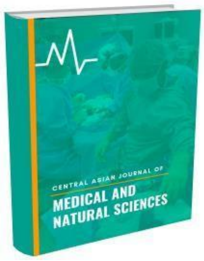

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Article

Understanding Parasitic Infections: The Ultimate Guide to Pathogenesis and Spread

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Abstract: Parasitic infections remain a global health challenge, affecting millions of individuals annually and imposing significant socioeconomic burdens. This study employs a comprehensive review approach to investigate parasitic infections. This comprehensive study delves into the mechanisms of pathogenesis and transmission strategies employed by various parasitic organisms. It explores the interplay between parasite biology, host immune responses, and environmental factors that facilitate infection spread. Key focus areas include the molecular pathways of host invasion, immune evasion tactics, and the role of vectors in disease propagation. The review also highlights advancements in diagnostic techniques, treatment strategies, and preventive measures, offering a holistic understanding of parasitic diseases and paving the way for innovative approaches in public health management.

Keywords: Parasitic Infections, Pathogenesis, Immune Evasion, Disease Transmission, Host-Parasite Interaction, Vector-Borne Diseases

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1. Introduction

Parasitic infections are an overwhelming health problem, especially in tropical countries, which have adverse effects on the socioeconomic status of the infected individuals. Some of these infections are public health challenges worldwide, including in the developed world. Human parasitic infections have existed as long as human beings have and have influenced human evolution. It has been shown through fossil findings and parasitological necropsies of desiccated humans, mummies, and loess that the oldest known infectious diseases are parasitic infections, with the parasites having evolved with humans, entering the genus Homo and other primates more than 50 million years ago. In the epidemiology of human parasitic diseases, host factors, environmental factors, and parasitic life-cycle aspects play a role [1]. These life-cycle aspects are parasite-related, vectors, and the transmission process. In addition to data on the epidemiology, pathogenesis, diagnosis, and treatment, it is important to understand the economic and public health aspects of human parasitic infections, present and future control scenarios linked to public awareness for disease prevention. This review provides information on the pathogenesis and spread of these challenging infectious diseases among blood, tissue, and intestinal parasitic infections [2,3].

2. Materials and Methods

This study employs a comprehensive review approach to investigate parasitic infections, focusing on their pathogenesis and transmission mechanisms. The research integrates data from various sources, including scientific journals, epidemiological studies, and historical accounts of parasitic evolution. Key methodologies include comparative analysis of molecular pathways in host-parasite interactions and synthesis of advancements in diagnostic techniques and therapeutic interventions.Statistical and observational data from global health reports are analyzed to assess the socioeconomic impacts of parasitic diseases, particularly in resource-limited settings. The study also explores vector dynamics and environmental factors contributing to disease spread, supported by graphical representations and case studies.The narrative approach ensures a holistic understanding of parasite-host relationships, combining biological insights with public health implications. This multidisciplinary framework aims to provide actionable strategies for improving prevention, management, and control measures for parasitic infections, contributing to global health policy and innovation in the field.

3. Results and Discussion

Definition and Classification of Parasites

A parasite is the biological meaning of the concept of an organism that lives in or on other organisms, the true purpose of which is to parasitize the host, i.e., it extracts from the host products of direct metabolism of the tissues or products synthesizing metabolic processes. The term "parasitism" comes from Greek and means "in addition to feeding." In reality, this is one of the types of nutrition in the natural environment. It consists of various forms of interrelationship between organisms of different species, in which one (the parasite) benefits while the other (the host) is harmed but, in most cases, not killed. Another kind of feeding involves mutualism between two different organisms. The latter presents a complex and contradictory ecological problem since they combine different ecological links that occur between species in various relationships. In these different types of connections, one of the parties benefits. Parasitism is a special species relationship [4].

Understanding the differences and diversity of parasites, or, in other words, the unique properties of protozoa and helminths, which are their attributes, makes it possible to use the knowledge more effectively in medical practice. How far the scientific study of this fascinating world, the world of living organisms, has come became clear to the professional community only a few decades ago. Great discoveries and insights have led humanity to significant changes in the understanding of the uniqueness of eukaryotes that differ from the multicellular organisms we are used to observing. In this case, the unicellular organization of the cells that make up the animal body, as well as unusually "simple" structural characteristics, if analyzed schematically, play a role. The simplification is not the result of the degradation of higher-order organisms, but shows an amazing adaptation to specific environmental conditions, which in turn are within the body of multicellular animals [5,6].

Global Impact and Public Health Significance

Introductory narrative

Parasitic diseases, both those caused by eukaryotic parasites and some traditionally thought of as caused by "protozoa," have a significant impact on the world. These diseases cause a high burden of illness: they afflict the poorest of the poor, often living in remote rural areas, urban slums, or conflict zones. Since these diseases almost exclusively affect the poor, there is little financial incentive for pharmaceutical companies to invest in the development of new pharmaceutical agents to treat them. The health impact of these diseases also spans physical, academic, and economic domains [7].

In addition to the burden of disease as we conventionally understand it, other co-symptoms or sequelae can negatively impact growth, cognitive function, childhood nutritional status, and athletic and other physical abilities. Some believe the neglected tropical diseases should also be classified as a broader set of "interfering conditions." They rob the poor of a significant part of their health and are considered threatening to national security because of the impact they could have on global and national economies [8]. Therapy for these diseases is often less than perfect. Some medicines have serious side effects, and our ability to keep up with other species as they continue to evolve is not as strong as we would like to believe. Many of the drugs used to treat these infections are old and have been superseded by newer, better, and more effective agents used to control other infectious diseases. Despite the interest they generate among the one billion poorest people on earth, the costs of treating these diseases are often the equivalent of more than a month's salary [9,10].

Parasite Life Cycles

Life cycle provides an understanding of an organism's life cycle, development, and reproductive processes. This is important for forecasting the condition of their numbers and especially for developing methods to control their undesirable propagation. It is also useful in detecting some interspecies links that can be the grounds for an exchange of infectious diseases between these species. In the case of infectious diseases, the parasite life cycle indicates the moments of disease susceptibility. Knowledge of their biological properties is important when controlling and forecasting the numbers of insects, the malignant organism species that can transmit parasites, and to support humans and animals affected by parasitic diseases. The definition of their roles and the powers of the vectors of the parasites within the area can contribute to the control of the vectors used in management programs. Arthropod characteristics such as adult and immature forms, type of glutted feed, where the egg is laid, how many white eggs are laid over a certain time, offspring, and pathogens such as parasites appear in excretion products. Symptoms of parasite-induced diseases produce answers to some basic questions [11]. These answers also have important interactions between predictive information and management choices, whether it is an information or operational alternative, due to the diversity inherent to arthropods and their mechanisms among all parasites. They allow making compromises that are influenced only by direct and indirect alternatives by understanding this urban pest and the skills of understanding development restrictions, response capabilities, and feedback [12,13].

