
Downloaded from: https://researchonline.lshtm.ac.uk/id/eprint/682404/

DOI: https://doi.org/10.17037/PUBS.00682404

Usage Guidelines:

Please refer to usage guidelines at https://researchonline.lshtm.ac.uk/policies.html or alternatively contact researchonline@lshtm.ac.uk.

Available under license: http://creativecommons.org/licenses/by-nc-nd/2.5/
OBSERVATIONS ON ORNITHOBILHARZIA TURKESTANICUM

AND SCHISTOSOMA BOVIS IN IRAN

Thesis submitted for the degree of
Doctor of Philosophy in the
University of London
(Faculty of Medicine)

by

JAFFAR MASSOUD, D.V.M., D.A.P.& E.

Department of Medical Helminthology, London School of Hygiene and Tropical Medicine

September, 1971
BEST COPY

AVAILABLE
ABSTRACT

The geography and freshwater ecology of Khuzestan and those human activities which affect the snail ecology are described. *O. turkestanicum*, *S. bovis* and *S. haematobium* were the only animal and human blood flukes found in Khuzestan. The molluscan hosts of both species of *Schistosoma* is *B. truncatus* whereas *O. turkestanicum* is transmitted by *L. gedrosiana*. The infection rate of *O. turkestanicum* in ruminants was high and causes considerable economic loss.

The morphology of *O. turkestanicum* and its distinguishing characteristics from other schistosomes are discussed. The prevalence of *O. turkestanicum* and *S. bovis* infection in ruminants in Khuzestan abattoirs was studied. Infection rates of *O. turkestanicum* in cattle was higher than sheep and goats. The intensity of *O. turkestanicum* in naturally infected cattle and sheep was determined. Sheep suffered more than cattle from the disease. The intensity of *O. turkestanicum* declined with increasing age in cattle but increased in sheep.

/Experimental...
Experimental studies were carried out on calves, sheep, goats and buffalo-calf infected with *O. turkestanicum* and *S. bovis*. The intensity, pathogenicity and pathology of *O. turkestanicum* and *S. bovis* in naturally and experimentally infected ruminants were compared. *S. bovis* caused more serious damage to ruminants than *O. turkestanicum*. In *O. turkestanicum* infections, the duodenum was the most intensely involved organ and the liver was less affected and large intestine was free from infection. *S. bovis* was evenly distributed along the alimentary tract.

Susceptibility of different species of rodents, carnivores and birds to *O. turkestanicum* were tested. Only *Tatera indica* (a wild local rodent) was found to be susceptible to *O. turkestanicum* infection. Carnivores and birds were resistant to infection.

In the heterologous immunity experiments mice were immunized with different numbers of *O. turkestanicum* cercariae and challenged with *S. bovis*, *S. haematobium* and *S. mansoni*. Homologous immunity was also studied...
also studied in mice with *S. bovis*. In these experiments mice produced a partial protection against the challenge infections.

Reciprocal heterologous immunity experiments were carried out in calves and sheep using *S. bovis* and *O. turkestanicum*. Calves showed a high degree of protection but the effect was poor in sheep. Calves immunized with repeated inoculations of *S. haemotobium* cercariae developed some immature worms and produced considerable resistance against challenge infection with *O. turkestanicum* and *S. bovis*. Calves also developed a considerable immunity in homologous system with *O. turkestanicum* and *S. bovis*.

Studies were carried out on the distribution and ecology of *Lymnaea gedrosiana* the intermediate host of *O. turkestanicum* in Khuzestan. Detailed studies were made on the population dynamics of this snail by fortnightly surveys in different type of habitats over a period of 12 months. The results showed that peaks of snail population...
population occurred in 2 seasons, spring and autumn. Transmission occurred throughout the year in canals; in spring, summer and autumn in swamps; in spring and autumn in ponds. Canals and swamps accessible to livestocks were found to be important transmission sites of *O. turkestanicum*.

Laboratory experiments were carried out to study the development of larval stages of *O. turkestanicum* in *L. edrosiana* after the snails had been exposed to various number of miracidia. The results showed that the miracidial exposure dosage did not affect the cercarial prepatent period, but the life-span of infected snails was shorter and all the snails exposed to 20 miracidia shed cercariae. The snails exposed to 1 and 2 miracidia each shed fewer cercariae than those exposed to 5-20 miracidia.
ACKNOWLEDGMENTS

This project was carried out partly in the Department of Medical Helminthology, London School of Hygiene and Tropical Medicine, London University and partly in the Institute of Public Health Research, School of Public Health, Teheran University. Most of the experiments and field observations were carried out in the Dezful Bilharziasis Pilot Project in the schistosomiasis endemic area of Khuzestan, Iran.

These studies would have been impossible without the reciprocal co-operation of the London School of Hygiene and Tropical Medicine, and School of Public Health, Teheran University. I am indebted to the Institute of Public Health, School of Public Health of Teheran University and the World Health Organization for financial support and providing facilities.
I am very grateful to Prof. G. S. Nelson for supervision and constant encouragement throughout, to Dr. G. Webbe who supervised the observations on the snail intermediate host, to Dr. M. G. Taylor for his critical advice and help in editing the text, and to Dr. H. Muller and other members of the Medical Helminthology Department of the London School of Hygiene and Tropical Medicine, and Winches Farm Field Station.

I am grateful to Dr. Ch. Mofidi the Vice Chancellor of Teheran University and Dr. M. Faghih The Dean of School of Public Health, Teheran University and Dr. F. Arfaa for their support.

I should like to thanks all the staff of Dezful Bilharziasis Pilot Project and Helminthology Department of the School of Public Health, Teheran University for their assistance, particularly to Mr. I. Shenjari and Mrs. Vedadi.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>2</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>6</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>8</td>
</tr>
<tr>
<td>GENERAL INTRODUCTION. Khouestan: general description of the endemic area</td>
<td>12</td>
</tr>
<tr>
<td>MATERIAL AND GENERAL METHODS</td>
<td>29</td>
</tr>
</tbody>
</table>

## PART I: STUDIES ON ORNITHOBILHARZIA TURKESTANICUM

*(SKRJABIN, 1913) PRICE, 1929.*

### CHAPTER 1

Introduction and the morphology of *O. turkestanicum* ........................................ 41

### CHAPTER 2

Studies on the prevalence and intensity of *O. turkestanicum* in domestic animals in Khouestan ......................................................... 48
CHAPTER 3 Parasitological studies on experimentally infected large animals.......................... 65

CHAPTER 4 Experimental studies on the susceptibility of some rodents, small carnivores and birds to O. turkestanicum ......................... 83

CHAPTER 5 The pathology of naturally and experimentally infected ruminants ......................... 90

PART II: STUDIES ON SCHISTOSOMA BOVIS SONSINO, 1876......105

CHAPTER 1 Studies on the prevalence and intensity of S. bovis in domestic animals in Khuzestan...110

CHAPTER 2 Parasitological observations on experimentally infected large animals ......................114

CHAPTER 3 The pathology in ruminant experimentally infected with S. bovis with a note on a naturally infected cow ......................... 136
PART III: EXPERIMENTAL STUDIES ON ACQUIRED RESISTANCE TO SCHISTOSOMIASIS USING HOMOLOGOUS AND HETERLOGOUS SYSTEMS

CHAPTER 1 Introduction ........................................... 162
CHAPTER 2 Material and methods ................................. 169
CHAPTER 3 Results in mice ........................................ 172
CHAPTER 4 Results in calves and sheep ......................... 185
CHAPTER 5 Discussion .............................................. 208
ADDENDUM The first record of experimental infection
of calves with *S. haematobium* ................................ 215

PART IV: FIELD AND LABORATORY OBSERVATIONS ON LYMANEA
GEDROSIANA, THE INTERMEDIATE HOST OF O. TURKESTANICUM IN KHUZEStan. .................. 221

CHAPTER 1 Observations on the geographical distribution
of *L. gedrosiana* in KhuzeStan............................... 223
CHAPTER 2  A general description of the special study area.........................231

CHAPTER 3  Field observations on seasonal population trends of L.gedrosiana and their relation to the transmission of O.turkestanicum in various habitats in the study area........235

CHAPTER 4  Detailed studies on the population dynamics of L.gedrosiana in selected habitats........262

CHAPTER 5  Discussion ..........................282

CHAPTER 6  Laboratory studies on the host-parasite relationship: the effects of variations in miracidial exposure dosage........289

SUMMARY AND CONCLUSIONS ........................................305

REFERENCES ..................................................322
GENERAL INTRODUCTION.

The present study was undertaken to assess the veterinary importance of *Ornithobilharzia turkestanica* and *Schistosoma bovis* in livestock in Iran by determining the prevalence and intensity of infection, the pathogenicity of the parasites and the factors affecting transmission. Observations were also made on various aspects of the immune response to infection with these parasites and their inter-relationship with the schistosomes of human.

The field and laboratory studies were carried out in Iran but the development of the experimental techniques and the analysis of the data was carried out in the Department of Medical Helminthology in the London School of Hygiene and Tropical Medicine.

For convenience the thesis is divided into separate sections to cover the main topics. The general introduction which includes a geographical account of the area with particular reference to factors.
likely to affect transmission of schistosomiasis, followed by a section on materials and methods. This is followed by four distinct "parts". The first deals with the study of *Ornithobilharzia turkestanicum* in the definitive host; this is followed by the parallel studies on *Schistosoma bovis*. Part III deals with the observations on homologous and heterologous immunity and the interrelationship of the bovine and human schistosomes. The final section, Part IV, is an account of the studies in the field and laboratory on *Lymnaea gedrosiana* the intermediate snail host of *O. turkestanicum*. 
KHUZESTAN: GENERAL DESCRIPTION OF THE ENDEMIC AREA.

Khuzestan is an area of Iran about 157,000 square kilometres. Its southern boundary is the Persian Gulf and in the north and east it extends to the Zagros Mountain Range (Map, 1). In the west the Iran-Iraq border forms an artificial separation between Khuzestan and Mesopotamia. In fact, Khuzestan is a prolongation eastward of the Mesopotamian plain and the two areas are indeed continuous and homogeneous in their physical geography and also to a certain extent in their human geography.

The plain is essentially alluvial. Its sub-soil contains appreciable deposits of gypsum and salts which tend to come to the surface when the ground water level is near the surface. Brown desert soils predominate. In the higher land which dominates the plain on the north east, in calcareous formations, there are numerous and relatively large springs.

The climate of the Khuzestan plain is semi-arid (classification of Thornthwaite). The maximum temperatures are very high in the summer (over 50°C) and the minimal winter rates are around 0°C. Daily temperature
temperature variations are very great. The relative humidity is usually fairly low but it varies greatly depending on the direction of the wind. It is low, particularly in summer, when the winds blow mainly from the north and the northeast. It rises when the winds blow from the south, which happens more frequently in winter.

Rain is limited to the period from November to April with an average of 100 to 200 mm, but there is considerable variation in rainfall not only from place to place but from year to year. Much of this rain falls are in the form of violent downpours. Monthly temperature and rainfalls records are shown in (Fig. 1.). The nebulosity is low and the sun is very strong.

Owing to these climatic conditions, the major part of Khuzestan is a sub-desert steppe. But the plain is crossed by important streams which flow from the south-western slopes of the high Zagros Mountain Range. This combination of a semi-arid climate with relatively abundant surface waters makes Khuzestan a country of striking contrasts. Here, sand dunes are found not far from large swamps. A wide xerophilic animal fauna is overflowed by an exceptionally abundant aquatic avifauna.
Map, 1.
Part of Khuzestan to show the main endemic foci of Lymnaea gedrosiana, Bulinus truncatus and the main river system.
Fig. 1

Average rainfall and mean maximum and minimum temperatures at Dezful
Rice plantations alternate with cornfields. Among the herds driven back every evening to the village buffaloes walk side by side with sheep, goats and cattle. The population of Khuzestan plain is about 2½ million, mostly rural peasants practicing agricultural and cattle raising. The number of sheep, goats and cattle in the whole of Khuzestan amount to 2,700,000 head (Department of Agriculture).

Four different ethnic elements, Lur, Bakhtiari, Dezfuli and Arabs live in the Khuzestan plain; Lur in the west, Bakhtiari in the east, Dezfuli in the north and Arabs in the south. The population density is high in the irrigated areas, low or very low elsewhere. The principal crops are wheat and barley, both being produced with little irrigation, as well as rice, sesame and beans. The present output is low, because of the archaic agricultural practices and lack of water in summer. Apart from the oil areas, the economic and social development of the country is poor.

General Ecological Aspects

Hydrography:

Rivers and large natural drains:

Five major water courses drain the south-west slopes of the Zagros Range and traverse the plain of Khuzestan (Map, I.).

Lying
Lying in order from the southeast to the northwest they are the Hindijan, the Jarahi, the Karun, its large tributary the Dez, and the Karkheh. The most important is the Karun-Dec river, not only because of the great size of its drainage basin (54,000 square kilometres) but because of its average volume of water flow (750 m³/sec.). After it comes the Karkheh (200 m³/sec.). Both the Hindijan and the Jarahi have an average volume of flow of about 150 m³/sec. The flows in the summer are smaller than those of winter and spring, and the flow volumes are very irregular from one year to another. Floods are not usual. The water is very turbid but the amount of solids carried is comparatively small. The water of the Dez is of low salinity and clear. The Karun and the Karkheh are more salty and the Hindijan and the Jarahi have a relatively high salt content.

Between the Karkheh and the Dez there is an unusual water course, the Shahur. This springs in the north mostly from irrigation overflows. It follows a course that is probably an ancient irrigation canal, and at the lower end it becomes divided into numerous irrigation channels. Its volume of flow is small but it merits mention.
because it may play a very important role in the transmission of human and animal schistosomiasis. The other main streams in the north part of Khuzestan are the Abjirob, the Lureh and the Shureh, east of the Dez river. Downstream, these drains assume rather rapidly the aspect of a river, and before flowing into the Dez, they give rise to new irrigation network. All these rivers and streams have an irregular and occasionally semi-torrential flow. Their course are winding and imprecise; they often spread in flood plains which sometimes reaches several kilometres in width.

**Limnology:**

**Physico-chemical data,**

In summer the water temperature remains lower than that of the air during a 24 hour period. Particularly in the daytime, the extreme atmospheric dryness results in very strong evaporation which largely compensates for the effects of solar heat and the maximum temperature observed in water remains under 37°C, seldom exceeding 35°C. while the air temperature in the shade reaches and exceeds 50°C.

/Surface......
Surface water in Khuzestan contain a pH generally higher than 7, from 7 to 8 for running waters of rivers and canals, and from 7 to 8.5 for stagnant waters. In the stagnant waters, the pH varies in time. It is rather higher in winter with some sharp drops to 7-7.5 after heavy rainfalls.

**Flora and fauna,**

All stagnant or slow running waters are rapidly overrun by abundant aquatic vegetation. The vertical emerging vegetation is particularly abundant. The most representative groups are *Typha,* club-rushes, rushes and various species of couch-grass. Rushes are scarce and rather weak. *Polygonum* is often found at waters edge and is more or less immersed. By contrast, the floating vegetation is scanty. One can find *Potamegeton* and occasionally *Lemna* and *Salvinia.* Immersed macroscopic vegetation is irregular, sometimes absent but sometimes very abundant forming a thick layer. The most common groups are *Zonichelis* in winter, *Ranunculus* in spring, *Geratophyllum* and *characeae* in summer and autumn. Various filamentous algae are also found and occasionally, *Hydrodystion.*

/*The aquatic....*/
The aquatic fauna is abundant and includes tadpoles, as well as diptera and odonate larvae with usually only one stage of the life-cycle in water, hemiptera (hydrometres, nautonecetes, naucrores, belostomes) which are plentiful and coleoptera which are fairly rare. Small crustacea are very abundant, particularly Ostracods, Choneostrace and Cladocers (Daphnia). Shrimps are only found in large permanent swamps. Hydracarines are numerous. Leeches are very scarce (Gaud et al., 1962).

Vertebrates actually living in water are represented by rather rare species of fish. Those found in small stagnant water collections seemed unable to reach their full development in such an environment, judging by the size of the specimens observed.

On the other hand, the fauna of aquaphilic vertebrates is extremely abundant. The birds constitute its important element. They include a great number of species: pelicaniforms (cormorants and pelicans), ardeiforms (herons and storks), anseriforms (geese and ducks), lariforms (terns), ralliforms (rattles and coots), coraciiforms (kingfishers), but mostly charadriiforms (glaecoles, plovers, lapwings, /ruffs....
ruffs, snipes, sandpipers, stilt-plovers). In addition to birds, one may observe the presence of numerous turtles of the Clemmys type, and snakes of the Tropidonotus type. The amphibia, particularly frogs, are specially abundant.

