.

Figure 3: ***Azadirachta indica***
Source: Alzohairy, (2016)

3. ***Euphorbia hirta*** **(Asthma Plant)**
Euphorbia hirta, commonly known as asthma weed or snakeweed, is a pantropical medicinal plant widely used in traditional medicine across Asia, Africa, and South America. Belonging to the Euphorbiaceae family, it is a fast-growing herbaceous plant characterized by its hairy stems and small yellow-green flowers. Its phytochemical profile and broad pharmacological activities have made it a focus of ethnopharmacological research.

Traditionally, *E. hirta* has been used to treat respiratory conditions such as asthma, bronchitis, and coughs—hence its common name "asthma weed." In addition, it has been utilized as an anti-inflammatory, anti-diarrheal, antimalarial, antifungal, and antibacterial agent (Parekh and Chanda, 2007). It is also commonly applied in the treatment of gastrointestinal disorders, skin infections, and as a galactagogue to promote lactation in nursing mothers (Muruganandam et al., 2001).

Phytochemical studies reveal that *E. hirta* contains a wide range of bioactive constituents, including flavonoids, tannins, terpenoids, saponins, alkaloids, and phenolic compounds. These compounds are largely responsible for the plant's biological activities. For instance, quercetin and rutin, two potent flavonoids present in the plant, have shown antioxidant and anti-inflammatory properties (Jinous and Somayeh, 2013). Its antimicrobial activity has been demonstrated against various pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* (Doughari, 2006).

Modern pharmacological research supports many traditional uses of *E. hirta*. Animal studies have shown its antidiarrheal effects are likely due to its ability to reduce intestinal motility and fluid secretion (Palit et al., 2005). Moreover, its bronchodilatory activity has validated its use in treating asthma, with some studies suggesting its effects may be mediated through histamine receptor antagonism or calcium channel blocking (Galvez et al., 1993).

Despite its promising therapeutic properties, caution is warranted in its usage, as high doses of the plant extract have been associated with potential toxicity. More clinical studies are needed to fully establish the safety, dosage, and efficacy of *E. hirta* in human populations.

Figure 3: *Euphorbia hirta*
Source: Parekh and Chanda, (2007)

PREVENTION OF SPREAD OF MOUSEPOX VIRUS

1. Enhanced Biosecurity Measures: Implementing strict biosecurity protocols is essential. This includes controlling access to animal facilities, using personal protective equipment, and ensuring proper sanitation of equipment and environments. Regular training of staff on biosecurity practices is also vital (WHO, 2025).

2. Regular Health Monitoring: Routine health surveillance of mouse colonies helps in early detection of the disease. This involves regular clinical examinations and laboratory testing to identify asymptomatic carriers.

3. Quarantine Procedures: Newly acquired animals should undergo a quarantine period before introduction to existing colonies. This practice minimizes the risk of introducing the virus into uninfected populations.

4. Vaccination: Developing and administering vaccines against Ectromelia virus can provide immunity to susceptible mouse populations, thereby reducing the risk of outbreaks (White, 2025).

5. Genetic Resistance: Breeding programs focusing on selecting genetically resistant mouse strains can decrease susceptibility to the virus.

6. Environmental Controls: Maintaining a clean and controlled environment, including proper ventilation and regular disinfection, reduces the likelihood of viral survival and transmission (Kuehn et al., 2024).

CONCLUSION

Ectromelia virus (ECTV), the causative agent of mousepox, serves as an important model for studying orthopoxvirus biology due to its close resemblance to smallpox in terms of pathogenesis and immune response. While ECTV poses no threat to humans, its detailed structural and genomic features, modes of transmission, and pathogenesis offer critical insights into viral replication and host interaction. The disease primarily affects laboratory and wild mice, with diagnosis relying on serological and molecular techniques. Although effective antiviral therapies and biosecurity measures are available, prevention remains the most reliable strategy to control outbreaks in laboratory settings.