Direct and Indirect Life Cycles

Humans are hosts to a myriad of different parasitic organisms. In general, these parasitic infections are classified as either ecosystem or community organisms, which means that depending on the type of host, a parasitic infection can be nonthreatening and even beneficial, or conversely, it may be highly parasitic and dangerous. Through consuming contaminated water or food, contact with infected animals or microbes, traveling to tropical tourist destinations, and poor sanitary habits or living conditions, humans, especially children, are at great risk of acquiring a parasitic infection. The life cycles of parasites can typically be divided into two categories: direct or indirect. During a direct life cycle, larval stages continue directly onto the next life cycle stage, with either no or the original host species involved. A direct life cycle transmission of disease usually involves fecal-oral ingestion, such as pinworms, hookworms, trichurids, and ascarids, or skin penetration, such as those initiated by adult worms that lay eggs that become trapped in water [14]. Conversely, whether the circular form of the development of intermediate host species is required for parasites to develop an indirect life cycle. During an indirect life cycle, when a host ingests the infective stage during grazing or hunting, the intermediate host can participate in the life cycle concerning grazing, and the next stage of the parasitic larvae is threatening. After consumption, the infective form of the parasite is acquired, progresses through the life stage, and continues. Entering the next stage, the definitive host eats the infective stage. It is common to see this pathway in flukes, tapeworms, and roundworms [15,16].

Key Stages in Parasite Development

Incursion: This is the initial stage in which the parasite invades the host. It is typically achieved through decreased host immune function, for example, a reduction in macrophage or neutrophil activity, or through other channels such as reproductive biology, where the parasite utilizes a host reproductive structure to access the next host. Once the parasite has infected the host, realization of the hospitable environment and provision of the resources necessary for the parasite's survival are critical. Here again, replication is a central theme [17]. Most mature-stage parasites have finite active times, making reproduction necessary for continued life. Proliferation: It is a key part of parasite establishment and disease and has the capacity to completely debilitate, if not kill, the host for the promotion of parasite survival and transmission. Parasite numbers do not always reach the levels required to negatively affect host health, and it is possible for proliferation to be negatively regulated. In fact, this interaction may be a case example for the cost of resistance hypothesis. Post-zygotic, non-infective larval stages are sometimes found in definitive host guts or other niche environments specifically to prevent proliferation in the intermediate host. These stages consume gut resources and occupy restricted space, so fewer infective stage parasites can develop [18,19].

Host-Parasite Interactions

Parasitic helminths cause chronic and sometimes lethal infections in their hosts. These large animals have developed a multitude of complex defense mechanisms, both passive and active, to maintain the infection for a long time in order to complete their life cycle. While host-parasite interactions with bacteria or viruses as model parasites can be studied in much more detail, it is much more complicated to work with parasites. Fortunately, technical developments have made it easier to understand these interactions. The development of efficient in vitro culture systems and the introduction of transgenics and knockouts in mouse models have greatly improved our understanding of these complex and fascinating interactions [20].

The fine-tuning of the host immune response is essential for the survival of helminths, and worms have developed a plethora of local and systemic modulation strategies targeting immune responses. Regulation of early developmental stages and the immune system are prerequisites for the success of the host-parasite interaction. In addition, different tissue environments, distinct effector mechanisms, and the role of the commensal flora, as well as interactions of the host-bacterial-parasite, have to be coordinated in such a way that the worm is able to mount a survival strategy [21,22].

Immune Responses to Parasitic Infections

Parasites have developed complex strategies that help them evade the host’s immune defenses. A genetic component is also required for resistance to infectious diseases caused by parasitic worms. Helminth parasites are thought to establish chronic infections in part because they induce a strong type 2 immune response. A conserved mechanism common to many infections involves activation of pattern recognition receptors on immune cells. This triggers activation of key transcription factors that promote expression of genes that drive different aspects of the immune response [22].

The strong type 2 immune response induced during helminth infections is characterized by a production of type 2 cytokines that promote parasite expulsion by, for example, causing peristalsis of smooth muscles, preventing worm establishment and fending off the immune response. The pathological consequences of this are often prevented by strong regulatory responses. These immune responses to helminth infections are triggered by specific molecules on the surface of parasites. Pattern recognition receptors detect these parasite molecules and help to initiate type 2 activation. Any defect in recognition or regulation of helminth infections at a genetic level can effectively fine-tune and regulate the host’s immune response to helminth parasites. A correct balance is imperative for such host-parasite relationships. Helminth infections can also effectively modulate host immune responses to bystander inflammatory diseases [23,24].

Mechanisms of Evasion and Survival

Because parasitic infections establish for long periods of time in the host, they have adapted sophisticated mechanisms to suppress immunity and evade detection, allowing for establishment and survival inside the host. The mechanisms differ from organism to organism. Parasites possess unique adaptations to survive and can stimulate an immune response that is at least partly neutralized by their survival strategies [25]. Host cells play an important role in supporting the development and survival process of many parasites, or play a key role in the spread and transmission between hosts. Helminth proteins can directly stimulate innate responses, which can trigger the development of adaptive responses [26,27]. However, evasion strategies are important to support their breaks in any successful immune response. This survival strategy interferes with the ability to process antigens and to block the direct presentation of the peptide to the major histocompatibility complex. Cell signals can suppress T-cell transmission and fight against action. Additionally, the helminth protein can block the transmission of T-cell interaction with the antigen [28,29].

Parasitic Pathogenesis

How do parasites function and cause harm through the generations? How long have they been killing humans and other animals? An examination of parasitic pathogenesis explores the nature of parasites in depth and reveals how and why they cause sickness and even death. Comparative evolutionary exploration highlights the means by which single-celled parasites use diverse arsenals at every level of attack; complex multicellular parasites using an equally wide variety of strategies and tactics have followed in their footsteps. Inherited pathogenicity in the form of transmissible genes that confer benefit upon the root was identified as the driver for the majority of model conditions, from toxic proteins to cells intent on manipulating the host [30].