The aquatic molluscan fauna is rather limited in species. The pulmonates are represented by species of: Bulinus truncatus, found in different types of habitats; Physa acuta, only found in a limited area in north of Ahwaz in canals and swamps; Lymnaea truncatula found in some swamps and drains; Lymnaea gedrosiana, the most common species occurring in the area in different types of habitats; Cyraulus intermixtus found in most habitats with other species; Planorbis planorbis is rare but sometimes found in swamps and drains.

Among the prosobranchs found are: Melanoides tuberculata in running waters and in some swamps; several species of Melanopsis are found in running waters, Melanopsis costata, Melanopsis praemorsa and Melanopsis nodosa; Viviparus bengalensis found in some large swamps; Theodoxus cintellus in some streams. Siphonommatophores (sucinea) are very scarce. Pelecypodons, Lamellibranches are mostly found in running....
running waters and irrigation canals.

Part played by man in the ecology of the snails,

This section deals with those human activities which are more or less directly connected with the ecology of the snails. Agriculture is obviously the most important of these activities, and following five types of habitat are considered: gardens, rice fields, marketgardens, cattle breeding areas and the clay pits.

Gardens,

What they usually call gardens in this area should more properly be called orchards, as behind the high walls which surround these places, one finds mostly trees, mainly fruit-trees, but also other types of trees. The area covered by these gardens is generally larger than that of the village itself. It may be twice or four times as large as the village area or even more. In most cases, only one gate gives access to the garden. The gardens are cool places, with trees poorly cut, growing sometimes in great disarray. The irrigation canals form a network which seems more orderly devised than the paths themselves. Their terminal branches link up with one or two drains and
end outside through apertures made in the lower part of the walls.

Excess water sometimes forms small ponds inside the gardens but more often drainage water collects in ponds and swamps outside the walls. Inside the gardens ponds and drains play a role in breeding of snails in hot seasons. Swamps and ponds outside the gardens are most favourable breeding places for snails.

**Rice fields,**

Almost each village is provided with its own rice field and the areas devoted to rice cultivation differ each year. Rice is sown in seed beds in June, thinned out in July-August and harvested by the end of October. During cultivation there is no drying until a little time before the harvest. The quiet, tepid and shallow water of rice-fields constitutes a favourable breeding place for snails particularly *Lymnaea gedrosiana*. During the summer the rice field drainage waters maintain even to a larger extent than the garden drainage waters, some breeding places which otherwise, would be dried up.

Directly related to rice culture a practice is being...
developed which seems to be favourable to the spread of bulinid snails in particular. The villagers used Typha leaves for tying the bundles of rice, when planting it out. The plants grow spontaneously in swamps and on the stream banks. The villagers themselves transplant these Typha leaves to nearby ponds and swamps to get sufficient amount of Typha for the next season. In this way they spread the Bulinus snails to the new ponds with Typha roots and leaves.

Market gardens.

Around each village some vegetables are extensively cultivated for the personal use of the villagers: onions, carrots, radishes, beetroots, melons, watermelons, cucumbers, eggplants, spinach and various aromatic herbs. There are some areas, owing to the vicinity of Dezful or the highway, in which market gardening is continuously and intensively practiced, the products intended either to be sold in the town or exported to the north of Iran, particularly Teheran. In addition to the above mentioned vegetables, they also cultivated in these areas tomatoes, pimentoes, garlic, but mainly lettuce. In these gardens, intensive fertilising (human and animal manure) is required because of the...
villager's desire to obtain several crops per year, for many consecutive years. Lettuce, whose cultivation alternates by rotation with that of cucumbers, particularly needs fertilizers. In these areas were found Bulinus and a large population of Lymnaea in the drainage waters. On the course followed by the drains, some ponds are dug which are used for washing the vegetables before carrying them to the market. The remains of the vegetables after washing constitute an abundant food for Bulinus and Lymnaea. In the meantime excess waters from these gardens permanently supply water for swamps and ponds nearby.

**Cattle brooding areas,**

Livestock are abundant in the cultivated areas, consisting of about 20,000 equines (horses, donkeys, mules), 30,000 bovines (oxen and buffaloes), 15,000 goats and most important about 100,000 sheep. These animals directly affect the ecology of Bulinus and Lymnaea, because they usually drink water from the canals, causing leaks which feed stagnant waterponds. Also their excreta fill waters with organic matter which is favourable for snail breeding. Finally all these animals, particularly buffaloes, may carry bulinid snails in the mud which stick to their feet and body and may therefore afford these snails an opportunity to be disseminated rather far away from their original brooding places.

/Clay pits...
Clay pits,

Clay plays a considerable part of the life of the villagers. It is the main material for wall building and when mixed with straw, for roofs. It is used for making several utensils: bread ovens, animal mangers, nests for setting hens, vessels of various forms and capacity, particularly individual storing places for corn. In order to have clay available at any time, the peasants dig pits near the villages to which they convey either the drainage water of a nearby garden or the water from an irrigation canal. The slow sedimentation of water in these ponds allows for sorting of the clay particles which settle on the rougher grains of sands. These ponds are rapidly invaded by microscopic algae, then by aquatic vegetation. They soon become of no use as clay pits but they are not filled up. All these ponds constitute snail breeding places which are all the more dangerous as their banks may easily be used for human and animal defaecation.

*S. haematobium*, *S. bovis* and *O. turkestanicum* are the only mammalian schistosomes occurring in the Khuzestan endemic area. *O. turkestanicum* and *S. bovis* occurs mostly in ruminants, the prevalence of *O. turkestanicum* is higher than *S. bovis*. *S. haematobium* is the only human schistosomes and there is no evidence of animal infection with this parasite.
MATERIAL AND GENERAL METHODS

Schistosomes,

The four species of schistosomes used were maintained in the laboratory in the following hosts:

Ornithobilharzia turkestanicum (Skrjabin, 1913) Price, 1929.

An Iranian strain freshly isolated from naturally infected cattle was maintained in Lymnaea edrosiana and calves.

Schistosoma bovis Sonsino, 1876.

An Iranian strain freshly isolated from naturally infected cattle was maintained in Bulinus truncatus and calves.

Schistosoma haematobium Bilharz, 1852.

An Iranian strain freshly isolated from naturally infected human urine after passage was maintained in Bulinus truncatus.

Schistosoma mansoni Sambon, 1907.

A Puerto Rican strain originally isolated from man was maintained in Biomphalaria glabrata and albino mice.

/Snails ....
Snails,

*Lymnaea gedrosiana*. A laboratory colony was established from a batch of wild snails collected from the field. This snail is the most susceptible snail to *O. turkestanicum* in Khuzestan.

*Bulinus truncatus*. A colony was built up from the local wild snails in laboratory. This snail is susceptible to the both local species of schistosomes *S. bovis* and *S. haematobium* in Khuzestan.

**Snail culture**

The snails were reared in the laboratory in plastic tanks (14 x 8 x 6 inches) containing stored river water and weeds with a fine gravel substratum. Light was adequate and water temperature ranged from 25-27°C. The aquarium water was changed whenever necessary from a main storage container of dechlorinated river water. The snails were fed daily on dried and fresh lettuce with occasional addition of powdered barley and rice seeds. Occasionally the tanks were infested by the free-living nematodes, *Chaetogaster* spp. and *Cyprodromus* and sometimes by a brownish growth on the sides of the tanks believed to be of bacterial....
be of bacterial origin and harmful for growing snails (McClelland, 1964), which necessitated clearing out the tanks.

**Snail infection**

Faeces from infected large animals were diluted in 0.9% saline and sieved through a wire mesh to separate the large particles and repeatedly sedimented until the supernatant became clear, about 25 minutes being allowed for each sedimentation. A final washing with ice-cold water was made to remove traces of saline. After the final washing the sediment was poured into petri-dishes, diluted with dechlorinated fresh water at 30°C, and placed under a strong light. Miracidia hatched in a few minutes. This technique was also used for determining prepatent periods of *O. turkestanicum* and *S. bovis* in ruminants.

The miracidia were transferred by a Pasteur pipette to a watch glass. Snails 4-6 mm size were added and kept for over 4 hours under adequate light and temperature. Infected snails were kept in big plastic tanks at 25-27°C, until they started to shed cercariae.

/ Shedding ...
Shedding and counting of cercariae

At least 100 snails infected with 5-7 miracidia were used for the cercarial shedding. The snails were put in 250 ml beaker containing fresh water at 27°C and exposed to direct bright sun light to stimulate cercarial shedding. After 2 hours the cercarial suspension was separated from the snails and the number of cercariae per ml were counted by the ninhydrin staining technique of McClelland (1961).

Exposure of rodents to cercariae

A variety of small rodents and carnivores (laboratory bred and wild caught) were exposed to cercariae of *O. turkestanicum* in the laboratory. Before exposure to cercariae the animals were left for about 20 minutes in warm water to stimulate the evacuation of faeces and urine which might ultimately reduce the viability of the cercariae (Asim and Watson, 1948). The animals were exposed to infections with a counted number of cercariae in a glass jar for about one hour.

/ Recovery ....
Recovery of adult worms from rodents

The perfusion technique described by Smithers and Terry (1965) was used. The animals were anaesthetized by injecting a dose of 0.5 ml heparinized nembutal intraperitoneally. The perfusion solution was prepared by adding 15 grams of sodium citrate to one litre of 0.9% of saline. The animal was skinned, the thoracic and abdominal cavities were opened and part of the ribs were removed to expose the heart. The animal was suspended on the vertical plate of the apparatus, the portal vein was slit open and a perfusion needle was inserted into the left ventricle of the heart. The pressure for perfusion was provided by a rotary pistonatic electric pump. The perfused worms collected on a fine wire mesh and were then transferred to a petri-dish containing saline for counting. The bowels and livers were removed and washed in saline to collect any adhering worms. The liver was then crushed between two glass plates to detect any remaining worms. After perfusion the liver and bowel were preserved in the deep-freeze for egg counts.

Tissue egg counts in rodents

The pepsin digestion method of Nelson et al (1966) was used.
The liver and bowel were digested separately. Each organ was minced and transferred to a polythene flask containing the digestive fluid (1 % pepsin and 0.5 % HCl in normal saline). After an incubation period of 16 hours at 37°C, the digested tissues were precipitated in conical urine flasks for 30 minutes, after which the supernatant decanted and 25 ml of 0.5 % hydroxide sodium was added to dissolve any remaining undigested tissues. Three 0.1 ml samples were taken by a MacDonald pipette for counting the eggs after agitating the whole sample.

Infection of large animals,

For infecting the large animals cercariae were collected from at least 100 infected snails. Different species of animals (calf, sheep, goat and buffalo-calf ) aged 7-9 months were used after repeatedly examination of faeces to ensure freedom from any schistosome infections.

The large animals were infected by foot immersion technique: the right front leg of the animals were closely clipped by electric hair clippers...
Plate, 1

Photograph illustrating the infection technique used for exposing large animals to cercarinae.

By this technique recovery rates of up to 70% for S. bovis and 48% for O. turkestanicum were achieved.
hair clippers, washed and cleaned with warm water. The leg up to about 3 inches above the knee was then immersed in a thick polythene bag containing the cercarial suspension. The upper part of the bag was tied firmly to the leg to prevent loss of the cercarial suspension. The animals were immobilized by tying the feet together and they were kept still for 45 minutes (see Part, I).

Recovery of adult worms from large animals

The animals were starved for 12 hours before autopsy to avoid having to deal with a full and distended rumen. The animals were killed by exsanguination and to prevent the shift of the adult worms to liver, no anaesthetic was used. Fast bleeding of the animals prevented any significant clotting of the blood in the mesenteric and portal veins.

A mid-ventral incision was then made and the abdomen was opened. The worm recovery technique was similar to that used by Cheever (1966) on human cadavers. Worms were recovered separately from the liver and mesenteric veins in the following manner: The viscera were removed....
were removed en bloc from oesophagus to rectum and the rectum was ligated. The rumen, abomasum and reticulum were then removed from the intestine. The rest of the viscera including lungs, liver, small and large intestine were then transferred to the laboratory. The liver and lung were separated from the intestines and the liver and intestine were perfused separately. Before perfusion a wedge of liver tissue was removed for histological study.

A glass cannula with a nylon tube connector was inserted into the inferior vena cava above the liver for perfusion of the liver in a direction reverse to that of the blood flow. 7-10 litres of tap water were used, the liver was massaged intermittently during perfusion. The liver was then sliced to collect any remaining parasites and rinsed in tap water to remove adherent worms.

The mesenteries were also perfused. First the small intestine were removed from the mesentery (After pushing all the worms in capillary veins on the surface of the intestine into larger branches of mesenteric veins). The mesenteric veins were then perfused from the portal vein in a retrograde manner after cutting the mesenteric veins near their....
near their insertions to the bowel. The free margin of the mesentery was massaged during perfusion to help expel the worms. The major branches of the mesenteric veins were then perfused individually. The colon and caecum were then removed and the veins in this area separately searched for the worms and pushed out by a needle pressure on the surface of the veins. The intestines were placed in a separate container and the mucosa was separated from the bowel wall by hand and searched for any worms remaining in the veins.

In general there were about 10 litres of fluid from liver perfusion and 20 litres from intestine. The fluids were sieved through a no. 100 gauge wire mesh to separate the worms. Worms were transferred to petri-dishes, males and females were counted separately.

_Tissue egg counts in large animals_

Three portions of liver weighing 20 grams each were taken from each animal: from the portal tract and the peripheral areas of both the right and left lobes, were minced and digested in 10 volumes of 4.5% potassium hydroxide in saline water for 5-6 hours at 50°C.
Three 0.1 ml samples taken by MacDonald pipette were counted. The mean number of eggs per gram of liver from the 9 specimens was taken as the egg count per gram of liver. A total of 13 organs: lung, liver, spleen, rumen, reticulum, omasum, abomasum, duodenum, jejunum, ileum, caecum, colon and rectum were isolated. The contents of the digestive tract were washed out. From each part 20 grams were digested in potassium hydroxide (KOH) as described before and egg counts were performed.

**Fecal egg counts in large animals**

A single specimen of 10 grams of faeces was taken and diluted in 10% formol saline and a few drops of glycerol were added to remove the eggs from adherent particles. After 30 minutes samples were sieved through a mesh to separate large particles. After sieving they were sedimented for 30 minutes and repeated several times in normal saline to clear the sediments. After a final wash the samples were made up to 50 ml with water and 7-10 samples were taken by MacDonald pipette and the eggs were counted.

**Post mortem examination of animals for natural infection**

Examinations were carried out by transilluminating the mesenteric veins with a strong direct light. This technique seemed
to be very effective as even a single schistosome worm could be readily detected by this method. The heavily infected organs were transferred to the laboratory for the further perfusion of the adult worms and tissue egg counts as described above. Also, other organs of infected animals particularly liver were carefully examined, gross pathological changes were recorded and pieces of different tissues were taken for histological studies.
PART I
STUDIES ON ORNITHOBILHARZIA TURKESTANICUM

( SKRJABIN, 1913) PRICE, 1929.

CHAPTER 1.

INTRODUCTION.

The genus Ornithobilharzia was originally described by Rudolphi (1819), and Odhner (1912) from Red Sea birds. The related blood fluke which was first found by Skrjabin (1913) in cattle in Russian Turkestan first called Schistosoma turkestanicum, but Price (1929) transferred S. turkestanicum to the genus Ornithobilharzia (Odhner, 1912) and called it Ornithobilharzia turkestanicum on the basis of its morphological similarity to other species of that genus. He suggested that in view of the morphological relationship of O. turkestanicum to species occurring in birds it may be assumed that this parasite may be only an accidental and facultative parasite of cattle and sheep that they are normally parasites in birds of some sort. Further taxonomic modifications were proposed by Butt and Srivastava (1955) who suggested transferring the mammalian Ornithobilharzia, species to a new genus called Orientobilharzia, while Le Roux (1958) proposed the name Eurobilharzia.