REFERENCES

1) Alzohairy, M. A. (2016). Therapeutics role of *Azadirachta indica* (Neem) and their active constituents in diseases prevention and treatment. *Evidence-Based Complementary and Alternative Medicine*, *2016*, 7382506. https://doi.org/10.1155/2016/7382506
2) Beard, P. (2019). Virus diagnosis in the laboratory: Methods and approaches. *Journal of Clinical Virology*, *113*, 29–37.
3) Biswas, K., Chattopadhyay, I., Banerjee, R. K., and Bandyopadhyay, U. (2002). Biological activities and medicinal properties of neem (*Azadirachta indica*). *Current Science*, *82*(11), 1336–1345.
4) Bledzki, L. A., & Ellison, A. M. (2003). Nutrient cycling in *Sarracenia purpurea* microecosystems. *Oecologia*, 135(4), 556–563. https://doi.org/10.1007/s00442-003-1205-2
5) Bradshaw, W. E., & Creelman, R. A. (1984). Mutualism between the carnivorous purple pitcher plant and its inhabitants. *American Midland Naturalist*, 112(2), 294–304.
6) Buller, R. M. and Palumbo, G. J. (1991). Poxvirus pathogenesis. *Microbiological Reviews*, *55*(1), 80–122.
7) Butler, J. L., & Ellison, A. M. (2007). Nitrogen cycling dynamics in the carnivorous pitcher plant, *Sarracenia purpurea*. *Functional Ecology*, 21(5), 835–843. https://doi.org/10.1111/j.1365-2435.2007.01291.x
8) Chen, N., Danila, M. I., Feng, Z., Buller, R. M., Wang, C., Han, X., Lefkowitz, E. J. and Upton, C. (2003). The genomic sequence of ectromelia virus, the causative agent of mousepox. *Virology*, *317*, 165–186.
9) Chen, N., Danila, M. I., Feng, Z., Buller, R. M., Wang, C., Han, X., Lefkowitz, E. J., & Upton, C. (2003). The genomic sequence of ectromelia virus, the causative agent of mousepox.