These findings point to an ongoing selective dialogue, or evolutionary arms race, to which both parties contribute. Understanding the nature of the products of this race at each stage can help us develop better strategies against the enemy, whether they act externally or as a fifth column, regulated shapes or silently integrate into our DNA. These tactics of both hosts and parasites are set against the backdrop of environmental conditions that change with potential rapidity and that may include equally potent enemies. Focusing on the specific needs of parasites shaped by their clandestine lifestyles, parasitic occupants of each environmental niche occupy a place staggered on the unit of natural selection with their evolutionary partners. Many of the strategies parasites use to confuse, damage, or facilitate their host could only have been perfected after some form of communication had been established; indeed, there is increasing evidence that platforms other than those recognized by the host can be created [31,32].

Tissue Invasion and Damage

A parasitic infection starts with the amount of tolerance hosts have for these intruders, as the first act is to overcome the host’s defenses so it is capable of entering its target tissues. Pathogens need to adhere to and invade the epithelium of the hosts in order to survive and replicate. Some of the first points of contact occur in mucous membranes, which are therefore sites of important defenses against infection. Mucous barriers are physically and chemically capable of delaying and trapping migrating zoites. Epidermal cells secrete antimicrobial peptides such as the beta defensins, which also work on remodeling cell structures and inhibiting movement. Cuts, scratches, and mucosal sites through the respiratory and digestive tracts offer parasite larvae entry to the tissues underneath the barrier. Parasites, primarily nematodes and cestodes, excrete factors that damage the surface and/or are able to migrate into the tissues locally [33]. Most damage is due to the migration of developmental stages, for example, as the excretory/secretory glands of parasites migrate between host vaccine administration and host generation. Interactions between migratory parasites and the physiological changes inflicted by larvae involve helminths toll-like receptor signaling [34,35].

Toxin Production and Effects

Thus far, we have focused on the infection strategies and host-parasite interplay that primarily involve the host's chemical and biochemical structures. Parasitic organisms also deliver potent toxins to their hosts, and it seems likely that these toxins are an adaptation that has evolved to give the parasite either an immediate survival advantage or a lasting means of discouraging host defense strategies. Toxins, like the other parasite delivery strategies, can be highly complex, some being expressed from the parasites themselves, and others either synthesized or scavenged from host tissues. They then cause a range of effects that can harm the host in various ways. Some toxins create an environment that is favorable to the infective form of the parasite; some are active on the host's epithelial layer, disrupting it to further the parasite's ability to feed on the host's bodily fluids; other consequences include loss of behavioral and immune functions and the modulation of the immune response [36].

It is clear that the study of parasite toxins in the immediate host-parasite interaction is still an emerging field and that a deep understanding of many of these toxins is not yet fully achieved. However, it is an area that is rapidly expanding. There are numerous known and hypothetical parasite toxins acquired from a diverse range of parasites: parasitic protozoa, parasitic helminths, and parasitic arthropods, and the full taxonomic complement of these species will be covered throughout this section. Briefly, however, parasites show a number of heavily modified and specialized adaptations to develop and successfully survive in their hosts. Furthermore, because these parasites are specifically evolved to colonize host systems and control, modify, or simulate host cell functions, they are also the best models for the determination and understanding of the molecular strategies developed by these organisms [37,38].

Modes of Transmission

Transmission of parasitic infections greatly depends on the particular life cycles of the organisms. Therefore, it is important to understand the life cycles not only for epidemiological studies trying to prevent these infections, but we should also be aware of the risk to our pets because infected canines and felines can be a great source of domestic or farm life cycle completion. The most important transmission ways of parasitic infections in pets are the following: infectious eggs, larvae, oocysts, or cysts can contaminate the environment. Both canines and felines are able to defecate outdoors, and they can spread soil with fecal material in the environment by actively scratching the ground. It is important to mention that the size of the territory of canines and also of cats living outdoors is considerable, so these animals can potentially contaminate a large part of arable land around [39]. Surface mining can lead to the accidental ingestion of eggs of Toxocara larvae, infected frogs, and toads; waterfowl babies are able to get infected by ingesting L3 Toxocara larvae. When neither animals living in the territory can access the contaminated soil, it can become a source of infection for grazing animals or even for children playing in squares and parks wherever they are traveling to and from [40,41].

Vector-Borne Transmission

There are many modes of transmitting parasites to the next host. Some of the major forms of transmission in regard to parasites are oral, fecal-oral, skin, mucous membrane, gravid proglottids, horizontal direct contact, sexual, parent to offspring, and vertical. However, there are far more ways that parasites transfer from one host to the next that are relevant and important in understanding the life cycle, pathology, and transmission. Mice, ticks, and even some protozoa, along with leeches and a large majority of the flukes, employ a method that we refer to as vector-borne transmission. Of course, the most common vector-borne transmission is the transmission of parasitic infection through mosquitoes [42].

Vector-borne transmission is the process where an organism transfers a pathogen into another organism but does not get infected itself. The vector of the pathogen is usually an arthropod such as a fly or mosquito, and it facilitates the transmission of the parasite, typically distanced over a larger area. Certain species of ticks are vectors of over one hundred different pathogenic species. They rely on animals such as squirrels, deer, and mice to complete their life cycle. If contagious males complete their cycle, females traffic organisms to the next victim by feeding off their host and transmitting the organisms into the next host. This behavior perpetuates the life cycle of flukes between wildlife, livestock, and human beings. This is then the likely transmission causing schistosomiasis. Certain flukes infect livestock, and the hosts can give the infection to human beings through fecal matter. Human beings excrete parasite eggs, which then hatch and infect snails. The life cycle of the parasite has then been completed, which assures the continuation of the parasite and its ability to transmit itself into many different creatures [43,44].

Waterborne and Foodborne Transmission

Waterborne and foodborne transmission - Many parasites are spread through water and food supplies or via vectors or carriers that rely on water. In this way, some parasites can have fecal-oral or vector-borne transmission, but the actual transmission of the infective stages typically depends on an aquatic environment. The ingestion of viable infective stages such as cysts, oocysts, or eggs usually leads to parasitic infection of the intestine, and many of the stages will excyst or hatch only after being ingested. Infective stages of several parasitic protozoa and helminths are conserved and can be effectively killed through various wastewater treatment processes, reducing the risk of infection. The scarcity of clean water can force individuals to use pathogen-rich water sources for cooking, bathing, and hygiene, which can lead to ingestion of the infective stages and continued transmission of multiple waterborne infections. Foodborne transmission typically involves the ingestion of infective stages on food such as fruit, vegetables, or meat, and the transmission of parasites spread via food can be broken or reduced through effective cooking and cleaning methods. Contaminated surfaces can be a source of parasite transmission, and how food is handled and prepared can lead to infection. Finally, a large number of parasites are spread by arthropod vectors such as mosquitoes and flies that rely on water for part of their life cycle. These parasites will likely factor into future outbreaks and become more prevalent issues due to environmental changes and setbacks resulting from the continued struggle to establish clean, sustainable water supplies [45,46].