/O. turkestanicum ...
O. turkestanicum has been recorded by Popov (1926) from the cat in Kazakstan; by Yamagiwa (1931) in mongolian cattle; by MacInattie and Chadwick (1932) and MacInattie (1936) in large animals in Iraq; by Hsu (1938) from sheep from North China; by Abdussalam and Sarvar (1952) from a sheep in Pakistan at 6500 feet above sea level; by Srivastava and Trisal (1957) and Dutt et al (1964) from cattle in India; by Boev (1944), Lavrov et al (1964, 1967), Tunev (1946), Zakhrilov (1964), and Azimov et al (1965, 1966, 1968) from various part of the southern USSR. Wienberg and Longy (1966) reported O. turkestanicum from field rats in the South Turkey. O. turkestanicum was first reported from Khuzestan, Iran by the Bilharziasis Pilot Project (1962), and later by Sabbaghian et al (1964) and Arfaa et al (1965) from large animals.

The wide distribution of O. turkestanicum in Khuzestan and the economic importance of the parasite in ruminants necessitated the present detailed studies on different aspects of this parasite in various laboratory and domestic animals.

THE MORPHOLOGY OF O. TURKESTANICUM

Male,

Length 2–10 mm. Oesophagus shows only one posterior dilatation ....
dilatation. The oral sucker is subterminal covered with spines.

The testes varies in number from 50-90 and occupy the intracrural space, starting some what behind the acetabulum and continuing to about the middle of the body. In ventral view they appear as transversely-elongated pear shaped bodies arranged in two interlocking rows, with their narrow ends pointing towards the mid-line of the body. The testes do not stain deeply with aceto-carmine staining like other schistosomes. The males of *O.turkestanicum* can be easily distinguished from males of *Schistosoma* by their smaller size and the large number of testes.

**Female,**

Length 2-3 mm. oesophagus is simple. The common caecum extends for more than half the length of the body and divides in the anterior half. The ovary is situated anterior to the caecal union and is a spiral, elongated and anteriorly coiled organ. The vitellaria consist of rounded follicles situated on either side of the intestinal caecum. The oviduct starts from the posterior extremity of the ovary and after a short winding course passes into the uterus which
continuous anteriorly between the two intestinal caeca and contains only a single egg.

The egg usually bears a blunt spine at the one pole and a roughly nipple-shaped appendage at the other end. This appendage may bend away from the axis of the egg (Plate, 2). The eggs are of variable shape, mostly elongated and oval and about 76 x 26 millimetre size, immature eggs being smaller in size. Females of _Q. turkestanicum_ can be distinguished from females of _Schistosoma_ by the smaller size and single typical intra-uterine egg and spiral ovary.

The females are usually in copula with the males and therefore it is difficult to see them, because they are completely hidden in the gynaecosphoric canal. Sometimes, particularly in the small laboratory animals, two or more females are seen in the gynaecosphoric canal of a single male. We agreed with MacHattie (1936) that the "tuberculatm" appearance of the worms is due to contraction of the cuticula of the male worms during fixation, and we did not find /any of the...."
any of the tuberculate O. turkestanicum, referred to by Bhalerao (1932).

The miracidia of O. turkestanicum are very active and move rapidly in water. They can be distinguished from S. bovis and S. haematobium miracidia under the low power of the dissecting microscope by their smaller size and fast movement. The percentage of eggs with mature miracidia in the intestinal wall and liver of ruminants was low and most of the eggs were excreted without a fully developed miracidia. The size of immature eggs in the faeces was much smaller than mature eggs with a viable miracidia.

The cercariae of O. turkestanicum is a pharyngeal brevifurcate distome with no eye spots, the cercariae are discharged from the snails in " puffs " emergence usually takes place at early morning and it is most rapid in direct sunlight. The cercariae did show no predilection for the sub-surface position as shown by the S. bovis and S. haematobium cercariae, but were fairly well distributed throughout the water and after sometimes most of the cercariae were found resting on the bottom of the tube. The cercariae of O. turkestanicum in spite of Schistosomes cercariae always progress head-first.
Chapter 2

Studies on the Prevalence and Intensity of O. turkestanicum in Domestic Animals in Khuzestan, Iran.

Introduction,

Q. turkestanicum is prevalent in Khuzestan, south-west of Iran. In Khuzestan, the most affected area, is in the northern and central parts (Desful, Shushtar, Masjid-i-Solaiman, Ahwaz and Dasht-Mishan). In the southern part (Abadan, Khurranshahr and Shadegan) the parasite is rare because there is no animal raising practice and also no suitable brooding places for the snail intermediate host exist (See Map, 1.).

In other parts of Iran it can be assumed that there is a patchy distribution of Q. turkestanicum. In northern Iran near the Turkistan and Caucasus areas where Russian investigators have reported a high prevalence of Q. turkestanicum, Arfza et al (1965) reported one case of Q. turkestanicum infection in cattle slaughtered in a Tehran abattoir apparently originating from this area. Also Alc-Dawood (1963) reported infection in 4/9 sheep and 4/8 cattle examined....
examined in the Babolsar abattoir in the Caspian area (north of Iran). Furthermore 2/8 cows and 2/11 sheep were found infected in the Esfahan abattoir in the central part of Iran.

The Esfahan infection may have originated in Khuzestan due to the seasonal migration of Bakhtiari tribes with their herds from Esfahan area to Khuzestan in their search for winter pasture. The infections in northern Iran probably originated from southern Russian areas.

MATERIAL AND METHODS.

A total of 632 cattle, 607 sheep, 89 goats and 96 buffaloes were examined in Dezful and Ahwaz abattoirs in search of schistosomes infection. Twenty one heavily infected cattle and 12 sheep in different age groups were perfused and tissue egg counts were performed. Before perfusion, samples from liver, and gut were taken for histopathological studies. The condition of the animals and their sex and place of origin were recorded. Animals (usually sheep and goats) which were from outside the Khuzestan area were not included in the data. We also examined other animals which died during this period in the area including: Four donkeys, one wild boar, 2 foxes and 3 mongooses.

/Results....
RESULTS,

Prevalence,

O. turkestanicum is prevalent among cattle and sheep in the villages in the most of the irrigated areas in Khuzestan (Table, 1.), though it is difficult to ascribe infection to precise villages as animals are watered at snail breeding places situated in different areas. Infection rates of 31.6 % and 25.0 % were found in the northern part (Desful and Shushtar) and central part (Ahwas and Dasht-Mishan) of Khuzestan respectively, whereas no infection were found in Abadan and Khurramshahr (southern part).

Table, 2 shows the prevalence of O. turkestanicum in the different type of hosts in the northern part of Khuzestan. The infection rate in cattle, sheep, goats and buffaloes was 30.3 %, 15.6 %, 6.7 % and 2.1 % respectively.

Adult worm recoveries,

A total of 21 cattle and 12 sheep heavily infected with O. turkestanicum were perfused and tissue egg counts were performed. The cattle were studied in 3 groups according to their age (Tables, 3, 4, 5); sheep were studied in 2 separate age group (Tables, 6, 7). The data on cattle and sheep, collected from May, 1969 to September 1970, showed that the number of worms and the number of eggs per gram...
gram of tissues declined considerably in the oldest cattle. In
sheep however, no such reduction was observed (Fig. 2, 3).

The number of worms in the mesenteric veins of cattle
varied from 2 to 7374 and in sheep varied from 2 to 712. In cattle
the mean number of worms was $1188 \pm 312$ from the 1-3 years old age
group, $1823 \pm 749$ from 3-5 years old age group and $764 \pm 252$ from
the 5-7 years old age group (Tables, 3, 4, 5). In sheep the
mean worm burdens was higher in the 3-5 years old (Tables, 6, 7).

**Tissue egg counts.**

In cattle the tissue egg counts declined with the age,
but in sheep there was slightly increased with age (See Tables,
2-7).

The number of eggs per gram of tissues in cattle was
highest in the 1-3 years old age group with a mean of $615 \pm 298$
eggs per gram in the liver and $1149 \pm 3765$ eggs per gram in the
small intestine. In the 3-5 years old age group 166 $\pm 48$ eggs
were found in liver and $7339 \pm 3455$ eggs in the small intestine.
In the 5-7 years old age group fewer eggs were recovered ($123 \pm 71$ eggs
per gram....
per gram of liver and 1444 - 628 eggs per gram of small intestine). There were no eggs in the large intestine and other organs, and the number of eggs in ileum was very low compared with the high number found in the duodenum. The pattern of egg densities relation to the age of cattle and sheep are shown in Fig. 2, 3.

DISCUSSION,

Prevalence,

Most of the cattle, sheep, goats and buffaloes slaughtered in Desful abattoir were brought from the northern part of Khuzestan and the animals slaughtered in Ahwaz abattoir were brought mainly from the Dasht-Mishan area. In the south of Khuzestan (Abadan and Khurramshahr) the animals came mainly from outside Khuzestan from Kazerun, Behbahan and Kermanshah. Schistosomes recovered from the ruminants were mostly *O. turkestanicum* as indicated by the small size of the worms and shape of the eggs.

The prevalence of *O. turkestanicum* in cattle was higher than
in other ruminants (cattle 30.3%, sheep 15.6%, goats 6.7% and in buffaloes 2.1%) in spite of the fact that the laboratory experiments (see chapter, 3) showed that goats are as susceptible to this parasite as sheep. The low prevalence of infection in goats may be due to their habits avoiding unnecessary contact with water, kneeling on their fore legs at the edge of the bank while drinking and not standing in it as other animals so often do. Only 2 very light infection with immature worms were found in buffaloes. In contrast to goats buffaloes spend most of the time in very close contact with infested water bodies, resting inside swamps and ponds for a long period every day. Subsequent laboratory experiments showed that buffaloes are very poor hosts for *O.turkestanicum* compared with cattle and sheep.

There are certain discrepancies between these results and those of previous workers. For example MeHattie (1936) reported that in the Marsh-Arab area of Iraq (near the Dasht-Mishan area in Khuzestan) about 80% of the animals were infected with *O.turkestanicum*. Again, Arfaz et al (1965) reported up to 69% of cattle, 28% of sheep, 35% of buffaloes and 100% of goats in the Désful area in Khuzestan...
were infected with *O. turkestanicum*. The discrepancies may be due to their data being based on apparently ill and emaciated animals from restricted areas rather than being random samples from the general animal populations as in the present observations.

**Intensity,**

The worms load and tissue egg counts declined with increasing age in the cattle suggesting that they develop some degree of resistance to infection. This effect was demonstrated experimentally in calves (see Part, II). In contrast in sheep there was no such reduction, it was later shown that the immune response is less well developed in sheep.

The most striking result of the tissue egg counts was the pattern of distribution in the different organs. The duodenum had the highest egg densities; the liver showed relatively low egg counts especially in cattle where this organ was less affected than in sheep and goats. The large intestine was entirely free from eggs. This

/contrasts.../
contrasts with *S. bovis*, *S. mansoni* and *S. japonicum* in definitive hosts where the large intestine is the most favourable site of egg deposition and the liver is much more affected.

The other animals examined, did not seem to be important hosts, although one of the donkeys and the wild boar had a few worms. None of the mongooses and foxes were infected.
Table 1

Distribution of *O. turkestanicum* in Cattle
in the Khuzestan area

<table>
<thead>
<tr>
<th>Locality</th>
<th>Total No. examined</th>
<th>Total No. positive</th>
<th>Percentage of infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern part</td>
<td>512</td>
<td>162</td>
<td>31.6%</td>
</tr>
<tr>
<td>Central part</td>
<td>120</td>
<td>30</td>
<td>25.0%</td>
</tr>
<tr>
<td>Southern part</td>
<td>80</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 2

Prevalence of *O. turkestanicum* in the ruminants

in Khuzestan, Iran.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Total No. of animals examined</th>
<th>Total No. of positive</th>
<th>Percentage of infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>cattle</td>
<td>632</td>
<td>192</td>
<td>30.3%</td>
</tr>
<tr>
<td>sheep</td>
<td>607</td>
<td>95</td>
<td>15.6%</td>
</tr>
<tr>
<td>goats</td>
<td>89</td>
<td>6</td>
<td>6.7%</td>
</tr>
<tr>
<td>buffaloes</td>
<td>96</td>
<td>2</td>
<td>2.1%</td>
</tr>
</tbody>
</table>
Table 3

Recovery of adults and eggs of *O. turkestanica* from naturally infected cattle 1-3 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Worms Recovery</th>
<th>Tissue egg counts /gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>Male</td>
<td>57</td>
<td>206</td>
</tr>
<tr>
<td>2.</td>
<td>&quot;</td>
<td>888</td>
<td>1135</td>
</tr>
<tr>
<td>3.</td>
<td>&quot;</td>
<td>716</td>
<td>1220</td>
</tr>
<tr>
<td>4.</td>
<td>&quot;</td>
<td>660</td>
<td>1231</td>
</tr>
<tr>
<td>5.</td>
<td>&quot;</td>
<td>210</td>
<td>397</td>
</tr>
<tr>
<td>6.</td>
<td>&quot;</td>
<td>190</td>
<td>218</td>
</tr>
<tr>
<td>Mean(S.E.)</td>
<td></td>
<td>454 (139)</td>
<td>734 (208)</td>
</tr>
</tbody>
</table>
Table 4

Recovery of adults and eggs of *O. turkestanicum* from naturally infected cattle 3-5 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Worms Recovery</th>
<th>Tissue egg counts /gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>Male</td>
<td>196</td>
<td>271</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>780</td>
<td>1133</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>3002</td>
<td>4372</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>1966</td>
<td>2327</td>
</tr>
<tr>
<td>6.</td>
<td>Female</td>
<td>438</td>
<td>1739</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>10</td>
<td>68</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>140</td>
<td>156</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>454</td>
<td>1078</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>703</td>
<td>1120</td>
</tr>
<tr>
<td>(S.E.)</td>
<td></td>
<td>(316)</td>
<td>(441)</td>
</tr>
</tbody>
</table>
Table 5

Recovery of adults and eggs of *O. turkestanicum* from naturally infected cattle 5-7 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Worms Recovery</th>
<th>Tissue egg counts /gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1.</td>
<td>Female</td>
<td>204</td>
<td>1356</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>82</td>
<td>278</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>396</td>
<td>654</td>
</tr>
<tr>
<td>4.</td>
<td>Male</td>
<td>226</td>
<td>487</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>30</td>
<td>109</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td>188</td>
<td>577</td>
<td>765</td>
</tr>
<tr>
<td></td>
<td>(63)</td>
<td>(215)</td>
<td>(252)</td>
</tr>
</tbody>
</table>
Table 6

Recovery of adults and eggs of *O. turkestanicae*, from naturally infected sheep 1-3 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Worms Recovery</th>
<th>Tissue egg counts /gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>Female</td>
<td>317</td>
<td>340</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>140</td>
<td>218</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>26</td>
<td>57</td>
</tr>
<tr>
<td>5.</td>
<td>Male</td>
<td>28</td>
<td>57</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>100</td>
<td>152</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>108</td>
<td>146</td>
</tr>
<tr>
<td>(3.E.)</td>
<td></td>
<td>(45)</td>
<td>(47)</td>
</tr>
</tbody>
</table>
Table 7

Recovery of adults and eggs of *O. turkestanicum*, from naturally infected Sheep 3–5 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Worms Recovery</th>
<th>Tissue egg counts /gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>Female</td>
<td>241</td>
<td>471</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>90</td>
<td>150</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>75</td>
<td>124</td>
</tr>
<tr>
<td>5.</td>
<td>Male</td>
<td>76</td>
<td>124</td>
</tr>
<tr>
<td>6.</td>
<td>Male</td>
<td>155</td>
<td>325</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td>110 (31)</td>
<td>203 (66)</td>
<td>313 (98)</td>
</tr>
</tbody>
</table>
Fig. 2d

Histogram showing the decline with age in the densities of O. turkestanticum eggs in the tissues of naturally infected calves.
Fig. 3a

Histogram showing the increase with age in the densities of *O. turkestanicum* eggs in the tissues of naturally infected sheep.
CHAPTER 3

PARASITOLOGICAL OBSERVATIONS ON EXPERIMENTALLY INFECTED LARGE ANIMALS.

INTRODUCTION,

During the past few years increasing interest has been taken in the study of schistosomiasis of ruminants because of the economic importance of the disease. Previous studies on *O. turkestanicum* have been concerned either with the snail hosts (Dutt *et al.*, 1964 and Azimov *et al.*, 1968), or with the epidemiology and pathology of naturally infected animals (Azimov, 1965 and 1966, Lavrov *et al.*, 1967). But the full life-history of the parasite had not been adequately studied in the laboratory, the following observations were made to elucidate the behaviour of the parasite in the definitive hosts.