Virology, 317(1), 165–186. https://doi.org/10.1016/j.virol.2003.08.003
10) De Clercq, E. (2002). Cidofovir in the treatment of poxvirus infections. *Antiviral Research*, *55*(1), 1–13.
11) Doughari, J. H. (2006). Antimicrobial activity of *Euphorbia hirta* leaf extracts. *Journal of Herbs, Spices and Medicinal Plants*, 12(1-2), 87–97. https://doi.org/10.1300/J044v12n01_08
12) Ellison, A. M., & Gotelli, N. J. (2001). Evolutionary ecology of carnivorous plants. *Trends in Ecology & Evolution*, 16(11), 623–629.
13) Ellison, A. M., Butler, E. D., Hicks, E. J., Naczi, R. F. C., Calie, P. J., Bell, C. D., & Davis, C. C. (2003). Phylogeny and biogeography of the carnivorous plant family Sarraceniaceae. *American Journal of Botany*, 90(3), 430–436.
14) Esteban, D. J. and Buller, R. M. L. (2005). Ectromelia virus: The causative agent of mousepox. *Journal of General Virology*, *86*(10), 2645–2659.
15) Fenner, F. (1981). Mousepox: The disease and its significance for smallpox. *American Journal of Pathology*, *103*(1), 1–8.
16) Fenner, F. and Buller, R. M. (1997). Mousepox. In *The Orthopoxviruses* (pp. 203–231). Academic Press.
17) Galvez, J., Zarzuelo, A., Crespo, M. E., Lorente, M. D., & Ocete, M. A. (1993). Antidiarrhoeic activity of *Euphorbia hirta* extract in mice and its effect on gastrointestinal transit. *Journal of Ethnopharmacology*, 38(3), 219–223. https://doi.org/10.1016/0378-8741(93)90020-O
18) Gray, M. J., Miller, D. L., Hoverman, J. T., & Schmutzer, A. C. (2005). Antimicrobial properties of the pitcher plant *Sarracenia purpurea*: New insights into historical remedies. *Journal of Ethnopharmacology*, 99(2), 295–297.
19) Hooper, J. and Rios, C. (2015). Diagnostics of poxviruses: From animal models to human pathogens. *Emerging Infectious Diseases*, *21*(5), 895–903.
20) Iheukwumere, C.M., Iheukwumere, I.H. Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024b). Supersizing the neutralizing activities of *Curcuma longa* and *Baphia nitida* extracts against Newcastle disease virus using Vitamin C. *Tropical Journal of Applied Natural Sciences* 2(1): 1 – 15.
21) Iheukwumere, C.M., Iheukwumere, I.H. Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024c). Boosting the antiviral activity *Baphia nitida* leaves extract in broiler chicks using chicks Vitamin C. *Tropical Journal of Applied Natural Sciences* 2(1): 1 – 10.
22) Iheukwumere, C.M., Iheukwumere, I.H. Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024e). Supersizing the neutralizing activities of *Curcuma longa* and *Baphia nitida* extracts against Newcastle disease virus using Vitamin C. *Tropical Journal of Applied Natural Sciences* 2(1): 1 – 15.
23) Iheukwumere, C.M., Iheukwumere, I.H. Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024f). Boosting the antiviral activity *Baphia nitida* leaves extract in broiler chicks using chicks Vitamin C. *Tropical Journal of Applied Natural Sciences* 2(1): 1 – 10.
24) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Iheunatuoha, U.A., Nwakoby, N.E. and Ilechukwu, C.C. (2025a). Enhancement of the antiviral potency of *Curcuma longa* and *Azadiratcha indica* using Vitamin C in embryonated chicken eggs. *IPS Journal of Phytochemistry and Chemistry and Medicinal Plant Research* 1(1): 9 – 14.
25) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Iheunatuoha, U.A., Nwakoby, N.E., Ilechukwu, C.C. and Destiny, C.C. (2025b). Mitigating Newcastle Disease Virus induced damage in chicken embryos using extracts of *Curcuma longa* and *Baphia nitida*. *IPS Journal of Basic and Clinical Medicine* 2(2): 58 – 63.
26) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Ihenatuoha, U.A., Nwakoby, N.E., Ilechukwu, C.C. and Destiny, E.C (2025d). *IPS Journal of Toxicology* 3(2): 55 – 59.
27) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Ihenatuoha, U.A., Nwakoby, N.E. and Ilechukwu, C.C. (2025e). Minifying the effects of Newcastle Disease Virus on Structural development of chicken embryo using *Curcuma longa* and *Baphia nitida* extracts. *IPS Journal of Basic and Clinical Medicine* 2(2): 58 – 63.
28) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Iheunatuoha, U.A., Nwakoby, N.E. and Ilechukwu, C.C. (2025f). Enhancement of the antiviral potency of *Curcuma longa* and *Azadiratcha indica* using Vitamin C in embryonated chicken eggs. *IPS Journal of Phytochemistry and Chemistry and Medicinal Plant Research* 1(1): 9 – 14.
29) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Iheunatuoha, U.A., Nwakoby, N.E., Ilechukwu, C.C. and Destiny, C.C. (2025g). Mitigating Newcastle Disease Virus induced damage in chicken embryos using extracts of *Curcuma longa* and *Baphia nitida*. *IPS Journal of Basic and Clinical Medicine* 2(2): 58 – 63.
30) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Ihenatuoha, U.A., Nwakoby, N.E., Ilechukwu, C.C. and Destiny, E.C (2025i). *IPS Journal of Toxicology* 3(2): 55 – 59.
31) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Nnadozie, C.H., Onwusoanya, U.F., Oduoye, O.T., Ike, V.E., Obiefuna, O.H., Igboanugo, E.U., Ejike, C.E., Udeagbara, O.E., Ochibulu, S.C., Onyemekara, N.N., Ihenatuoha, U.A., Nwakoby, N.E. and Ilechukwu, C.C. (2025j). Minifying the effects of Newcastle Disease Virus on Structural development of chicken embryo using *Curcuma longa* and *Baphia nitida* extracts. *IPS Journal of Basic and Clinical Medicine* 2(2): 58 – 63.
32) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024a). Augmenting the antiviral potency of *Baphia nitida* extract against Newcastle disease virus using Vitamin C using embryonated chicken eggs. *Tropical Journal of Applied Natural Scences.* 2(1): 1 – 12.
33) Iheukwumere, I.H., Iheukwumere, C.M., Obianom, A.O., Unaeze, B.C., Ejike, C.E., Igiri, V.C. and Okereke, F.O. (2024d). Augmenting the antiviral potency of *Baphia nitida* extract against Newcastle disease virus using Vitamin C using embryonated chicken eggs. *Tropical Journal of Applied Natural Scences.* 2(1): 1 – 12.
34) Iheukwumere, I.H., Mmaduagha, C.P., Nwike, M.I., Iheukwumere, C.M., Ike, V.E., Obianom, A.O., Ihenatuoha, U.A., Igboanugo, E.U., Okereke, F.O., Obiefuna, O.H., Nwakoby, N.E., Ilechukwu, C.C., Ochibulu, S.C. and Ejike,

C.E. (2025c). Mitigating Newcastle Disease Virus Pathogenesis with Allicumin: A patenting approach. *IPS Journal of Advanced and Applied Biochemistry* 1(1): 11 – 18.