Epidemiology and Surveillance

The epidemiological characteristics of parasitic infections are quite intricate as they are influenced by various factors relating to the host, parasite, and environment. These infections are prevalent in virtually all animal species in the world. Notably, animals play host to numerous parasites, and conversely, many animals as diverse as birds and humans can be hosts of some of the same parasites. Wild animals, zoo animals, and pets also host many wild-type parasites, putting zookeepers, veterinarians, animal handlers, and pet owners at risk of becoming infected. The abundant reservoir of parasites in the environment poses a critical threat to human health, and insufficient epidemiological monitoring constitutes a public health issue. The behavior of humans and omnivores likewise increases the risk of parasite infection [47]. Surprisingly, the vast diversity of parasitic life cycles ensures that, from an evolutionary perspective, host switching and zoonosis events occur more frequently for parasites than for pathogens. As a result, some parasites are able to thrive in unfamiliar hosts, flourish, and even persist over the long term by inducing minimal harm to the secondary host's survival. These 'opportunistic' parasites are an important subset of agents, adding much to the complexity of biological interactions among organisms in the ecosystems of the world. Such interactions are of biological interest and have significant implications within the realms of public policy, environmental conservation, and the effective implementation of environmental regulations [48,49].

Incidence and Prevalence Data

Of the recognized number of parasites, many are considered of great importance in veterinary medicine. Interest in this area was primarily based on the need for effective control and eradication of these parasites from a variety of hosts. A presumption frequently made is that parasites are uniformly distributed among host populations. With some exceptions, this is probably not true, and data on the incidence of infections in some host-parasite systems indicate a clumped or negative binomial distribution. Prevalence data from taxonomic groups of parasites are rarely subjected to more than the simplest of statistical treatments and usually consist of arithmetic means. These data frequently have a wide variation in their constituent figures. This variation is another aspect that is seldom discussed [50].

These figures are frequently high and significantly higher than statistical population theory predicts, given a positive binomial distribution. It is suggested that qualitative considerations do not provide much help in predicting host-parasite population relationships. Establishment of the residence requirement, immigration, and transmission of parasites, and hence maintenance of some parasites, especially on intensively managed farms, may be due to processes that are not necessarily predictable from models and may differ from one taxon of parasite to another. Thus, the importance of good quality scientific data on many aspects of the host-parasite relationship is re-emphasized. In the future, statistics based on computer analyses may provide more reliable relationships [51,52].

Surveillance Strategies and Tools

The decision as to whether surveillance of human hosts is warranted when identifying pathogen reservoirs is complex. If the reservoir does not act as a zoonotic bridge, then the implications of detecting an infection in the reservoir are unclear. Surveillance describes a systematic, quantitative process of monitoring the health and well-being of populations and is central to public health. Its two functions are notifiable disease surveillance and the implementation, testing, and ongoing monitoring of specific preventive control programs. The outcome of surveillance should lead to correct attribution of causality to attrition of health and well-being, reductions of suffering, and reduction in the impact of diseases at the population level. The process requires multiple steps, and especially prior to identifying pathogen reservoirs, its ability to prevent disease emergence is reliant on comprehensive evidence for public health action [53].

The concept of external population surveillance applies equally to surveillance of endemic, non-zoonotic infections in host reservoirs. Furthermore, in some instances, surveillance activities are performed in order to 'prove a negative' in order to implement or reduce the frequency of medical eradication programs. The logic of this approach runs counter to preventive medicine in which treatments or control measures are implemented on the basis of scientific evidence that they do work. Development of effective prevention programs requires that public health officials have high-quality information readily available to ensure that they can enact vigilant, early intervention that is epidemiologically linked to evidence of the presence of the pathogen [54,55].

Clinical Manifestations

The spectrum of consequences of parasitic infection is wide, encompassing the pathogens' effects on host tissues, any associated hyperimmunity, and the potential for inducing immunosuppression. From a clinical aspect, this range spans from completely asymptomatic infection to rapidly fatal or slowly progressive and agonizing or deforming disease. A single species or genus might cause only one of such variables. However, most parasites can cause several forms of disease as infections differ in the amount of exposure to infective stages, the number of resulting parasites, the susceptibility of the host because of its age, general state of health, pregnancy, or concurrent disease, as well as the immune complex that has been induced due to autoinfection several times. In addition, many parasites of the same group, even species, can present differential, or even exactly the opposite, clinical manifestations. These differences are not only in their own spectrum of possible pathological alterations, for example, in terms of site preference, ultimate outcome of migration, as well as immunomodulation; they might determine the outcome and the response by the host to other pathogens [56,57].

Duration is an important aspect of the clinical characteristics of parasitic infections, either because they are brief and self-limited, so they can be ignored in everyday medical practice unless they are several in an acute case, or because the parasites causing the infection are with the patient for a very long time. As many of them cannot be cured but only controlled, and this control is often enabled only by a correct diagnosis, also timing in a patient's clinical history. This part of the clinical characteristics has to be present in every microenvironmental human infectious disease in the anthropophylum. The pathologists use a galaxy of terms to specify kinds of parasitic infections, different from one another for the clinical presentation, severity, and duration. In many cases, however, diagnoses can only be provisional and as per the criteria above, or in combination with the comparison of other test results [58].

In this endless world of manifestations of parasitic infections, a brief guide to help the clinician is a useful tool. In it, we have reported respective clinical diagnosis and other clinical aspects of the liver-dwelling flukes, about the hosts of Taenia solium and T. saginata, about the possible coincidence between sarcocystosis and an inflammatory muscle disease, and, last, about the occurrence of occult and overt autochthonous chronic human fascioliasis [59].