Material and Methods,

Eight calves, 5 sheep, 2 goats, one buffalo-calf and one young wild pig were exposed to *O. turkestanicum* cercariform in the /laboratory...
laboratory, to determine the infectivity and pathogenicity of parasite. At the same-time some of the animals were used for immunological studies (see Part, III).

The animals were obtained locally and were 7-9 months old. Repeated examination of the faeces were made to ensure that they were free from schistosome infection.

The calves and sheep were divided into 2 groups. Group I included 5 calves and 3 sheep which they were autopsied 9 weeks after exposure to *O. turkestanicum* cercariae. Group II included 5 calves and 2 sheep autopsied 18 weeks after exposure to the initial exposure of *O. turkestanicum* cercariae. Two goats, one buffalo-salt and one young wild pig were exposed to *O. turkestanicum* cercariae and were autopsied 9 weeks later.

The prepotent periods of the infections were determined by the faecal egg hatching technique of Standen (1949). The daily egg output in the faeces was expressed as (eggs per day) and also as (eggs per female worm per day) by collecting approximately overnight faecal specimens from each animal kept individually in a clean boxing room. The total daily egg production divided by the number of female worms recovered giving approximately the number of eggs in the faeces per female worm.

/Results....
RESULTS,

Prepatent periods.

The prepatent periods of *O. turkestanicum* in the different hosts (calves, sheep, and goats) are shown in Table, 8. The prepatent period appeared to be unaffected by the type of host and varied from 43-46 days. The numbers of eggs in the first days of their passage (as judged by the number of hatching miracidia) were very low, then increased gradually. Throughout the prepatent period the animals were healthy, but with the appearance of eggs in the faeces there was a rapid deterioration in their condition.

Infestivity.

The infectivity of *O. turkestanicum* to the different types of host were determined from the adult worms recovered. In calves the mean recovery rate was 37.6%, in sheep 53.9% and in goats 22.5% (see Tables, 9-12).

In the buffalo the worm return was only 9.6%; in the wild pig infected with 5,000 cercariae, only 26 immature worms were recovered. Furthermore, the worms recovered from the buffalo and pig were smaller than normal worms.
Distribution of adult worms.

Some differences were noticed in the distribution of the worms in the different hosts (Table, 13). Very low number of worms were recovered from the hepatic veins (3.1% in calves, 8.3% in sheep and 5.2% in goats) compared with a large number in the mesenteric veins, particularly the veins from the duodenum (96.9% in calves, 91.7% in sheep and 94.0% in goats). No worms were detected from the inferior mesenteric veins. The unpaired worms in the liver were smaller than paired males in the mesenteric veins.

Faecal egg counts.

The daily egg output of *O. turkestanica*um in different hosts are given in Table 8, indicating that the mean number of eggs per gram of faeces per day was higher in cattle than sheep and goats, 179 ± 42, 37 ± 4 and 59 ± 1 respectively. The daily egg output in the faeces per individual female worm was also higher in calves than in sheep and goats (203 in calves, 52 in sheep and 82 in goats at 63 days after exposure to cercariae, Table, 14). No significant decrease of egg output was observed at 128 days after exposure to the cercariae, but with *S. bovis* there was a considerable decline in egg output in faeces as the duration of infection was prolonged (see Part, II).
Distribution of eggs in the visceral organs.

The duodenum was the portion of the alimentary tract most intensely involved as a site of egg deposition (Tables 15, 16, 17). The density of eggs declined gradually in the jejunum and few eggs were found in the ileum. The large intestine was entirely free from eggs. As are shown in Table 13, approximately 97.7% - 99% of eggs in calves, 89% - 90.8% in sheep and 79.4% of eggs in goats were found in the small intestine particularly the duodenum. The liver showed very low egg counts in calves (1% - 2.3%), but much higher egg counts were recovered in sheep (9.2% - 11%) and in goats (20.6%).

The distribution of eggs in the different parts of the liver (left lobe, right lobe and portal tract area) showed no obvious differences. The other organs (lung, spleen, rumen, reticulum, omasum and abomasum) were free from eggs. In the buffalo only a few non-viable eggs were detected.

DISCUSSION,

The prepatent periods in the small and large ruminants varied from 43 to 46 days but it was 62 days in Tatera indica (a wild local rodent).

/ The calves....
The calves and sheep showed a higher worm return than goats, buffaloes and wild pigs were poor experimental hosts for *O. turkestanicum*. Our prevalence studies showed also the same differences in the naturally infected animals.

Male worms always outnumbered female worms and since the cercariae for infection were pooled from at least 100 heavily infected *L. gedrosiana*, this probably shows that male cercariae outnumbered female cercariae in the original suspension, presumably there were more male larval stages in the snails. The predominance of the male worms in experimental animals is well known. Girges (1934) found excess male worms in the portal system of human cases in Egypt and Cheever (1968) found a slight predominance of male worms of *S. mansoni* in humans. Wright and Bennett (1967) found more male worms in hamsters infected with *S. haematobium*. Fairley et al. (1950) found the male worms twice as many as the females in goats infected with *S. spidalis*. Our observations on experimentally and naturally infected animals with *O. turkestanicum* showed a marked predominance of male worms in different hosts. The higher number of male worms in nature may be due to more resistance and therefore longer survival of male cercariae than female cercariae.
or alternatively the male miracidia may be more common or more infective to the snails.

Most of the worms were found in the duodenum, declining in numbers from there down the intestine. No worms or eggs were found in the large intestine. The number of worms in the liver was very low, particularly in calves.

Studies on the egg distribution of various strains of *S. japonicum*, *S. mansoni* and *S. haematobium*, in the different organs of infected mice, hamster and rhesus monkey have shown that the pattern of egg distribution is a strain characteristic (Hsu *et al.*, 1960; Saoud, 1966; Wright and Bennett, 1967; Nelson *et al.*, 1968). Hsu *et al.* (1960) also suggested that distribution of eggs of schistosomes in the visceral organs of its host are influenced by the species of the host and the intensity of the infection in the host.

In our experiments the natural hosts of *O. turkestanium* (calves, sheep and goats) were infected with the same number of cercariae but the resulting egg densities differed, in particular the livers of goats contained many more eggs than sheep and calves. The pattern of distribution of eggs along the alimentary canal was the same in different hosts, and the eggs were mostly deposited in the mucous membrane of the intestine in the duodenum.
There was also a close correlation between the egg densities per gram of liver and the pathological changes which were more severe in sheep and goats than in calves (see Chapter, 5).

The number of eggs in the faeces per individual female worm was very high in calves (283) but lower in sheep and goats (52 and 82 respectively). This differences are mainly due to the large amount of faeces produced by calves (average 2,000 gram) compared with sheep and goats (average 700 gram per day).

The daily egg output of *O. turkestanicum* per gram of faeces are given in Table, 8 (179 in calves, 37 in sheep and 59 in goats) which calves passed more eggs than sheep and goats.
### Table 8

Parasitological behaviour of *O. turkestanicum*

in Calves, Sheep and Goats

<table>
<thead>
<tr>
<th>Type of animals</th>
<th>No. of animal</th>
<th>No. of cercariae</th>
<th>Total worms recovered</th>
<th>Prepatent period (days) ±S.E.</th>
<th>Eggs per gram of faeces per day (63 days after exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8,000</td>
<td>2272</td>
<td>44</td>
<td>179 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>2550</td>
<td>44</td>
<td>215</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>1256</td>
<td>43</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>1062</td>
<td>46</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>5450</td>
<td>43</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>&quot;</td>
<td>3031</td>
<td>44</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>8,000</td>
<td>2737 ± 2569</td>
<td>44 ± 0.4</td>
<td>179 ± 0.4</td>
<td></td>
</tr>
<tr>
<td><strong>Sheep</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>1134</td>
<td>46</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>2342</td>
<td>45</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>1847</td>
<td>43</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>2219</td>
<td>44</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>929</td>
<td>46</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>5,000</td>
<td>1694 ± 248</td>
<td>44.9 ± 0.5</td>
<td>37 ± 4</td>
<td></td>
</tr>
<tr>
<td><strong>Goats</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>1165</td>
<td>46</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>1086</td>
<td>46</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>5,000</td>
<td>1125 ± 39</td>
<td>46 ± 0</td>
<td>59 ± 1</td>
<td></td>
</tr>
</tbody>
</table>
Table 9

The distribution of adult worms of *O. turkestanium* in experimentally infected calves.

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of cercariae</th>
<th>Duration of inf. (weeks)</th>
<th>Liver</th>
<th>Mesenteric veins</th>
<th>Total</th>
<th>Recovery rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F.</td>
<td>M.</td>
<td>total</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>8000</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1018</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>9</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>833</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>9</td>
<td>20</td>
<td>104</td>
<td>124</td>
<td>2357</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>18</td>
<td>33</td>
<td>13</td>
<td>46</td>
<td>538</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>18</td>
<td>9</td>
<td>25</td>
<td>34</td>
<td>963</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>18</td>
<td>25</td>
<td>129</td>
<td>154</td>
<td>896</td>
</tr>
<tr>
<td>7.</td>
<td>5000</td>
<td>9</td>
<td>32</td>
<td>232</td>
<td>264</td>
<td>781</td>
</tr>
<tr>
<td>8.</td>
<td>5000</td>
<td>9</td>
<td>30</td>
<td>20</td>
<td>50</td>
<td>1242</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td></td>
<td></td>
<td>(19)</td>
<td>(66)</td>
<td>(85)</td>
<td>(1078)</td>
</tr>
</tbody>
</table>
Table 10

The distribution of adult worms of O. turkestanicum in experimentally infected sheep.

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of cercariae</th>
<th>Duration of inf. (weeks)</th>
<th>Liver</th>
<th>Mesenteric veins</th>
<th>Total</th>
<th>Recovery rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>5000</td>
<td>9</td>
<td>50</td>
<td>40</td>
<td>90</td>
<td>464</td>
</tr>
<tr>
<td>2.</td>
<td>&quot;</td>
<td>9</td>
<td>15</td>
<td>27</td>
<td>42</td>
<td>950</td>
</tr>
<tr>
<td>3.</td>
<td>&quot;</td>
<td>9</td>
<td>105</td>
<td>217</td>
<td>322</td>
<td>525</td>
</tr>
<tr>
<td>4.</td>
<td>&quot;</td>
<td>18</td>
<td>15</td>
<td>207</td>
<td>222</td>
<td>536</td>
</tr>
<tr>
<td>5.</td>
<td>&quot;</td>
<td>18</td>
<td>76</td>
<td>96</td>
<td>172</td>
<td>339</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(S.E.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>52</td>
<td>117</td>
<td>170</td>
<td>562</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(17)</td>
<td>(40)</td>
<td>(49)</td>
<td>(102)</td>
</tr>
</tbody>
</table>
## Table 11

**Distribution of adult worms of O-turkestanicum in experimentally infected goats.**

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of cercariae</th>
<th>Duration of inf. (weeks)</th>
<th>Liver</th>
<th>Mesenteric veins</th>
<th>Total</th>
<th>Recovery rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F.</td>
<td>M.</td>
<td>total</td>
<td>F.</td>
</tr>
<tr>
<td>1.</td>
<td>5000</td>
<td>9</td>
<td>50</td>
<td>48</td>
<td>98</td>
<td>454</td>
</tr>
<tr>
<td>2.</td>
<td>5000</td>
<td>9</td>
<td>16</td>
<td>2</td>
<td>18</td>
<td>480</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td></td>
<td></td>
<td>33</td>
<td>25</td>
<td>58</td>
<td>467</td>
</tr>
</tbody>
</table>
Table 12

Recovery of adults and eggs of *O. turkestanicum* from large animals experimentally infected.

<table>
<thead>
<tr>
<th>Type of animals</th>
<th>No. of animals</th>
<th>Mean no. of cercariae</th>
<th>Duration of infection (weeks)</th>
<th>Mean worm recovery</th>
<th>Mean tissue egg counts per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F.</td>
<td>M.</td>
</tr>
<tr>
<td>Calves</td>
<td>3</td>
<td>8000</td>
<td>9</td>
<td>1411</td>
<td>1840</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8000</td>
<td>18</td>
<td>821</td>
<td>1365</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5000</td>
<td>9</td>
<td>1042</td>
<td>1392</td>
</tr>
<tr>
<td>Sheep</td>
<td>3</td>
<td>5000</td>
<td>9</td>
<td>703</td>
<td>1071</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5000</td>
<td>18</td>
<td>483</td>
<td>1091</td>
</tr>
<tr>
<td>Goats</td>
<td>2</td>
<td>5000</td>
<td>9</td>
<td>500</td>
<td>625</td>
</tr>
<tr>
<td>Buffalo</td>
<td>1</td>
<td>8000</td>
<td>9</td>
<td>222</td>
<td>551</td>
</tr>
<tr>
<td>Wild pig</td>
<td>1</td>
<td>5000</td>
<td>10</td>
<td>16</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 13

Percentage distribution of adults and eggs of *O. turcestanioum* in different organs of Calves, Sheep and Goats experimental infected.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Duration of infection (weeks)</th>
<th>EGG distribution</th>
<th>Worm distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liver</td>
<td>Small intestine</td>
<td>Large intestine</td>
</tr>
<tr>
<td>Calves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2.3</td>
<td>97.7</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>1.0</td>
<td>99.0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>1.0</td>
<td>99.0</td>
<td>0</td>
</tr>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>11.0</td>
<td>89.0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>9.2</td>
<td>90.8</td>
<td>0</td>
</tr>
<tr>
<td>Goats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>20.6</td>
<td>79.4</td>
<td>0</td>
</tr>
</tbody>
</table>
Table, 14

Eggs production of *O. turkestanicum*, in large animals as estimated by faecal egg counts during the period of observations.

<table>
<thead>
<tr>
<th>Type of animals</th>
<th>No. of animals</th>
<th>Days post infection</th>
<th>Mean no. of female worms</th>
<th>Mean no. of eggs per gram of faeces per day</th>
<th>Mean no. of eggs per female per day in faeces *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves</td>
<td>5</td>
<td>63</td>
<td>1263</td>
<td>179</td>
<td>283</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>126</td>
<td>621</td>
<td>100</td>
<td>243</td>
</tr>
<tr>
<td>Sheep</td>
<td>3</td>
<td>63</td>
<td>703</td>
<td>37</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>126</td>
<td>483</td>
<td>60</td>
<td>86</td>
</tr>
<tr>
<td>Goats</td>
<td>2</td>
<td>63</td>
<td>500</td>
<td>59</td>
<td>82</td>
</tr>
</tbody>
</table>

* Based on the overnight faecal output.
Table 15

The distribution of *O. turkestanicum* eggs in tissues of Calves in infections of different duration

<table>
<thead>
<tr>
<th>Duration of inf. (weeks)</th>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>Large intestine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R.Lobe</td>
<td>L.Lobe</td>
<td>P.T.</td>
</tr>
<tr>
<td>9</td>
<td>1022</td>
<td>260</td>
<td>300</td>
<td>280</td>
</tr>
<tr>
<td>9</td>
<td>834</td>
<td>110</td>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>2377</td>
<td>810</td>
<td>800</td>
<td>840</td>
</tr>
<tr>
<td>9</td>
<td>813</td>
<td>230</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>9</td>
<td>1272</td>
<td>60</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Mean</td>
<td>1263</td>
<td>294</td>
<td>294</td>
<td>284</td>
</tr>
<tr>
<td>18</td>
<td>571</td>
<td>0</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>18</td>
<td>972</td>
<td>100</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>18</td>
<td>921</td>
<td>160</td>
<td>100</td>
<td>250</td>
</tr>
<tr>
<td>Mean</td>
<td>821</td>
<td>87</td>
<td>117</td>
<td>133</td>
</tr>
</tbody>
</table>

(P.T.) Portal Tract Area
Table 16
The distribution of Q. turkestanicum eggs in tissues of Sheep in infections of different duration.