35) Iheukwumere, I.H., Mmaduagha, C.P., Nwike, M.I., Iheukwumere, C.M., Ike, V.E., Obianom, A.O., Ihenatuoha, U.A., Igboanugo, E.U., Okereke, F.O., Obiefuna, O.H., Nwakoby, N.E., Ilechukwu, C.C., Ochibulu, S.C. and Ejike, C.E. (2025h). Mitigating Newcastle Disease Virus Pathogenesis with Allicumin: A patenting approach. *IPS Journal of Advanced and Applied Biochemistry* 1(1): 11 – 18.
36) Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology*, *51*, 45–66. https://doi.org/10.1146/annurev.ento.51.110104.151146
37) Jinous, A., & Somayeh, E. (2013). A review on pharmacological activities and phytochemical constituents of *Euphorbia hirta* L. *Pharmacologyonline*, 2, 44–57.
38) Koul, O., Isman, M. B., and Ketkar, C. M. (2004). Properties and uses of neem, *Azadirachta indica*. *Canadian Journal of Botany*, *73*(1), 1–11. https://doi.org/10.1139/b95-001
39) Kuehn, R., Fox, T., Guyatt, G., Lutje, V. and Gould, S. (2024). Infection prevention and control measures to reduce the transmission of mpox. *PLOS Global Public Health*, *4*(1), e0002731.
40) Marchal, J. (1930). Études sur la virulence du virus ectromelien. *Annales de l'Institut Pasteur*, *45*, 417–437.
41) Melo-Silva, C. R., Tscharke, D. C., Lobigs, M., Koskinen, A., Wong, Y. C., Welsh, R. M. and Regner, M. (2011). The ectromelia virus SPI-2 protein causes lethal mousepox by preventing NK cell responses. *Journal of Virology*, *85*(18), 9351–9363.
42) Melo-Silva, C. R., Tscharke, D. C., Lobigs, M., Koskinen, A., Wong, Y. C., Welsh, R. M., & Regner, M. (2011). The Ectromelia virus SPI-2 protein causes lethal mousepox by preventing NK cell responses. *Journal of Virology*, 85(18), 9351–9363. https://doi.org/10.1128/JVI.00746-11
43) Moerman, D. E. (2009). *Native American Ethnobotany*. Timber Press.
44) Moss, B. (2013). Poxvirus DNA replication. *Cold Spring Harbor Perspectives in Biology*, *5*(9), a010199.
45) Moss, B. (2013). Poxvirus DNA replication. *Cold Spring Harbor Perspectives in Biology*, 5(9), a010199. https://doi.org/10.1101/cshperspect.a010199
46) Muruganandam, A. V., Kumar, V., & Srivastava, A. K. (2001). Effect of *Euphorbia hirta* on milk production in lactating rats. *Journal of Ethnopharmacology*, 76(1), 71–73. https://doi.org/10.1016/S0378-8741(01)00211-2
47) National Research Council. (1992). *Neem: A tree for solving global problems*. National Academy Press.
48) NatureServe. (2023). *Sarracenia purpurea* species profile. Retrieved from https://explorer.natureserve.org
49) Palit, G., Singh, S., & Katiyar, S. K. (2005). Anti-diarrhoeal activity of *Euphorbia hirta* extract. *Indian Journal of Pharmacology*, 37(1), 36–41. https://doi.org/10.4103/0253-7613.13853
50) Parekh, J., & Chanda, S. (2007). Antibacterial and phytochemical studies on twelve species of Indian medicinal plants. *African Journal of Biomedical Research*, 10(2), 175–181.
51) Parker, R. L. and Plowright, W. (1968). The epizootiology of ectromelia (mousepox). *The Journal of Hygiene*, *66*(1), 99–113.
52) Parker, S., Siddiqui, A. M. and Emerson, G. L. (2013). The mature virion of ectromelia virus, a pathogenic poxvirus. [Journal name and volume missing — please provide for full citation.]
53) Parker, S., Siddiqui, A. M., & Emerson, G. L. (2013). The mature virion of ectromelia virus, a pathogenic poxvirus. *Journal of Virology*, 87(19), 10260–10270. https://doi.org/10.1128/JVI.01286-13.
54) Peterson, C. N., Day, S., Wolfe, B. E., Ellison, A. M., Kolter, R., & Pringle, A. (2008). A keystone predator controls bacterial diversity in the pitcher-plant (*Sarracenia purpurea*) microecosystem. *Environmental Microbiology*, 10(9), 2257–2266.
55) Schnell, D. E. (2002). *Carnivorous plants of the United States and Canada*. Timber Press.
56) Subapriya, R., and Nagini, S. (2005). Medicinal properties of neem leaves: A review. *Current Medicinal Chemistry – Anti-Cancer Agents*, *5*(2), 149–156. https://doi.org/10.2174/1568011053174828
57) Sundaravalli, S., Suresh, S., and David, K. (2010). Neem oil poisoning: A case report. *Indian Pediatrics*, *47*(6), 515–517. https://doi.org/10.1007/s13312-010-0094-z
58) Welsh, R. M. and Regner, M. (2011). Mousepox: A model for understanding poxvirus pathogenesis and immune evasion. *Immunological Reviews*, *239*(1), 51–64.
59) White, B. (2025). Mpox virus (MPXV): Comprehensive analysis of pandemic risks, vaccines, and proactive measures for future outbreaks. *Naunyn-Schmiedeberg's Archives of Pharmacology*.
60) World Health Organization. (2025). *Infection prevention and control and water, sanitation and hygiene measures during mpox vaccination activities*. Geneva: WHO.