Symptoms and Diagnostic Criteria

Other more specific symptoms of E. histolytica infection include diarrhea (with or without blood), inflammation, and ulceration of the rectum and colon. Rectal prolapse is common in children; necrotizing infection and perforation are common in neonates [60]. Approximately 10% of those with an invasive infection have extensive symptoms, such as extra-intestinal abscesses in the liver or other organs; these cases may be fatal. This form of amoebiasis is referred to as invasive extraintestinal amoebiasis. Pre-existing malignancy, immunosuppressive drugs, and malnutrition are some of the influencing factors that turn a typical infection into invasive extraintestinal amoebiasis. Generally, malnutrition is both a significant cause and result of amoebiasis, and infection is typically exacerbated by severe flagellate imbalance [61,62].

Complications and Long-Term Effects

Parasitic infections can cause numerous complications. The complications of parasitic diseases are varied and interesting. The different interactions between the host and the parasites are remarkably intricate. Even though some complications are routinely anticipated, others are not. Some complications can be life-threatening, while others are associated with long-term debilitation or the development of other conditions. Even after the parasite is gone, echinococcosis, cysticercosis, and fimbreasis are often long-lasting complications. Parasite-induced disease is a disorder that is imitated by conditions where the parasite plays a role in causing the disease. Several different types of tumors and masses are a result of parasites growing in the body tissues of humans [63].

Peritonitis, pericarditis, glomerulonephritis, obstructive uropathy, and mesenteric lymphadenitis are all well-established sequelae of ascariasis. Eggs are eradicated from the body, but once embryonated eggs hatch in any non-intestinal tissue, treatment may need to be launched. Host lung development can be severely interfered with by pulpal migration, which can be deadly. Pulmonary nematodiasis, like other zoonotic helminth diseases, is linked to diminished small airway function and high-resolution computed tomography irregularities in the affected persons. Cysticercosis, an infection of the host, not the human, is often a rapidly re-emerging complication of man. In the context of human encapsulation, the poultry tapeworm evokes an antibody response. Several toxins released by the parasite are also believed to have a detrimental impact on the host [64].

Diagnostic Methods

Before any medical treatment can be used, there has to be a proper confirmatory diagnosis after there is a clinical suggestion, a so-called reasoning for medical treatment. In cases of serious medical problems, parasitic disease was a diagnosis frequently made by the French expression, "clinique difficile," and it was said to develop by exclusion clinical method basis. Because the methodology, as we have briefly described, is complicated by many factors including: 1) some parasites have an impaired host, i.e., the hosts are less symptomatic; 2) not all organs are affected; 3) parasites prefer different seasons for invasion of the hosts; 4) on some occasions, together with some signs, there is a wide variation in their symptom severity; 5) immunocompromised people are infected with opportunistic organisms that normally would not be suspected. In parasites, any single parasite at any time alone and combined during a detailed clinical approach is generally preferred and rarely can provide many tests and treatments that are not clinically important together with a generalist or specialist parasitologist who can properly and easily analyze these data. Sometimes an internist should be directed especially by a parasitologist [65,66].

Microscopic Examination

There are a number of different methods of microscopy available for the examination of parasites. They provide, respectively, information on live parasites, their complexes, and their interrelations, something essential to the identification of the host and searching for suitable conditions for parasite development, as well as the fixation of parasite forms of practical interest for morphological studies. The selection of the adequate method will therefore be determined by the following factors: nature of the sample, specific purpose of the microscopy examination, panel of techniques and equipment available, and also the preparative steps taken in advance of the microscope observation [67].

According to the nature of the sample and specific purpose of the microscopy examination, we can focus on two types of microscopic analyses: ex vivo techniques applied to the observation of live specimens, i.e., living or controlled fixed parasites in their natural context, by means of direct visual opportunity, a microscope slide bored into the host integument or into lesions, or cultures, and in situ or histology applied to the observation of parasites that are too small, heavily pigmented, encysted, or altered by the preparative process that cannot be observed with light microscopy, but their forms and localization within the host tissues are of special interest for characterization of the infection [68].

Serological Tests and Molecular Techniques

The diagnosis of AL is often based on specific radiological findings, the parasite's ability to invade the deep layers of the humoral tissues, and a long history of persistence. Muscular EL diagnosis is mainly based on clinical signs, muscle air images, and the history of eating raw and/or undercooked paratenic or carnivorous hosts [69].

Haematological and Biochemical Tests Haematological tests are not specific; thus, their significance in the diagnosis of F. hepatica-infected humans is modest. In most of the studied cases of F. hepatica, an increase in the white blood cell count, particularly eosinophilia, was observed, arising in response to inflammatory mediators secreted by the parasite's host immunity. Clinical biochemistry often demonstrates increased alkaline phosphatase, bilirubin, gamma-glutamyltransferase, transaminases, and creatinine kinase, reflecting various affected organs. However, haematological and biochemical tests often may not reveal any specific indication of the liver and biliary tract inflammation process [69].

Serological Tests Serological tests are the most practical diagnostic tools. The detection of specific antibodies or antigens in a suitable test system has significantly increased the potential for the early diagnosis of these parasites in definitive, paratenic, and even aberrant hosts. A variety of serological tests are available, most of which are used in animals and are not fully validated for human samples. Serological tests include the fluke URS-1 enzyme-linked immunosorbent assay for F. gigantica. This test uses CSF of experimental mice and IgG from cattle, goats, and human samples as primary antibodies and rabbit anti-cattle IgG as the secondary antibody. A TFPA test has been described for F. gigantica that identifies a complete antigen. Fasciola hepatica fluke antigens are prepared from both fresh and frozen adult flukes [70].

Treatment and Management

In general, the treatment for a parasitic infection is difficult due to the lack of therapeutics and due to the shared cells and systems between mammalian hosts and these eukaryotic parasites. One must be careful when picking an effective drug as they can also have a toxic effect on the host. Popular therapeutics include anthelmintic drugs, drugs that target various aspects of ATP production or stability in protozoans, anti-infective inhibitors of rigidity in certain parasites, non-structural compounds interfering with specific activities in others, and essential components in various pathogens. Despite possible toxic side effects, chemotherapy is the most common method and is most effective in the early stages of protozoal infection and is used to eliminate the chances of relapse of helminthiasis [71].

To help support mammalian host effectiveness, one can take the next steps after chemotherapy of parasitic infections which help the host adapt and alter the expression of their immune response through either molecular mimicry or mediated apoptosis. A few downstream strategies that are involved include probiotics to alter the flora of the gut, immunostimulants to boost immunity in food animals, vaccines that block infection by causing an adaptive immune response, and passive immunization through various immune therapies. In order to fight against foodborne parasitic diseases at each stage, many fields of our scientific world must collaborate to create a better understanding of pathogenesis, lysosome escape and host manipulation, target validation, and veterinary diagnostics [72].