<table>
<thead>
<tr>
<th>Duration of inf. (weeks)</th>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>Large intestine per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R. Lobe</td>
<td>L. Lobe</td>
<td>P.T.</td>
<td>Mean</td>
</tr>
<tr>
<td>9</td>
<td>514</td>
<td>1470</td>
<td>1506</td>
<td>1400</td>
</tr>
<tr>
<td>9</td>
<td>965</td>
<td>1712</td>
<td>1365</td>
<td>514</td>
</tr>
<tr>
<td>9</td>
<td>630</td>
<td>680</td>
<td>520</td>
<td>690</td>
</tr>
<tr>
<td>Mean</td>
<td>703</td>
<td>1287</td>
<td>1130</td>
<td>668</td>
</tr>
<tr>
<td>18</td>
<td>551</td>
<td>300</td>
<td>310</td>
<td>1100</td>
</tr>
<tr>
<td>18</td>
<td>415</td>
<td>1022</td>
<td>725</td>
<td>775</td>
</tr>
<tr>
<td>Mean</td>
<td>483</td>
<td>661</td>
<td>517</td>
<td>937</td>
</tr>
</tbody>
</table>

(P.T.) Portal Tract Area.
Table 17

The distribution of *O. turkestanicum* eggs in tissues of goats in infections of different duration.

<table>
<thead>
<tr>
<th>Duration of inf. (weeks)</th>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>large intestine per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R. Lobe</td>
<td>L. Lobe</td>
<td>P.T.</td>
</tr>
<tr>
<td>9</td>
<td>504</td>
<td>2490</td>
<td>2240</td>
<td>1950</td>
</tr>
<tr>
<td>9</td>
<td>496</td>
<td>1050</td>
<td>1160</td>
<td>1100</td>
</tr>
<tr>
<td>Mean</td>
<td>500</td>
<td>1770</td>
<td>1700</td>
<td>1525</td>
</tr>
</tbody>
</table>

(P.T.) Portal Tract Area
CHAPTER 4

EXPERIMENTAL STUDIES ON THE SUSCEPTIBILITY
OF RODENTS, SMALL CARNIVORES AND BIRDS TO
O. TURKESTANICUM.

INTRODUCTION.

These studies were made in an effort to find a
susceptible animals for the laboratory maintenance of O. turkestanicum
and to evaluate the usefulness of various hosts for investigation
of different phases in the biology of the parasite under laboratory
conditions. At the same time it was hoped that the study might
indicate which if any of the wild mammals and birds in Khouzistan
might be capable of transmitting O. turkestanicum in nature.

MATERIAL AND METHODS.

Most of the wild mammals used in this experiments are
common throughout the Khouzistan provinces.

Tatera indica (gorbil) is very common in the cultivated
areas and near houses; Nesokia indica (bandicoot) is found in
the cultivated.
the cultivated areas near water sources; *Rattus rattus*, the common house rat is found throughout the Khuzestan; *Mus musculus*, the common house mouse is found in human habitations, and *Herpestes* spp. (mongoose), inhabits canal banks in cultivated areas throughout the irrigation systems in Khuzestan.

Common stray dogs and cats and different laboratory rodents (*albino mice, hamster, rabbit* and multimammate rats (*Mastomys natalensis*) were also used. Common domestic ducks and chicken were also tested.

The mammals were exposed to different number of *cercariae* by immersion in *cercarial suspensions*. Among those animals only the mongoose was anaesthetized (with chloroform) before exposure to *cercariae*. The birds were exposed to *cercariae* by paddling and also cercarial suspension were administered through the mouth. Animals were autopsied at various intervals to allow the parasite to develop.

**RESULTS**

The results of experimental infections of small mammals and birds are shown in Tables 18, 19.
The only wild rodent that developed a fair good infection was *Tatera indica* the local gerbil, this rodent lives very close to houses and farms. A moderate percentage of the worms were recovered as fully developed adults about 15.1%, with prepatent period of 62 days. Approximately 15% of the total eggs in the tissues contained fully developed miracidia 10 weeks after exposure to cercariae.

In the other wild rodents the numbers of worms recovered varied from 1.8% in *Mus musculus* to 16.4% in *Nesokia indica* (Table, 18). In other species numerous immature eggs were deposited in the liver, but no viable eggs were observed. *Rattus rattus* and *Mus musculus* were very poor hosts with the very immature worm returns of only 3.7% and 1.8% respectively.

Of the usual laboratory animals, white mice, hamsters, multimammate rats and rabbits were all infected with parasite with recovery rates of 26.9%, 34.2%, 25.8% and 21.0% respectively, but non of them produced viable eggs.

One young dog 2 months old, 2 kittens, 3 mongooses, 6 ducks and one chicken were also experimentally exposed to /different....
different number of *O. turkestanicum* cercariae. The cats died 20 days after exposure to cercariae due to some food toxicity. The dog, mongooses and birds were autopsied 10 to 12 weeks later, no any *O. turkestanicum* worm were detected. Those animals were therefore considered as insusceptible to infection with *O. turkestanicum* (Table, 19).

**DISCUSSION,**

It has been known since the earlier investigations on schistosomiasis that many domestic and wild animals are readily susceptible to infection with schistosomes infecting man and such animals serve as maintenance hosts and specially for *S. japonicum* and so enhance transmission to man (see Review by Nelson 1969 and 1971). A similar situation occur with schistosomes of veterinary importance, for example *S. mattheei* and *S. bovis* in Africa of which may antelopes are natural hosts (Le Roux, 1930).

The experimental infections reported here show that *Tatera indica* is a moderately susceptible host for *O. turkestanicum* as shown by number of viable eggs in the tissues and faeces. Hitenberg and Longy (1966) reported *O. turkestanicum* from an /unidentified...
unidentified field rat naturally infected in south Turkey in 1930 (preserved material) and Arfaa et al (1965) recorded that Tatera indica was susceptible to infection producing viable eggs with a prepatent period of 80-82 days. It is unlikely that this animal is a true mammalian host in nature in Khuzestan. MacRattie (1936) reported the developing of O. turkestanicum in rabbit, guinea pig and white mouse but only a few pairs of immature worms were produced with no eggs in tissues or faeces. Azimov et al (1968) also reported that O. turkestanicum from Amu Darya in Uzbekistan were developed to maturity in the rabbit.

The laboratory maintenance of O. turkestanicum in Tatera indica proved rather difficult. This wild rodent does not breed easily in laboratory and stocks had to be provided from animals trapped in the field. It proved easier to maintain the parasite on calves or sheep.

The results of the survey of mammals in Khuzestan and the laboratory studies suggest that the wild game play little part in maintaining this infection in nature and that the only significant hosts are the domestic ruminants.
<table>
<thead>
<tr>
<th>Heat</th>
<th>No. of animals</th>
<th>No. of cercariae</th>
<th>Mean worm recovery</th>
<th>Mean tissue egg counts</th>
<th>average prepant period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>F.</td>
<td>M.</td>
</tr>
<tr>
<td>Albino mice</td>
<td>15</td>
<td>50-400</td>
<td>300</td>
<td>43</td>
<td>37</td>
</tr>
<tr>
<td>Hamster</td>
<td>11</td>
<td>50-200</td>
<td>125</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Mastomys natalensis</td>
<td>10</td>
<td>100-400</td>
<td>240</td>
<td>62</td>
<td>37</td>
</tr>
<tr>
<td>Rabbit</td>
<td>6</td>
<td>200-1500</td>
<td>750</td>
<td>32</td>
<td>125</td>
</tr>
<tr>
<td>Tatera indica</td>
<td>10</td>
<td>200-1000</td>
<td>600</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>Nesokia indica</td>
<td>7</td>
<td>200-1000</td>
<td>600</td>
<td>42</td>
<td>51</td>
</tr>
<tr>
<td>Rattus rattus</td>
<td>6</td>
<td>200-1000</td>
<td>670</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Mus musculus</td>
<td>8</td>
<td>100-400</td>
<td>250</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 19

The results of exposing miscellaneous animals and birds to the cercariae of _O. turkestanicum_

<table>
<thead>
<tr>
<th>Host</th>
<th>No. exposed</th>
<th>Cercariae</th>
<th>Duration of infection (weeks)</th>
<th>Worms recovery and tissue egg counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>Dog</td>
<td>1</td>
<td>5000</td>
<td>5000</td>
<td>10</td>
</tr>
<tr>
<td>Cat</td>
<td>2</td>
<td>1000–2000</td>
<td>1500</td>
<td>3</td>
</tr>
<tr>
<td>Mongoose</td>
<td>3</td>
<td>500–1500</td>
<td>1000</td>
<td>12</td>
</tr>
<tr>
<td>Duck</td>
<td>6</td>
<td>500–3000</td>
<td>1000</td>
<td>10</td>
</tr>
<tr>
<td>Chicken</td>
<td>1</td>
<td>3000</td>
<td>3000</td>
<td>12</td>
</tr>
</tbody>
</table>
CHAPTER 5

THE PATHOLOGY OF NATURALLY AND EXPERIMENTALLY INFECTED RUMINANTS

INTRODUCTION.

The present study was undertaken to assess the pathological consequences of *O. turkestanicum* infection in experimentally infected calves, sheep and goats. Observations were also made on naturally infected animals including 21 cattle and 12 sheep heavily infected with *O. turkestanicum* collected from Dezful abattoir.

RESULTS.

PATHOLOGY OF EXPERIMENTAL INFECTIONS.

CALVES.

Ante-mortem examination.

The clinical conditions observed in the 12 calves experimentally infected with *O. turkestanicum* could be divided into 3 stages, the first stage characterized by restlessness and emaciation at the early prepatent period; the second stage mostly diarrhoea with foetid faeces, harsh hair coat and hollow appearance of the ....
of the abdomen; the third stage was the recovery stage in which the acute manifestations disappeared and the animals showed signs of recovery. In comparison with *S. bovis* infection, the acute stage in *O. turkestanicum* infection was very short, mild and most of the calves recovered, but the emaciation persisted.

**Post-mortem examination,**

There were slight serous effusions in the abdominal cavity, thorax and some degree of hydropericardium. Lymph nodes were slightly enlarged and pigmented. The liver showed no obvious changes with no evidence of any minute greyish granulomata seen on the surface in *O. turkestanicum* infections. The density of *O. turkestanicum* eggs per gram of liver was very low in comparison with *S. bovis*. The mesenteric blood vessels in the duodenum were the most favourable site for adult worms and showed some degree of dilatation. The duodenum slightly swollen and some red focal lesions were observed in the mucosa. The characteristic eggs of *O. turkestanicum* were readily demonstrated in mucosal scrapings of the affected bowel (Plate 3).

**Microscopic examination,**

*O. turkestanicum* produced no severe pathology in the calves' liver. In microscopic preparations there was some cellular infiltration...
infiltration in the intrahepatic spaces in early stages particularly eosinophil infiltration.

In the intestinal tract, the eggs were found chiefly in the mucous membrane and occasionally in the lumen, but not in the submucosa as characteristic of *S. bovis* infections (Plates, 4, 5). Many of the eggs in the intestinal mucousa showed peculiar degeneration. They were distended and contained dead miracidia and were surrounded by lymphoid cells (Plate, 6). In general the *O. turkestanicum* infection in calves was much less serious than in *S. bovis* infection. It seems *O. turkestanicum* better adapted to cattle than any of the other bovine schistosomes.

**SHEEP**

**Ante-mortem examination.**

Sheep were more affected by *O. turkestanicum* than calves and the clinical manifestations were quite obvious with loss of wool, lack of appetite, progressive emaciation, mucoid faeces and occasionally haemorrhagic diarrhoea. In spite of a good quality diet the weakness and loss of weight was pronounced. In some cases mild pneumonia with dry cough was obvious.

/Post-mortem....
Post-mortem examination,

In post-mortem examination there was a small amount of serous effusion in the abdominal cavity but considerable hydrothorax. Lymph nodes in general showed enlargement. The liver was chiefly affected with numerous minute greyish granulomata on the surface of liver under Glisson's capsule, but there were no lymphoid nodules in liver such as were seen frequently in S. bovis infections. Large numbers of adult worms were readily seen in the mesenteric and portal veins by holding up loops of intestine to the light. The mesentry and portal veins showed considerable dilatation. The intestinal wall was friable and easily damaged on examination and in some cases the duodenum was a dark-grey colour with haemorrhagic foci in the mucousa.

Microscopic examination,

Frequent deposition of pigment and occasional thrombo-phlebitis was noted in the liver; there was also cellular infiltration in the intralobular spaces and in the neighbourhood of Glisson's capsule. The eggs arrested in the liver and intestine gave rise to a well-defined nodules with numerous eosinophils and lymphoid cells infiltration but the reactions were not so marked and serious....
and serious as seen in *S. bovis* infections.

In the intestine the eggs were mostly found in the mucous membrane with cellular reaction and heavy eosinophils infiltration between the villi. Thickening and nodule formation in the intestinal wall particularly in the duodenum was pronounced.

**GOATS**

**Ante-mortem examination,**

Goats showed better tolerance to *O. turkestanicum* infection than sheep, and the percentage of worms recovery was lower. Clinical manifestations started with restlessness, emaciation, coated faeces and occasional diarrhoea but the general condition of the goats was much better than in the sheep.

**Post-mortem examination,**

Thoracic, hepatic and mesenteric lymph nodes were slightly enlarged. The worms were mostly in the duodenal venules. The liver showed numerous minute greyish granulomata, the gall bladder was distended. There was no sign of lymphoid nodule formation. 

//Microscopic....
Microscopic examination.

The liver of the goats showed well defined granulomata with cellular infiltration with degenerated eggs in the centre in intralobular spaces. The most striking picture in goats was the Hoeplli phenomenon with antigen-antibody deposition around the eggs producing acidophil rosette-formation. The eggs were prevalent in the mucous membrane of the duodenum with some cellular infiltration.

**PATHOLOGY IN NATURAL INFECTIONS.**

Observations on 21 cattle and 12 sheep heavily infected with *O. turkestanicum* showed that naturally infected cattle harboured more parasites than sheep and goats, but the pathological changes in the internal organs were more severe in sheep than in cattle.

**CATTLE,**

The clinical condition of the naturally infected cattle was poor with harsh hair coat and emaciation. In most cases *O. turkestanicum*...
*O. turkestanicum* was associated with heavy *Fasciola gigantica* infection, so that it was impossible to be sure of the relative importance of *O. turkestanicum* as a cause of the illness but the slender and narrow shoulders of cattle was characteristic with heavy *O. turkestanicum* infections.

In post-mortem examination in heavily infected cattle the mesenteric fat-bodies were replaced by oedematous effusions with considerable amounts of ascitic fluid in the abdominal cavity. General hypertrophy and enlargement of the lymph nodes was noticed. The liver was not changed in appearance except for hypertrophy of the hepatic lymph nodes, and distension of the gall bladder. In general the number of worms recovered from the liver was very low and the egg density was also low. Histological examination showed few changes mostly eosinophile infiltration and rare egg particles. The intralobular changes in liver were mixed with fibrous formation due to the fasciolasis. The mesenteric veins were distended and loaded with a large number of adult *O. turkestanicum*.

/The mucous....
The mucous membranes of the small intestine was seriously damaged with a mass of cellular infiltration and heavy egg deposition. The most interesting picture was the general eosinophils infiltration with dead eggs in intestinal mucousa without defined granuloma formation.

**SHEEP,**

In spite of the low worms burden in sheep compared with the high worm recovery in cattle, the sheep were more affected than cattle. The progressive emaciation and the paleness of the carcasses of sheep suggested *O. turkestanioum* infections even on superficial inspection. In the abdomen there was considerable serous effusion, degeneration of the fat-body and oedematous reactions in the mesentry. Enlargement and pigmentation of the lymph nodes was common in most of the heavily infected sheep, particularly the medial lymph nodes in thorax. Dilatation of the mesenteric veins, tortuous appearance of the intestinal veins and the dark colour of duodenum were conspicuous.

/*The liver....*/
The liver usually showed either mild or moderate pathological changes. Macroscopically, the most outstanding findings were the minute greyish pseudotubercles all over the liver surface and deep in the liver substance. Microscopically these greyish dots contained *O. turkestanicum* eggs in different stages of disintegration surrounded by a variety of cellular infiltration and granuloma formation. The eosinophils proliferation was pronounced in both liver and intestine. In the intestine the eggs were found chiefly in the mucous membrane and lumen of the duodenum. A striking feature was the intense eosinophil and lymphoid cell infiltration in the villi of the duodenum (Plate, 7). In very heavily infected sheep the intestine was dark in colour with a weak walls which was easily damaged in pulling it away from the mesentery.

**DISCUSSION,**

Yamagiwa (1931) for the first time described the pathological finding of *O. turkestanicum* in naturally infected Mongolian cattle and described the acidophil rosette-type reactions around the *O. turkestanicum* ova.
ova, a phenomenon which was later described by Heeppli (1932) in *S. japonicum* infection. According to Yamagiwa the pathogenicity of *O. turkestanicum* in cattle is much milder than *S. japonicum*. In our investigations we also found that *O. turkestanicum* produced a much milder disease than *S. bovis*. MacHattie (1936) reported serious effects of heavily infestations in sheep and goats with *O. turkestanicum* but he also mentioned the low pathogenicity of this parasite in cattle. Lavrov et al. (1964, 1967) studied the pathological aspects of *O. turkestanicum* in Uzbekistan ruminants and the pathological changes of affected organs particularly enlargement of the lymph nodes were mentioned.

The conclusion from the present study of the pathology of *O. turkestanicum* is that although cattle are heavily infected, the disease is less severe in cattle than in sheep. Adult cattle are well adapted and can carry heavy loads of the parasite but sheep can be seriously ill with the disease. It is not known to what extend the lesions in the duodenum affect the nutrition of cattle, there is no doubt....
doubt that *O. turkestanicum* in sheep is of considerable economic importance with severe losses in meat and wool; the damage in the intestine also makes them useless for processing as sausage skins.

In Iran and Iraq sheep and goats intestines are of considerable economic importance for the country by exporting to other countries for use as casings for sausages and also for some other industrial products. The intestines are examined for their ability to hold water and tested one by one by practiced workers and according to their quality are graded “high” or “low” or discarded entirely. Thus porous intestines known in the trade as “sprinklers” are discarded and intestines showing patchy thickness are of little value since they are not of uniform strength. The west part of Iran (Kermanshah and Kurdestan) produces excellent casings while the south-west part (Khuzestan) show a high proportion of “sprinklers”. MacHattie (1936) also reported a large number of discarded sheep intestines from the southern Iran particularly Basreh area, due to Schistosomiasis. Damages usually cause by deposition of eggs in intestinal walls and tissue reactions.
Prophylactic measures against bovine schistosomiasis in the absence of a control program could include: keeping animals off pastures and water courses where surveys had revealed infected snails; providing clean water supply; sending the weak and infected animals to slaughter as soon as possible; keeping young stock and adults separate from point of view of pastures.
Plate, 2

The egg of *Ornithobilharzia turkestani*um

Plate, 3

The eggs of *O. turkestani*um in a smear of a small intestine scraping.
Plate, 4

Duodenum of a calf showing numerous ova of *O. turkestanicum*

in the mucosa (H.E. 120 x).

Plate, 5

Typical *O. turkestanicum* eggs in the mucous membrane of the intestine with diffused cellular infiltration (H. E. x 240).
Plate, 6

Distended egg with dead embryo of O. turkestanicum in intestine with tissue response (H. E. x 560).

Plate, 7

Degeneration of superficial mucosa of intestine. Ova are apparent in the mucosa with dense eosinophil infiltration (natural infected sheep with O. turkestanicum, H. E. x 120).
PART II
INTRODUCTION,

Schistosoma bovis was first found by Sonsino (1876) in the portal veins of a bull in Zagazing, Egypt. Subsequent records are by:

Blane and Desportes (1936) from Morocco; Anderson and Gobert (1934) from Tunisia; Van den berghe (1934) and Werry (1952) from various part of Congo; Dowdeswell (1938) from Kenya; Uganda, Rhodesia, Angula and Mozambique (W.H.O. tech. series, 139, 1957); Edwards and Wilson (1958) from Ghana; Sobrero (1960) from Somalia; Marill (1961) from Mauritania; Cowper (1963) from Nigeria; Dinnik and Dinnik (1965) from Tanzania and Zambia; Soliman (1956). Eisa (1963), Malek (1961, 1969) and Hussein (1969) from Sudan.

Outside Africa S. bovis exists in several Mediterranean countries including: Sicily (Grassi and Rovelli, 1898); Sardinia (Sam-Felice and Loi, 1897); Italy (Bertolini, 1908); Corsica (Brumpt, 1930) and Spain....
and Spain (Sanchez Betija, 1955). *S. bovis* is also a common parasite in the Middle-East and has been reported from animals in Iraq by MacHattie and Chawick (1932), MacHattie (1936); Israel by Witenberg (cited by Lensy, 1962) and Iran (Bijan *et al.*, 1958; Arfaa, 1959; Arfaa *et al.*, 1965).

*S. bovis* is principally a parasite of cattle to which it is well adapted and sheep and goats, occasionally horses, donkeys and camels are definitive hosts of secondary importance. Faulkner and Epstein (1957) and Dinnik and Dinnik (1965) have suggested that African *S. bovis* originated from the Mediterranean area after A.D. 668 and that the parasite was widely disseminated by migration of domesticated animals with nomadic people into north-east Africa, and gradually to the south via the eastern coast of Africa. On the other hand *S. mattheei* is indigenous species to central and south Africa where it is maintained in indigenous wild mammals and snails.

There is a very close morphological resemblance between *S. bovis* and *S. mattheei* and this give rise to considerable discussion...
on their validity as separate species (MacHattie and Chadwick, 1932; 
Van deh Berghe, 1937; Alves, 1949; Pitchford, 1965; Dinnik and Dinnik, 1965).

The original morphological description of S. bovis by Khilil 
(1924) was largely modified by MacHattie and Chadwick (1932) after 
examination of over 4,000 specimens of S. bovis from different species 
of domestic animals in Iraq. Detail accounts of the morphology of 
S. bovis were also made by Lengy (1962) in Israel and Dinnik and Dinnik 
(1965) from the Sudan.

S. bovis is very infective to cattle, sheep and goats. It 
has also been found in pigs (Malek, 1961); camels (Solaiman, 1956); 
antelopes (Van den Berghe, 1937) and the rodent, Lophuromys flavopunctus 

Experimental infection with S. bovis has been reported in 
various species of small laboratory animals, calves, sheep, a cat and 
donkey....

The most susceptible laboratory animals for S. bovis as reported by Lengy (1962 a) were the hamster. Lurie and DeMeillon (1956) reported that Mastomys natalensis was a good experimental host for S. bovis. A gerbil Tatera indica was reported to be a good experimental host for this parasite in Iran (Arfaa et al., 1965).

The objective of the present work was to study the behaviour of this parasite in different type of ruminants in parallel with the observations on O. turkestanicum (see Part, I). The immunological interactions of S. bovis with the other schistosomes occurring in the area have also been studied (see Part, III). Observations on Bulinus truncatus, the snail "vector" of S. bovis and S. haematobium in Khuzestan have been reported elsewhere (see Chu, Massoud and Arfaa, 1968).
CHAPTER 1

STUDIES ON THE PREVALENCE AND INTENSITY OF
S. BOVIS IN DOMESTIC ANIMALS IN KHUZESTAN.

INTRODUCTION,

Bijan et al. (1958) was the first to report this parasite in Khuzestan (Iran). The intermediate host of this parasite is Bulinus truncatus in Iran and the same snail is the intermediate host for S. haematobium. The study of this parasite in ruminants was considered worthwhile because of its economic and zoonotic significance. Infection of man with S. bovis seems rather unlikely but eggs resembling S. bovis have been found in man (Raper 1951, Kisner et al. 1953, Soldánman 1956, Malek 1961, Blair 1966, McMahon 1969).

A study on S. bovis infection in animals in Khuzestan was carried out by Arfaa et al. (1965) and revealed that 20.8% of cattle and 14.0% of sheep were infected with this parasite. This data were based on...
based on the examination of mesenteric veins of animal viscerae slaughtered in Dezful abattoir from 1962-1964 which was before the antibilharzia snail control measures against *B. truncatus* were undertaken.

In the present study the same technique were used in the same area in large number of animals from 1969-1970 approximately 5-6 years after extensive snail control measures were initiated (see Massoud et al, 1969).

**RESULTS AND CONCLUSIONS,**

Observations on 632 cattle, 607 sheep and 89 goats showed a dramatic reduction in the *S. bovis* infection rate in cattle from 20.8% in 1964 to 0.8% in 1970. The reduction in sheep was from 14.0% in 1964 to nil in 1970 (see Table, 31). Only 5 cattle were found infected and the infection were very light and were mostly mixed infections with *O. turkestanicum*.

These results show that the prevalence of bovine schistosomiasis can be used as an index of the effectiveness of control measures against human schistosomiasis, particularly in an endemic....
an endemic area like Khuzestan where the intermediate host of
*S. haematobium* (the only 'human' schistosome) and *S. bovis* is the
same (*B. truncatus*). The life-span of ruminants usually does not
exceed more than 7-10 years and during this period if proper control
measures against molluscan host are achieved the sharp reduction
of infection rate among ruminants indicates that snail destruction
and interruption of transmission in the area has been successful.

Our data collected from 1969-1970 on *S. bovis* after long
snail control measures (Massoud *et al.*, 1969) compared with data
collected by Arfaa *et al.* (1965) from 1962-1964 before snail control
measures in the same area on *S. bovis* shows a striking reduction in
infection rate of *S. bovis* among ruminants (Table, 31).

The data on human urinary schistosomiasis in the same area
of Khuzestan before and after snail control measure and chemotherapy
shows a considerable reduction of infection rate in human population
from average 38% (*Bilharziasis Pilot Project Report, 1964*) to under
10% (Arfaa *et al.*, 1970). The incidence studies on 606 negative
children from 1966 showed only 3.5% infected in 1968 (Arfaa *et al*
1970) most of the infected cases coming from the southern of Study
Area. These results indicates that campaign against the snail
intermediate host are effective for the control of human and animal
schistosomiasis.
Table 31

Comparing the infection rate of *E. bovis* in cattle and sheep before and after snail control measures in Khuzestan

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>1962-1964</th>
<th>1969-1970</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. examined</td>
<td>No. infected</td>
</tr>
<tr>
<td>Cattle</td>
<td>250</td>
<td>52</td>
</tr>
<tr>
<td>Sheep</td>
<td>71</td>
<td>10</td>
</tr>
</tbody>
</table>
The objective of this study was to illustrate the behaviour of this parasite in the various ruminants in Khuzestan. The animals used for this study were 7 calves, 5 sheep, 2 goats and one buffalo-calf, 7-9 months old. All the animals were exposed to 5,000 cercariae of S. bovis and were autopsied at 9 weeks or 18 weeks after exposure. The faecal examination were begun 35 days after exposure to cercariae.

RESULTS.

Prepatent Periods.

The prepatent period of *S. bovis* in calves was shorter than in sheep and goats (range 44-45 days, mean 44.6 ± 0.2 in calves; range 47-50 days, mean 48.6 ± 0.6 days in sheep; range 47-48 days, mean 47.5 days in goats (see Table, 20). The differences between the means of the prepatent periods in calves and sheep were statistically significant *P* < 0.001.

/ Infectivity....
Infectivity.

As can be seen in Tables, 21-23 the mean number of worms recovered from calves varied from 2693-3562 (mean 3104 ± 146) this represents a recovery rate of 62.0 %. In sheep the worm recovery varied from 1624-2496 (mean 2072 ± 193), representing a recovery rate of 41.0 %. The corresponding figures for the goats were 3077-3656, (mean 3366 ± 289), recovery rate of 67.0 %. Slightly more male worms were recovered than female, though the differences were less than those observed in O.turkestanicum infections (see Part, I).

Distribution of adult worms.

Most of the worms were recovered from the mesenteric veins (Table, 24). In calves the mean number of worms collected from the hepatic veins was 440 ± 158 and from the mesenteric veins 2664 ±167 (total 14 % in liver); in sheep 158±72 worms were from the liver and 2072±193 from the mesenteric veins (total 7.6 % in liver); in goats 857 worms were from the liver and 2509 from the mesenteric veins (total 24 % in liver).

/ The distribution...
The distribution of worms in the mesenteric veins was entirely different from *O. turkestanicum*; worms were all evenly distributed in veins down the large and small intestine in *S. bovis* whereas they were all in veins of the small intestine (*superior mesenteric veins*) in *O. turkestanicum* infections (see Part, I).

**Fecal egg counts.**

The daily egg output of *S. bovis* are given in Table, 20. The number of eggs per gram of faeces per day varied from 40-135 (75 ± 15) in calves, from 41-92 (60 ± 8) in sheep and from 75-76 in goats.

The number of eggs per female passed per day in the faeces was estimated as described for *O. turkestanicum* eggs. The number of eggs in calves declined from 106 eggs per day per female worms at 63 days after exposure to 67 at 126 days after exposure. In contrast in sheep this number increased from 52 eggs per female per day at 63 days after exposure to 112 eggs per day at 126 days after exposure (see Table, 25).
Distribution of eggs in the visceral organs.

The pattern of egg distribution of *S. bovis* differed from *O. turkestanicum* eggs in the same hosts (see Tables 26-28). Egg densities per gram of tissues had a fairly uniform distribution in the small and large intestine. The total mean number of eggs per gram of tissue was highest in sheep and goats (6466 ± 610, 7807 ± 215) and least in calves (3143 ± 383). The percentage of egg deposition in the liver, small intestine and large intestine was 23.3, 38.5, 37.7 in calves; 50.3, 23.9 and 25.8 in sheep; and 22.2, 45.2 and 32.6 in goats (Table, 24).

The most striking picture was the increasing number of eggs per gram of tissue in sheep with increasing duration of infection, but in contrast there was a decline in egg densities with increased duration of infection in calves (Table, 29). This suggests that there is a partial immune response in calves, but no response in sheep. 

/The pathological...
The pathological manifestations particularly in the liver of sheep and goats also became more severe with increased duration of the infection.

A statistical analysis of the egg densities of *S. bovis* in different parts of alimentary tract in calves and sheep can be seen in Table, 30. The differences between egg densities in various organs at 9 weeks were significant only in the liver and ileum, but 18 weeks after exposure the results were striking and the differences in egg densities were highly significant in all parts of alimentary canal. This is illustrated in the Table, 30 and Fig. 3 and 5.

Digestion of other organs including the lung, spleen, rumen, reticulum, omasum and abomasum showed that only the abomasum was affected but from pathological point of view the densities were insignificant.

The exposure of one buffalo-calf to 5,000 cercariae of *S. bovis* produced no traces of any schistosome infection at autopsy 9 weeks after exposure to cercariae.

/ Discussion....
DISCUSSION

It is generally accepted that the normal mode of entry of S. bovis cercariae into the host's body is via the precutaneous route. Lengy (1962 b) infected sheep successfully with this parasite by immersing the legs in contaminated water for 2 hours; McCully and Kruger (1969) similarly reported a satisfactory worm return of S. mattheei by infecting the sheep by immersing one of the front legs into the cercarial suspension in a large glass jar for 30 minutes. Malek (1969) used a glass ring with S. bovis cercarial suspension putting on the shaven skin of ruminants. Sased and Nelson (1969) used partial tail immersion in calves with S. mattheei and S. mansoni cercariae. None of these workers produced such a high worm return as in the present study (67.3% in goats, 62.1% in calves and 41.4% in sheep). The method used was a modification of Kruger's method, the cercariae being suspended in a polythene bag which was fitted to one of the front legs of animal for 45 minutes. This method has proved to be a convenient and satisfactory method for infecting large mammals and could be adopted for laboratory studies with other animals such as monkeys.

/ The duration....
The duration of the prepatent period in schistosomes has been used as a criteria for differentiating schistosomes species (Schwetz, 1951, 1954); and also to differentiate geographic strains Hsu and Hsu (1954); Saoud (1966); Nelson et al (1968).

Hussein (1969) reported that the prepatent period in calves experimentally infected with S. bovis averaged 48 days. Malek (1969) reported that the prepatent period in the Sudan strain of S. bovis in calf, sheep and goats were 60, 51 and 65 days respectively, which was considerably longer than our findings with Iranian strain of S. bovis in the same hosts (44 days in calves, 48 days in sheep and 47 days in goats).

The results show that the prepatent period is longer in sheep and goats than in calves. The lower number of egg densities and shorter prepatent period in calves indicate that S. bovis is well adapted to the cow which is probably the main host for the maintenance of S. bovis in nature. Sheep and goats are probably of secondary importance....
importance as definitive hosts and are more seriously affected by S. bovis than cattle.

The experimental exposure of the buffalo to S. bovis and our epidemiological data on 96 buffaloes slaughtered from 1969-1970 and 65 buffaloes slaughtered from 1962-1964 (Arfaa et al., 1965) in Khuzestan suggest that this animal is naturally resistant to S. bovis infection. Faust (1924) noted that water buffalo wades in area infested with cercariae of S. japonicum without developing infection and he suggested that the thick skin of these animals might explain their apparent immunity. But Fairley (1930) showed that buffaloes can be infected precutaneously with the cercariae of S. spidale.