Antiparasitic Drugs and Therapeutic Approaches

Once a parasitic infection is discovered, treatment establishes the most urgent task. Antiparasitic drugs have been a target for drug development since modern chemotherapy began in the early 1900s. Because parasites share many features of their biology with other organisms, treatment is challenging because it is necessary to kill the pathogens without doing harm to the hosts. In many ways, antiparasitic drugs are unique in that they are used to treat infections instead of treating the host. Antiparasitic therapy usually targets the life cycle or the process of reproduction. This characteristic of biology is important because the number of progeny produced by parasites is a critical factor [73].

Common targets for antiparasitic drugs are the immune system, the parasite life cycle, and the metabolism. Variability between individuals, conditions between hosts, and the efficacy of therapies administered are determined by a multitude of external factors. Early progressive treatments of the most effective drugs at the appropriate dose are important because single parasite-resistant organisms are developing with the use of agents. New approaches now emphasize the combination of drugs with various effects against the same pathogen or complementary prophylactic measures. Moreover, environmental and genetic resistance of the susceptible animal populations can influence therapeutic success [74].

Preventive Measures and Control Strategies

Parasitic infections must initially be controlled by breaking the cycle of transmission. Generally, preventive measures must be taken to prevent humans from becoming infected with contaminated food or water, from being affected by vectors, or from coming into direct contact with parasitized domestic or wild animals. Infection is usually difficult to control in rural areas, where people live in close association with both domestic and wild animals and under poor sanitary conditions. It is thus nearly impossible to eradicate real reservoirs of infection in such areas, and it is hard to protect humans from any vectors present. The population can be mobilized if individuals understand the characteristics of the infectious agents and the routes of transmission by which humans are infected. Cleanliness and other measures, such as slaughter, elimination, or control measures, can be regarded as the obvious and practical ways to control causal factors, vectors, or carriers of the diseases [75].

Several specific measures can be taken to control the risk of parasitic infections at the local, national, and international levels. Education and dissemination, the provision of drugs, the control of food and water, and the disinfection of water, suppression of carriers in the environment, and the vaccination of the relevant animal species and the target host have all been used to control a number of major parasitic infections. Practicing good sanitation and consuming safe food and potable drinking water are still recognized as the best ways to prevent many parasitic infections. Safe human waste disposal is the keystone of the infrastructure of health promotion and provides a first line of defense against the risks of transmission of parasitic pathogens. Controlling the human reservoir for pathogenic parasites is essential for the success of preventive measures. Control strategies have generally been effective only if the relationships between the ecological niches of all of the factors involved in the intricate cycles of transmission are understood. Given this complexity, experts in medical entomology, tropical parasitology, public health, and infectious disease control have often had to work together in the field and in the laboratory [76].

4. Conclusion

Parasitic infections remain a global health challenge, driven by intricate mechanisms of pathogenesis and efficient transmission strategies. This study highlights the complexity of host-parasite interactions, where parasites exploit molecular pathways to invade, adapt, and evade immune responses. Environmental factors, social conditions, and vector dynamics further contribute to the widespread prevalence of these infections. Advancements in molecular diagnostics and therapeutic interventions have significantly improved the management of parasitic diseases. However, gaps in prevention and control, particularly in resource-limited settings, necessitate ongoing research and innovation. Strengthening public health systems and fostering global collaboration are essential to address the socioeconomic and health impacts of parasitic infections. This comprehensive understanding provides a foundation for developing targeted strategies to break the cycle of transmission. By integrating scientific research with public health initiatives, we can pave the way for effective prevention, improved treatment outcomes, and the ultimate reduction of parasitic disease burdens worldwide.

REFERENCES

[1] Bouwmeester, Mark M., et al. "Collateral diseases: aquaculture impacts on wildlife infections." Journal of Applied Ecology 58.3 (2021): 453-464.

[2] Sato, Shigeharu. "Plasmodium—a brief introduction to the parasites causing human malaria and their basic biology." Journal of physiological anthropology 40.1 (2021): 1.

[3] Alvar, Jorge, et al. "Implications of asymptomatic infection for the natural history of selected parasitic tropical diseases." Seminars in immunopathology. Vol. 42. Springer Berlin Heidelberg, 2020.

[4] Alvar, Jorge, et al. "Implications of asymptomatic infection for the natural history of selected parasitic tropical diseases." Seminars in immunopathology. Vol. 42. Springer Berlin Heidelberg, 2020.

[5] Arsenopoulos, Konstantinos V., et al. "Haemonchosis: A challenging parasitic infection of sheep and goats." Animals 11.2 (2021): 363.

[6] Vuitton, Dominique A., et al. "International consensus on terminology to be used in the field of echinococcoses." Parasite 27 (2020).

[7] Gessese, Abebe Tesfaye. "Review on epidemiology and public health significance of hydatidosis." Veterinary medicine international 2020.1 (2020): 8859116.

[8] Hotez, Peter J. Forgotten people, forgotten diseases: the neglected tropical diseases and their impact on global health and development. John Wiley & Sons, 2021.

[9] Alvar, Jorge, et al. "Implications of asymptomatic infection for the natural history of selected parasitic tropical diseases." Seminars in immunopathology. Vol. 42. Springer Berlin Heidelberg, 2020.