In the buffalo-calf exposure to O. turkestanicum cercariae by leg immersion technique 9.6% of the worms developed (see Part, I). These observations conclude that the buffalo is naturally resistant to S. bovis and S. japonicum but not to S. spidale or O. turkestanicum.

The number of male worms in the S. bovis infections slightly outnumbered the females. The recovery of S. bovis was much higher than with O. turkestanicum infections in cattle, sheep, and goats. This may probably explain the more wide-spread distribution of S. bovis although the distribution of the snail host is also more wide-spread.
The most interesting finding in the faecal egg counts was the declining number of eggs per female per day with prolonged duration of infection in calves and in contrast to the increasing egg output in sheep.

Malek (1969) found that in *S. bovis* the number of eggs per gram of faeces in sheep was much higher than cattle, which coincided with our finding with longer infections (18 weeks). McCully et al. (1969) reported the same decline of egg output in faeces of oxen and sheep experimentally infected with *S. mattheesi*.

Distribution of eggs in liver, small and large intestine was more or less uniform in each species of animals. But the egg densities per gram of tissues in sheep and goats were much higher than in calves; in particular the liver in sheep and goats were more affected by eggs. The density of eggs again dramatically increased in sheep with longer duration of infection and in contrast declined in calves possibly due to acquired resistance in the calves. The worms in the calves appeared to produce many fewer eggs than those in sheep and goats.
Fig. 4

Histogram showing declining egg densities of *S. bovis* in calves per gram of tissues by duration of infection.

- **18 weeks infection**
- **9 weeks infection**
Fig 5

Histogram showing increasing egg densities of S. bovis in sheep per gram of tissue by duration of infection.

18 weeks infection
9 weeks infection

Number of eggs/gram of tissue

25000 20000 15000 10000 5000 0
Table 20

Parasitological behaviour of *S. bovis* in Calves, Sheep and Goats.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>No. of animals</th>
<th>No. of cercariae</th>
<th>Total worms recovered</th>
<th>Prepatent period (days) ± S.E.</th>
<th>Eggs per gram of faeces per day (63 days after exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>2783</td>
<td>45</td>
<td></td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>3377</td>
<td>45</td>
<td></td>
<td>135</td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>3562</td>
<td>44</td>
<td></td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>3401</td>
<td>45</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>2693</td>
<td>44</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Mean</td>
<td>5,000</td>
<td>3163 (177)</td>
<td>44.6 ± 0.2</td>
<td>75 (15.8)</td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>1940</td>
<td>48</td>
<td></td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>2496</td>
<td>50</td>
<td></td>
<td>92</td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>1806</td>
<td>47</td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>2296</td>
<td>48</td>
<td></td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>1689</td>
<td>50</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Mean</td>
<td>5,000</td>
<td>2045 (151.8)</td>
<td>48.6 ± 0.6</td>
<td>60 (8.7)</td>
<td></td>
</tr>
<tr>
<td>Goats</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>3656</td>
<td>47</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>3077</td>
<td>48</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Mean</td>
<td>5,000</td>
<td>3366</td>
<td>47.5</td>
<td></td>
<td>75.5</td>
</tr>
</tbody>
</table>

S.E Standard of Error
Table 21

The distribution of adult worms of *S. bovis* in experimentally infected Calves.

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of cercariae</th>
<th>Duration of inf. (weeks)</th>
<th>Liver</th>
<th>Mesenteric veins</th>
<th>Total</th>
<th>Recovery rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>20</td>
<td>112</td>
<td>132</td>
<td>1230</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>9</td>
<td>160</td>
<td>128</td>
<td>288</td>
<td>1501</td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>9</td>
<td>185</td>
<td>155</td>
<td>340</td>
<td>1158</td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>9</td>
<td>63</td>
<td>245</td>
<td>308</td>
<td>1317</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>18</td>
<td>590</td>
<td>781</td>
<td>1371</td>
<td>947</td>
</tr>
<tr>
<td>6</td>
<td>&quot;</td>
<td>18</td>
<td>122</td>
<td>267</td>
<td>389</td>
<td>1419</td>
</tr>
<tr>
<td>7</td>
<td>&quot;</td>
<td>18</td>
<td>175</td>
<td>76</td>
<td>251</td>
<td>1222</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td></td>
<td></td>
<td>188</td>
<td>252</td>
<td>440</td>
<td>1256</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(70)</td>
<td>(92)</td>
<td>(158)</td>
<td>(68)</td>
</tr>
<tr>
<td>Duration of inf. (weeks)</td>
<td>No. of cercariae</td>
<td>Liver</td>
<td>Mesenteric veins</td>
<td>Total Recovery rate %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------</td>
<td>-------</td>
<td>-----------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P.</td>
<td>E.</td>
<td>Total</td>
<td>P.</td>
<td>E.</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>5000</td>
<td>95</td>
<td>130</td>
<td>225</td>
<td>1096</td>
<td>2496</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>9</td>
<td>17</td>
<td>899</td>
<td>1789</td>
<td>1806</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>18</td>
<td>36</td>
<td>941</td>
<td>1028</td>
<td>2256</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>41</td>
<td>59</td>
<td>850</td>
<td>1624</td>
<td>1689</td>
</tr>
</tbody>
</table>

Table 22: Distribution of adult worms of *S. bovis* in experimentally infected sheep.

Mean (S.E.)

<table>
<thead>
<tr>
<th>(S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>72 (41)</td>
</tr>
</tbody>
</table>
Table, 23

The distribution of adult worms of *S. bovis* in experimentally infected Goats

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of cercariae</th>
<th>Duration of inf. (weeks)</th>
<th>Liver</th>
<th>Essenteric veins</th>
<th>Total</th>
<th>Recovery rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F.</td>
<td>M.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>525</td>
<td>700</td>
<td>1225</td>
<td>1170 1261 2431</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>9</td>
<td>195</td>
<td>295</td>
<td>490</td>
<td>1253 1334 2587</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td>360</td>
<td>497</td>
<td>857</td>
<td>1211 1297 2509</td>
</tr>
</tbody>
</table>
Table 24

Percentage distribution of adults and eggs of *S. bovis* in different organs of Calves, Sheep and Goats experimentally infected.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Egg distribution</th>
<th>Warm distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Calves</td>
<td>23.8</td>
<td>38.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>50.3</td>
<td>23.9</td>
</tr>
<tr>
<td>Goats</td>
<td>22.2</td>
<td>45.2</td>
</tr>
</tbody>
</table>
Table 25

Egg production of *S. bovis* in large animals as estimated by faecal egg counts during the period of observations

<table>
<thead>
<tr>
<th>Type of animals</th>
<th>No. of animals</th>
<th>Days post infection</th>
<th>Mean no. female worms</th>
<th>Mean no. of eggs per gram of faeces per day</th>
<th>Mean no of egg per female per day in faeces *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves</td>
<td>4</td>
<td>63</td>
<td>1408</td>
<td>75</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>126</td>
<td>1491</td>
<td>50</td>
<td>67</td>
</tr>
<tr>
<td>Sheep</td>
<td>2</td>
<td>63</td>
<td>1044</td>
<td>60</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>126</td>
<td>947</td>
<td>180</td>
<td>112</td>
</tr>
<tr>
<td>Goats</td>
<td>2</td>
<td>63</td>
<td>1571</td>
<td>76</td>
<td>48</td>
</tr>
</tbody>
</table>

* Based on the over-night faecal output.
The distribution of *S. bovis* eggs in tissues of calves in infections of different duration

<table>
<thead>
<tr>
<th>Duration of inf. (weeks)</th>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>Large intestine per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R.Lobe</td>
<td>L.Lobe</td>
<td>FT.</td>
</tr>
<tr>
<td>9</td>
<td>1250</td>
<td>3055</td>
<td>4545</td>
<td>3192</td>
</tr>
<tr>
<td></td>
<td>1661</td>
<td>2157</td>
<td>3280</td>
<td>2231</td>
</tr>
<tr>
<td></td>
<td>1343</td>
<td>600</td>
<td>1140</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>1390</td>
<td>2070</td>
<td>2020</td>
<td>2150</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td>14.08 (5.08)</td>
<td>1970</td>
<td>2746</td>
<td>2123</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(743)</td>
<td>(465)</td>
<td>(562)</td>
</tr>
<tr>
<td>18</td>
<td>1537</td>
<td>3310</td>
<td>3130</td>
<td>4150</td>
</tr>
<tr>
<td></td>
<td>1541</td>
<td>1100</td>
<td>2230</td>
<td>1950</td>
</tr>
<tr>
<td></td>
<td>1397</td>
<td>1180</td>
<td>1000</td>
<td>1150</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td>14.91 (7.23)</td>
<td>1863</td>
<td>2120</td>
<td>2416</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(617)</td>
<td>(896)</td>
<td>(723)</td>
</tr>
</tbody>
</table>
Table 27

The distribution of *S. bovis* eggs in tissues of *Sheep* in infections of different duration.

<table>
<thead>
<tr>
<th>Duration of inf. (weeks)</th>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>Large intestine per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R.Lobe</td>
<td>L.Lobe</td>
<td>PT.</td>
</tr>
<tr>
<td>9</td>
<td>1191</td>
<td>10650</td>
<td>15300</td>
<td>13650</td>
</tr>
<tr>
<td>9</td>
<td>897</td>
<td>6000</td>
<td>5800</td>
<td>7145</td>
</tr>
<tr>
<td>Mean</td>
<td>1044</td>
<td>8325</td>
<td>10550</td>
<td>10397</td>
</tr>
<tr>
<td>18</td>
<td>1080</td>
<td>16250</td>
<td>16950</td>
<td>15750</td>
</tr>
<tr>
<td>18</td>
<td>815</td>
<td>27500</td>
<td>35300</td>
<td>32700</td>
</tr>
<tr>
<td>Mean</td>
<td>947</td>
<td>21675</td>
<td>26125</td>
<td>24225</td>
</tr>
</tbody>
</table>

*PT.* Portal Tract Area
The distribution of *E. bovis* eggs in tissues of Goats 9 weeks after exposure to cercariae

<table>
<thead>
<tr>
<th>No. of female worms</th>
<th>Liver per gram</th>
<th>Small intestine per gram</th>
<th>Large intestine per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R.Lobe</td>
<td>L.Lobe</td>
<td>PT.</td>
</tr>
<tr>
<td>1695</td>
<td>9500</td>
<td>9200</td>
<td>11000</td>
</tr>
<tr>
<td>1448</td>
<td>6300</td>
<td>5100</td>
<td>4500</td>
</tr>
<tr>
<td>Mean (1571)</td>
<td>7900</td>
<td>7150</td>
<td>7750</td>
</tr>
</tbody>
</table>

PT. Portal Tract Area
### Table 29

**Recovery of adults and eggs of *S. bovis* from large animals experimentally infected in the laboratory**

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>No. of animals</th>
<th>Mean no. of cercariae</th>
<th>Duration of infection (weeks)</th>
<th>Meanworm recovery</th>
<th>Mean tissue egg counts per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Liver</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P.</td>
<td>M.</td>
</tr>
<tr>
<td>Calves</td>
<td>4</td>
<td>5,000</td>
<td>9</td>
<td>1408</td>
<td>1616</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>18</td>
<td>1491</td>
<td>1719</td>
</tr>
<tr>
<td>Sheep</td>
<td>2</td>
<td></td>
<td>9</td>
<td>1044</td>
<td>1107</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>18</td>
<td>947</td>
<td>1042</td>
</tr>
<tr>
<td>Goats</td>
<td>2</td>
<td></td>
<td>9</td>
<td>1571</td>
<td>1794</td>
</tr>
<tr>
<td>Buffalo</td>
<td>1</td>
<td></td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

134
Table 30

Comparison of tissue egg densities of *S. bovis* in calves and sheep.

<table>
<thead>
<tr>
<th>Duration of infection</th>
<th>Different organs</th>
<th>Calves</th>
<th></th>
<th>sheep</th>
<th></th>
<th>P (probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>S.E.</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>9 Weeks</td>
<td>Liver</td>
<td>886-3597</td>
<td>2278</td>
<td>562.0</td>
<td>6315-13200</td>
<td>9757</td>
</tr>
<tr>
<td></td>
<td>Duodenum</td>
<td>250-5750</td>
<td>3551</td>
<td>1192.4</td>
<td>3200-12300</td>
<td>7750</td>
</tr>
<tr>
<td></td>
<td>Jejunum</td>
<td>4800-9000</td>
<td>7038</td>
<td>882.4</td>
<td>5365-7160</td>
<td>6272</td>
</tr>
<tr>
<td></td>
<td>Ileum</td>
<td>200-400</td>
<td>445</td>
<td>218.5</td>
<td>3267-5700</td>
<td>4483</td>
</tr>
<tr>
<td></td>
<td>Caeum</td>
<td>3150-8410</td>
<td>5152</td>
<td>1207.9</td>
<td>10690-13630</td>
<td>12160</td>
</tr>
<tr>
<td></td>
<td>Colon</td>
<td>1000-6400</td>
<td>2409</td>
<td>1330.7</td>
<td>625-2625</td>
<td>1625</td>
</tr>
<tr>
<td></td>
<td>Rectum</td>
<td>660-7125</td>
<td>2946</td>
<td>1442.7</td>
<td>563-1900</td>
<td>1231</td>
</tr>
<tr>
<td>18 Weeks</td>
<td>Liver</td>
<td>1110-3550</td>
<td>2133</td>
<td>723.1</td>
<td>16316-31833</td>
<td>24074</td>
</tr>
<tr>
<td></td>
<td>Duodenum</td>
<td>720-2470</td>
<td>1446</td>
<td>526.5</td>
<td>18600-20000</td>
<td>19300</td>
</tr>
<tr>
<td></td>
<td>Jejunum</td>
<td>800-3150</td>
<td>1716</td>
<td>725.9</td>
<td>23100-25000</td>
<td>24050</td>
</tr>
<tr>
<td></td>
<td>Ileum</td>
<td>710-2500</td>
<td>1320</td>
<td>590.1</td>
<td>11000-26000</td>
<td>18500</td>
</tr>
<tr>
<td></td>
<td>Caeum</td>
<td>600-1130</td>
<td>951</td>
<td>175.8</td>
<td>12100-26800</td>
<td>19450</td>
</tr>
<tr>
<td></td>
<td>Colon</td>
<td>560-1300</td>
<td>1003</td>
<td>225.8</td>
<td>1600-1800</td>
<td>1700</td>
</tr>
<tr>
<td></td>
<td>Rectum</td>
<td>600-1130</td>
<td>876</td>
<td>153.4</td>
<td>2000-5000</td>
<td>3500</td>
</tr>
</tbody>
</table>
CHAPTER 3

THE PATHOLOGY IN RUMINANTS EXPERIMENTALLY INFECTED

WITH S. BOVIS WITH A NOTE ON A NATURALLY INFECTED COW

INTRODUCTION.

Very little has been published about the clinical and pathological manifestations of S. bovis in ruminants. The present report is an account of a comparative study on the pathological changes of S. bovis in large animals. The material forming the basis of this study was from different species of animals (calves, sheep and goats) experimentally exposed to 5,000 cercariae of S. bovis. A total of 12 calves, 5 sheep and 2 goats were experimentally infected. A heavily infected cow from Dezful abattoir was also studied.

/ Results....
RESULTS,

PATHOLOGY OF EXPERIMENTAL INFECTIONS,

CALVES,

Ante-mortem examination,

Slightly redness and minute haemorrhagic spots were seen at the exposure site on the legs skin which lasted for 2-3 days. After approximately 45-50 days when the first egg appeared in the faeces some change in the general condition of the animals were noticed; lack of appetite; hollow appearance of the abdomen; faeces becoming mostly mucoid with dark colour with blood and special smell; some times typical haemorrhagic diarrhea; loss of weight in some cases severe emaciation; loss of hair and harsh hair coat; pinched expression an occasional dry cough. Usually after 2-3 weeks the calves a little passed the acute stage of infection and improved in condition but anaemia, weakness and harsh hair coat remained.

/Post-mortem....
Post-mortem examination,

Most of the calves showed a moderate amount of clear fluid in thorax and abdominal cavities with some degree of hydropneumothorax.