[10] Shokri, Azar, Sadaf Sabzevari, and Seyed Ahmad Hashemi. "Impacts of flood on health of Iranian population: Infectious diseases with an emphasis on parasitic infections." Parasite epidemiology and control 9 (2020): e00144.
[11] Trasia, Reqgi First. "The role of the parasite life cycle in pathogenesis of infectious diseases." Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi 7.1 (2022): 443556.
[12] López-Osorio, Sara, Jenny J. Chaparro-Gutiérrez, and Luis M. Gómez-Osorio. "Overview of poultry Eimeria life cycle and host-parasite interactions." Frontiers in Veterinary Science 7 (2020): 384.
[13] Valkiūnas, Gediminas, and Carter T. Atkinson. "Introduction to life cycles, taxonomy, distribution, and basic research techniques." Avian malaria and related parasites in the tropics: ecology, evolution and systematics (2020): 45-80.
[14] Trasia, Reqgi First. "The role of the parasite life cycle in pathogenesis of infectious diseases." Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi 7.1 (2022): 443556.
[15] Santa, Maria A., et al. "A review on invasions by parasites with complex life cycles: the European strain of Echinococcus multilocularis in North America as a model." Parasitology 148.13 (2021): 1532-1544.
[16] Benesh, Daniel P., Geoff Parker, and James C. Chubb. "Life-cycle complexity in helminths: What are the benefits?." Evolution 75.8 (2021): 1936-1952.
[17] Cerutti, Aude, Nicolas Blanchard, and Sébastien Besteiro. "The bradyzoite: a key developmental stage for the persistence and pathogenesis of toxoplasmosis." Pathogens 9.3 (2020): 234.
[18] Mévélec, Marie-Noëlle, Zineb Lakhrif, and Isabelle Dimier-Poisson. "Key limitations and new insights into the Toxoplasma gondii parasite stage switching for future vaccine development in human, livestock, and cats." Frontiers in cellular and infection microbiology 10 (2020): 607198.
[19] López-Osorio, Sara, Jenny J. Chaparro-Gutiérrez, and Luis M. Gómez-Osorio. "Overview of poultry Eimeria life cycle and host-parasite interactions." Frontiers in Veterinary Science 7 (2020): 384.
[20] Runghen, Rogini, et al. "Network analysis: ten years shining light on host–parasite interactions." Trends in Parasitology 37.5 (2021): 445-455.
[21] López-Osorio, Sara, Jenny J. Chaparro-Gutiérrez, and Luis M. Gómez-Osorio. "Overview of poultry Eimeria life cycle and host-parasite interactions." Frontiers in Veterinary Science 7 (2020): 384.
[22] Pinto, Derek J., and Sumiti Vinayak. "Cryptosporidium: host-parasite interactions and pathogenesis." Current Clinical Microbiology Reports 8 (2021): 62-67.
[23] Costa-da-Silva, Ana Caroline, et al. "Immune responses in leishmaniasis: an overview." Tropical medicine and infectious disease 7.4 (2022): 54.
[24] Mukhopadhyay, Debanjan, David Arranz-Solís, and Jeroen PJ Saeij. "Influence of the host and parasite strain on the immune response during Toxoplasma infection." Frontiers in Cellular and Infection Microbiology 10 (2020): 580425.
[25] Elmahallawy, Ehab Kotb, Abdulsalam AM Alkhaldi, and Amira A. Saleh. "Host immune response against leishmaniasis and parasite persistence strategies: A review and assessment of recent research." Biomedicine & Pharmacotherapy 139 (2021): 111671.
[26] Zheng, Shaowen, et al. "Porphyromonas gingivalis survival skills: Immune evasion." Journal of periodontal research 56.6 (2021): 1007-1018.
[27] Hambrook, Jacob R., and Patrick C. Hanington. "Immune evasion strategies of schistosomes." Frontiers in immunology 11 (2021): 624178.
[28] Mustafa, Hamssa M., Anas Abdullah Hamad, and Osama A. Mohsein. "Investigating Specific Calprotectin and Immunological Markers Associated With Intestinal Infections Caused by Entamoeba histolytica." Iranian Journal of Veterinary Medicine 18.4 (2024).
[29] Khan, Sameer Ullah, Kaneez Fatima, and Fayaz Malik. "Understanding the cell survival mechanism of anoikis-resistant cancer cells during different steps of metastasis." Clinical & experimental metastasis 39.5 (2022): 715-726.
[30] Pinto, Derek J., and Sumiti Vinayak. "Cryptosporidium: host-parasite interactions and pathogenesis." Current Clinical Microbiology Reports 8 (2021): 62-67.
[31] Badparva, Ebrahim, and Farnaz Kheirandish. "Blastocystis hominis: A pathogenic parasite." Archives of Clinical Infectious Diseases 15.4 (2020): e97388.
[32] Rawat, Aadish, et al. "Cysteine proteases: Battling pathogenic parasitic protozoans with omnipresent enzymes." Microbiological Research 249 (2021): 126784.
[33] Humayun, Mouhita, et al. "Innate immune cell response to host-parasite interaction in a human intestinal tissue microphysiological system." Science advances 8.18 (2022): eabm8012.

[34] Pérez-Mazliah, Damián, Alexander I. Ward, and Michael D. Lewis. "Host-parasite dynamics in Chagas disease from systemic to hyper-local scales." Parasite immunology 43.2 (2021): e12786.
[35] Liempi, Ana, et al. "Comparative ex vivo infection with Trypanosoma cruzi and Toxoplasma gondii of human, canine and ovine placenta: Analysis of tissue damage and infection efficiency." Parasitology international 76 (2020): 102065.
[36] Mukhopadhyay, Debanjan, David Arranz-Solís, and Jeroen PJ Saeij. "Influence of the host and parasite strain on the immune response during Toxoplasma infection." Frontiers in Cellular and Infection Microbiology 10 (2020): 580425.
[37] Frickel, Eva-Maria, and Christopher A. Hunter. "Lessons from Toxoplasma: Host responses that mediate parasite control and the microbial effectors that subvert them." Journal of Experimental Medicine 218.11 (2021): e20201314.
[38] Hajj, Rana El, et al. "Toxoplasmosis: Current and emerging parasite druggable targets." Microorganisms 9.12 (2021): 2531.
[39] Turner, Wendy C., et al. "The roles of environmental variation and parasite survival in virulence–transmission relationships." Royal Society open science 8.6 (2021): 210088.
[40] Guttery, David S., et al. "Division and transmission: malaria parasite development in the mosquito." Annual Review of Microbiology 76.1 (2022): 113-134.
[41] Hamad, A.A., Mustafa, H.M. & Mohsein, O.A. Detection of the levels of immune cytokines (IL4, IL5, TNF-α) in school-age and preschoolers with an Ascaris lumbricoides infection. J Parasit Dis 48, 782–787 (2024).
[42] Wright, Ian, et al. "Parasites and vector-borne diseases disseminated by rehomed dogs." Parasites & vectors 13 (2020): 1-4.
[43] Mojahed, Nooshin, Mohammad Ali Mohammadkhani, and Ashraf Mohamadkhani. "Climate crises and developing vector-borne diseases: a narrative review." Iranian journal of public health 51.12 (2022): 2664.
[44] O'Neal, Anya J., et al. "Lipid hijacking: a unifying theme in vector-borne diseases." Elife 9 (2020): e61675.
[45] Zahedi, Alireza, and Una Ryan. "Cryptosporidium–an update with an emphasis on foodborne and waterborne transmission." Research in Veterinary Science 132 (2020): 500-512.
[46] Yugo, Danielle M., and Xiang-Jin Meng. "Hepatitis E virus: foodborne, waterborne and zoonotic transmission." International journal of environmental research and public health 10.10 (2013): 4507-4533.
[47] Singal, Amit G., Pietro Lampertico, and Pierre Nahon. "Epidemiology and surveillance for hepatocellular carcinoma: New trends." Journal of hepatology 72.2 (2020): 250-261.
[48] Pullan, Rachel L., et al. "Spatial parasite ecology and epidemiology: a review of methods and applications." Parasitology 139.14 (2012): 1870-1887.
[49] Farrell, Maxwell J., Lea Berrang-Ford, and T. Jonathan Davies. "The study of parasite sharing for surveillance of zoonotic diseases." Environmental Research Letters 8.1 (2013): 015036.
[50] De Vlas, S. J., et al. "Review papers: statistical models for estimating prevalence and incidence of parasitic diseases." Statistical Methods in Medical Research 2.1 (1993): 3-21.
[51] Sissay, Menkir M., Arvid Uggla, and Peter J. Waller. "Prevalence and seasonal incidence of nematode parasites and fluke infections of sheep and goats in eastern Ethiopia." Tropical Animal Health and Production 39 (2007): 521-531.
[52] Guerra, Carlos A., et al. "Assembling a global database of malaria parasite prevalence for the Malaria Atlas Project." Malaria journal 6 (2007): 1-13.
[53] Noviyanti, Rintis, et al. "Implementing parasite genotyping into national surveillance frameworks: feedback from control programmes and researchers in the Asia–Pacific region." (2020): 1-20.
[54] Farlow, Robert, Tanya L. Russell, and Thomas R. Burkot. "Nextgen Vector Surveillance Tools: sensitive, specific, cost-effective and epidemiologically relevant." Malaria journal 19.1 (2020): 432.
[55] Goh, Brendon, et al. "The application of spectroscopy techniques for diagnosis of malaria parasites and arboviruses and surveillance of mosquito vectors: A systematic review and critical appraisal of evidence." PLoS neglected tropical diseases 15.4 (2021): e0009218.
[56] Belkessa, Salem, et al. "Prevalence and clinical manifestations of Giardia intestinalis and other intestinal parasites in children and adults in Algeria." The American journal of tropical medicine and hygiene 104.3 (2021): 910.
[57] Mustafa, Hamssa Majid1; Hamad, Anas Abdullah2; Mohsein, Osama A.3,4. Entamoeba histolytica and Giardia lamblia Predominance in Iraq's Southern Governorates. International Journal of Environmental Health Engineering 13(1):10, April 2024.
[58] Chagas, Úrsula Maira Russo, et al. "Correlations between tissue parasite load and common clinical signs in dogs naturally infected by Leishmania infantum." Veterinary Parasitology 291 (2021): 109368.

[59] de Carvalho, Bruna Caroline, et al. "Multiparametric analysis of host and parasite elements in new world tegumentary leishmaniasis." Frontiers in Cellular and Infection Microbiology 12 (2022): 956112.
[60] Garedaghi, Yagoob. "A review of the importance of stool test in the diagnosis of intestinal parasites." Int J Med Parasitol Epidemiol Sci Volume 1.2 (2020): 26.
[61] Guzman, Carolina, Hector H. Garcia, and Cysticercosis Working Group in Peru. "Current diagnostic criteria for neurocysticercosis." Research and Reports in Tropical Medicine (2021): 197-203.
[62] Yacubian, Elza Márcia, et al. "Common infectious and parasitic diseases as a cause of seizures: geographic distribution and contribution to the burden of epilepsy." Epileptic Disorders 6 (2022): 994-1019.
[63] Pittman, Kelly J., and Laura J. Knoll. "Long-term relationships: the complicated interplay between the host and the developmental stages of Toxoplasma gondii during acute and chronic infections." Microbiology and molecular biology reviews 79.4 (2015): 387-401.
[64] Halliez, Marie CM, and André G. Buret. "Extra-intestinal and long term consequences of Giardia duodenalis infections." World journal of gastroenterology: WJG 19.47 (2013): 8974.
[65] Tavares, R. G., et al. "Molecular techniques for the study and diagnosis of parasite infection." Journal of Venomous Animals and Toxins including Tropical Diseases 17 (2011): 239-248.
[66] Ndao, Momar. "Diagnosis of parasitic diseases: old and new approaches." Interdisciplinary perspectives on infectious diseases 2009.1 (2009): 278246.
[67] Zhang, Chi, et al. "Deep learning for microscopic examination of protozoan parasites." Computational and Structural Biotechnology Journal 20 (2022): 1036-1043.
[68] Valkiūnas, Gediminas, et al. "A comparative analysis of microscopy and PCR-based detection methods for blood parasites." Journal of Parasitology 94.6 (2008): 1395-1401.
[69] Ranjan, Koushlesh, P. Minakshi, and Gaya Prasad. "Application of molecular and serological diagnostics in veterinary parasitology." J Adv Parasitol 2.4 (2015): 80-99.
[70] Singh, Balbir. "Molecular methods for diagnosis and epidemiological studies of parasitic infections." International Journal for Parasitology 27.10 (1997): 1135-1145.
[71] Kumar, Niranjan, et al. "Internal parasite management in grazing livestock." Journal of parasitic diseases 37.2 (2013): 151-157.
[72] Hutson, Kate Suzanne, et al. "A decision support tool for parasite management in fish aquaculture." Reviews in Aquaculture 14.3 (2022): 1656-1670.
[73] Page, Stephen W. "Antiparasitic drugs." Small animal clinical pharmacology 2 (2008): 198-260.
[74] Dziduch, Katarzyna, Dominika Greniuk, and Monika Wujec. "The current directions of searching for antiparasitic drugs." Molecules 27.5 (2022): 1534.
[75] World Health Organization. "Prevention and control of intestinal parasitic infections: report of a WHO Expert Committee [meeting held in Geneva from 3 to 7 March 1986]." (1987).
[76] Sadhukhan, Sanjoy Kumar. "Prevention and Control of Parasitic Zoonoses." Textbook of Parasitic Zoonoses. Singapore: Springer Nature Singapore, 2022. 83-90.