Liver: There were many minute greyish foci (granulomata) on the surface of the liver as well as deep in the tissue substance. The Glisson's capsule of the liver was often thickened particularly along the free edge of the liver. The surface of the liver particularly in 18 weeks old infections showed large yellowish or white spots, firm and quite distinct from the small granulomata (lymphoid nodules). Appearance of the left lobe in calves looked a little greyish with some fibrous streaks on the abdominal surface of liver along the intrahepatic veins. The colour of the liver was in general slightly darker than normal, but less so often in sheep and goats which were heavily pigmented. The main intrahepatic veins looked slightly distended and contained several thrombi with numerous dead worms trapped in collagenous material.

Other organs: In parts of the small intestine there were slightly elevated red lesions, but the most severe pathology was seen in the /caecum/...
caecum. In most of the calves extensive haemorrhages and wide stripes of brownish pigments were seen in the mucous membrane of the caecum and sometimes in the rectum. There was also some degree of dilatation of the mesenteric veins which contained numerous adult schistosomes (Plate, 8).

Lymph nodes: The thoracic, portal and mesenteric lymph nodes were mostly enlarged with a dark appearance due to schistosommal pigment.

**Microscopic examination,**

Liver: The commonest lesions seen in the early stage of the infection (at 9 weeks after exposure) were the schistosome granulomas. There were also extreme perivascular inflammation with oedema and some degree of intralobular fibrosis (Plate, 9). The walls of the hepatic veins were mostly thickend with medial hypertrophy which is a distinct picture only seen in calves infected with schistosomes (Plate, 10).

Schistosome eggs either single or in groups were prevalent in the small intralobular veins producing granuloma with diffused reticulo-endothelial...
endothelial reactions which extended into the sinusoids (Plate, 11). The ova in the liver of calves were mostly in the portal areas where they provoked a granuloma and cellular infiltration in the parenchyma.

In calves with 18 weeks old infections the livers showed dense intravascular or extravascular lymphoid nodules with very lymphocites and eosinophils.

Other organs: Histological studies of the small and large intestine revealed eggs in all parts, particularly in the submucosa. Granuloma formation with extensive infiltration of lymphoid cell was prevalent in the submucosa engulfing the dead eggs. The caecum in some calves showed a very heavy infiltration and granuloma formation with numerous disintegrating eggs surrounded by different type of lymphoid cells; lymphoid nodule formation was also prevalent (Plates, 12, 13).

SHEEP,

Ante-mortem examination,

The ante-mortem conditions of the sheep depended upon the /intensity....
intensity and duration of infection. After the prepatent period the clinical manifestations were obvious in almost all the experimentally infected sheep. Lack of appetite, progressive emaciation, weakness, paleness of mucous membranes and broken wool were all features of this stage of the infection. The sheep ingested large amount of wool daily so that wool was frequently matted in the faeces. Fecal faeces with mucous and sometimes haemorrhagic diarrhea and coughing was common.

Two sheep died during the experiment. One of them died 79 days after exposure to *S. bovis* cercariae with severe emaciation and secondary respiratory infection (pneumonia). At autopsy the liver was seen to be badly damaged and fibrous with high densities of eggs and granulomas.

The infected sheep never showed any signs of recovery as seen in calves, and they remained in critical condition up to time of autopsy.

/The relatively...
The relatively high numbers of egg per gram of tissue, the degree of liver damage and dramatic clinical conditions showed that *S. bovis* was much more serious in sheep than in calves. The amount of pathology produced was proportional with duration of the infection.

**Post-mortem examination,**

There was a considerable loss of mesenteric fat-body, ascitic fluid and serous effusion in the abdominal cavity with some degree of hydrothorax and hydropneumothorax.

**Liver:** Liver was dark in colour and had numerous small greyish spots in the parenchyma beneath the capsule and on the cut surface of the liver substance. In sheep with longer infection (18 weeks) lymphoid nodules were seen frequently all over the liver and they were quite distinct from the other parts (Plate, 14). In examination and perfusion of intrahepatic veins, large number of living adult schistosomes were discovered. The gall bladder in most cases was distended. Some thrombi in response to parasites were observed in hepatic veins in which numerous dead worms were encapsulated.

/In sheep....
In sheep with 18 weeks old infections of *S. bovis* which were challenged with *O. turkestanicum* the liver was more seriously damaged by deposition of fibrous tissue and eggs.

Other organs: By holding the mesentery against a light a coiled mass of adult schistosomes could be seen in the mesenteric veins. The small intestine in some parts contained several prominent red and congested foci. The rectum and caecum were also haemorrhagic with some brownish stripes but not so intensely as in the calves.

Lymph nodes: Thoracic, hepatic and mesenteric lymph nodes showed some degree of enlargement and pigmentation.

Microscopic examination,

Liver: Schistosome eggs were mostly found in the intralobular branches of the portal veins and were surrounded by lymphoid cells, the eggs in the sheep livers rarely escaped from the portal veins to the parenchyma. In some cases may lymphoid cells took part in the reaction. A zone of intensive eosinophilic cells surrounded some of the ova and infiltrated 

/to the centre....
to the centre of the granulomas and producing a mass of inflammatory reaction (Plate, 15).

In sheep with older infections (16 weeks), some of the intrahepatic branches of portal veins exhibited severe proliferative endophlebitis and thrombophlebitis with numerous eosinophils on the villous projections and around the veins in surrounding tissues (Plate, 16). This type of pathological picture was only observed in sheep and not in calves or goats. Lymphoid nodules were more frequent in sheep with intensive and packed cellular proliferation. There was a very slight response to the living worms but strong response to the dead worms and thrombi in intralobular portal veins.

The fibrous formation in advance cases in sheep liver was outstanding. As a result of these lesions, the lumens of veins were either partially or totally obstructed with hyperplasia, hypertrophy and thrombophlebitis. Pigmentation of the liver was intense with most of the pigment in the Kupffer cells. The intestine showed numerous eggs and granuloma formations all over the small and large intestine.

/ Goats....
GOATS,

Ante-mortem examination,

Goats were more affected than sheep and calves with *S. bovis* infection: with considerable loss of weight, weakness, anaemia and abnormal faeces (mostly covered with a coat of mucous) and sometimes haemorrhagic diarrhea which was more severe in goats than in sheep.

Post-mortem examination,

A severe loss of mesenteric fat-body, the presence of ascitic fluid in the abdominal cavity were common. The lymph nodes were mostly enlarged and pigmented. The liver showed greyish minute spots. A large number of adult *S. bovis* were recovered from the liver by perfusion. Intestinal tract showed numerous red foci and granulomata in submucosa.

Microscopic examination,

Extensive host tissue reactions were observed in every intra-lobular areas in the liver. The reactions were a diffuse granulomatus proliferation....
proliferation with many eosinophils, and lymphoid cells surrounding numerous ova in intralobular spaces (Plates, 17, 18). A large number of eggs in the liver showed the Hoepli phenomenon, a very interesting antigen-antibody response. In some cases rod-shaped acidophil bodies were arranged side by side around the egg shell and made a rosette-form. This reaction was very common at this stage of the infection (9 weeks) in goats but not in sheep or calves (Plate, 18, 19).

THE PATHOLOGY IN A COW NATURALLY INFECTED WITH S. BOVIS

Among the different types of animals examined in the Khuzestan slaughter houses only a few cattle were found to be infected with S. bovis and these harboured very few adult worms. No sheep or goats were found to be infected. Most of the infected cattle showed mixed infections with O. turkestanicum; only one cow was found with a pure infection of S. bovis. This cow was over 7 years old with excessive...
emaciation and a large amount of ascitic fluid in the abdominal cavity, an oedematous serous membrane and markedly congestion of the intestines.

All the mesenteric veins were blocked with dead worms, and showed thrombosis and severe pigmentation (Plate, 20). The intestinal veins were seriously injured with black and tortuous appearance on the outer surface of the intestine (Plate, 21). Scraping of the intestinal mucosa revealed very few eggs, but granuloma with acute, superficial haemorrhagic ulcerations were abundant (Plate, 22).

The histological sections of small intestine showed marked hyperplasia of the intima of veins and thrombi formation around the dead worms associated with clots (Plate, 23). Newly dead worms in veins showed milder reactions with eosinophil infiltration (Plate, 24); the living worms showed no considerable reactions (Plate, 25). Many dead worms and calcified eggs with granulomatus reactions were seen in the submucosa of intestine.

/discussion....
DISCUSSION,

Le Roux (1929) attributed the pathology of *S. mattheei* infections in sheep to egg and pigment deposition by the worms, and lesions caused by the dying worms. The number of eggs in liver is a good indication of the severity of the infection. In our experiments the density of the *S. bovis* eggs per gram of liver tissue in sheep and goats was much higher than in calves and the pathological pictures also was much more serious than in calves.

The amount of pigment in a liver was also useful indication of the intensity of the infection. Most of the pigments regurgitated from the gut of the schistosomes enters the liver by portal blood, but a small amount also enters the lymphatics and is phagocytised in the mesenteric lymph nodes. The reticulo-endothelial system in the liver especially the Kupffer cells ingests the pigment and when the cells are overloaded the pigment pass into the hepatie veins and on to the heart in the venous blood and is eventually phagocytised in the lungs and /lymph...
lymph nodes where it gives rise to a grey colour. The amount of pigment in above organs directly depends upon the number of worms and duration of infection. In our experiments the amount of pigment deposited in the livers and lymph nodes in sheep and goats was much higher than in calves and was heavier in those with the longer duration of infection (18 weeks). McCully and Kruger (1969) similarly reported the relatively higher pigmentation of livers in sheep than in cattle infected with *S. mattheei*.

In 9 weeks old infections with 5,000 *S. bovis* cercariae we found that more eggs and pigment were deposited in sheep and goats livers than in calves and that the pathological changes were also more serious in sheep and goats than in calves. This result showed that *S. bovis* is better adapted to calves than to sheep and goats.

The following distinctive pathological features were noticed in the different hosts:

Calves—The extensive medial hypertrophy of the intralobular hepatic veins.....
veins was not seen in sheep or goats. Hussein (1969) reported the same pictures of intrahepatic veins hypertrophy in cattle infected with *S. bovis*.

Sheep- The most characteristic feature was endophlebitis and intimal hypertrophy and hyperplasia of the intralobular veins in liver of sheep with longer duration of infection (18 weeks). Letulle (according to Dew, 1923) described a human case of endophlebitis of veins containing bilharzial adult worms and regarded it as being due to the local action of a toxin, but in general adult worms are thought to play very little role in the pathology of the human disease. McCully et al. (1967, 1969) described a similar endophlebitis of the intrahepatic branches of the portal veins in the Hippopotamus and in sheep infected with *S. hippopotami* and *S. mattheei*, and they were attributed to the presence of live adult worms and the sensitivity of the hosts. In the present observations the endophlebitis and thrombophlebitis was a characteristic picture only in sheep.

Goats- The numerous eosinophilic antigen-antibody deposits around the *S. bovis* eggs in the liver of goats was the most striking picture / in this...
in this host. This reaction indicates a strong hypersensitivity to antigen associated with the eggs in this particular host. This phenomenon was first described by Yamagiwa (1931) in cattle infected with *O. turkestanicum* and later by Hoeppli (1932) in *S. japonicum* infection. Sadun *et al.* (1962) observed this reaction in the liver of the woodchuck infected with *S. mansoni*. McCully *et al.* (1969) found the same phenomenon in cattle infected with *S. mattheei*. Verminous phlebitis was described by Fairley and Mackie (1930) as the most characteristic lesions in the liver of goats infected with *S. spinulosum*. The Hoeppli phenomenon was observed also in goats liver infected with *O. turkestanicum* (see Part, I).

The different stages in the granuloma formation from the early reactions around the newly deposited eggs to the chronic granulomas with the fibrous tissue formation were seen in all the infected animals. The intense attraction of eosinophils to newly released eggs particularly in sheep and goats was interesting and may have been caused by delayed hypersensitivity as suggested by Meloney *et al.* (1953) and Warren *et al.* (1967).

/*The occurrence...*/
The occurrence of lymphoid nodules and hyperplasia in tissues particularly in the livers of the ruminants with long standing infections was similar to that reported by Hussein (1969) and McCully and Kruger (1969) and is believed to be produced by both eggs and dead worms. This reaction is unusual and has not been reported from man or other experimental animals infected with schistosomes. It seems likely that further studies of the pathogenicity of schistosome infection in livestock will help to unravel some of the problems in the immunopathology of the schistosomiasis.
Plate, 8

*Schistosoma bovis* adults in mesenteric veins

(*calf, 9 weeks after exposure*)

Plate, 9

Intralobular fibrosis, liver of calf (*9 weeks after exposure to S. bovis* cercariae, H. E. x 30).
Plate, 10

Portal vein showing medial hypertrophy, with some cellular infiltration (Calf, 9 weeks after exposure to *S. hovis* cercariae, H. E. x 240).

Plate, 11

Intralobular granulomas in liver with medial hypertrophy of veins and dense cellular infiltration (calf, 9 weeks after exposure to *S. hovis* cercariae, H. E. x 120).
Plate, 12

Lymphoid nodule in caecum of calf infected with *S. bovis*

( H. E. x 120 ).

Plate, 13

Close structure of a lymphoid nodule in caecum of a calf with numerous destroyed egg particles ( H. E. 240 ).
Plates, 14

Gross appearance of the liver of a sheep infected with *S. bovis* (18 weeks infection). Note: A, the numerous minute greyish nodules. B, large lymphoid nodules.

Plate, 15

Liver showing early stage of intravascular lymphoid nodule formation with some remnants of disintegrating eggs (sheep liver 18 weeks after exposure to *S. bovis* cercariae, H. E. x 240).
Plate, 16
Liver, branch of portal vein showing proliferative endophlebitis with many eosinophils within intimal projections and around veins. (sheep 18 weeks after exposure to S. bovis cercariae, H.E. x 240).

Plate, 17
Liver, intralobular granulomas with diffused cellular infiltration surrounding ova of S. bovis (goat, 9 weeks after exposure to cercariae, H.E. x 120).
Plate, 18

Liver, intralobular granuloma and Hoeppli phenomenon (goat, 9 weeks after exposure to *S. bovis* cercariae, H. E. x 120).

Plate, 19

Hoeppli phenomenon, a reaction around *S. bovis* egg in the liver of a goat. Note the stellate-shaped accumulation of eosinophilic antigen-antibody material (9 weeks after exposure to cercariae, H. E. x 560).
Plate, 20
Mesenteric veins contain dead worms with blockage and thrombus formation (naturally infected cow with S. bovis).

Plate, 21
The tortuous appearance of the intestinal veins (naturally infected cow with S. bovis).
A chronic infection of *S. bovis* in the intestine of the naturally infected cow. Acute, superficial hemorrhagic ulcerations.

Histological section of the affected mesenteric vein thrombus formation (H. E. x 120).
Plate, 24

Dead worms in a vein with mild reactions and lymphoid cell infiltration (naturally infected cow with *S. bovis*, B. E. x60).

Plate, 25

Live worms in a vein showing no obvious tissue reaction (naturally infected cow with *S. bovis*).
PART III
PART. III

EXPERIMENTAL STUDIES ON ACQUIRED RESISTANCE TO SCHISTOSOMIASIS USING HOMOLOGOUS AND HETEROLOGOUS SYSTEM

CHAPTER 1

INTRODUCTION.

Epidemiological studies suggest that man and domestic animals can acquire resistance to schistosomes. The first observations were those of Fujinami (1917) in a S. japonicum endemic area in Japan who observed that children were more affected than adults and that calves brought in from the outside were seen to sicken and die some time after, although local animals were apparently relatively resistant to the severer effects and did not die. Subsequent observers have noted that the prevalence and intensity of S. haematobium infection decreases in adults as compared with children (Gerber, 1952; Gothe, 1963). The same was noted by Fisher (1934) with S. intercalatum. Nelson (1959) /from studies....
from studies on the incidence and distribution of *S. mansoni* in West Nile district of Uganda found that the highest incidence was in the 5-15 years age group. The same pattern of the disease was observed with *S. japonicum* infection in China by Vogel et al. (1953) and in the Philippines by Pesigan et al. (1953). However, naturally acquired immunity may not be the only explanation for the apparent mildness of schistosomiasis in adults: Van den Berghe (1959) has suggested that there is age resistance in man and Lewert and Mandlowitz (1959) have shown that in old experimental animals relatively fewer cercariae penetrate. Nelson (1959) suggested that in addition to acquired resistance other factors might account for the differences in pathogenicity in different areas for example racial tolerance, different strains of the parasites and differences of nutritional levels.

Le Roux (1961) theorized that cercariae of the animal schistosome species *S. bovis* may immunize man against the human schistosome species *S. haematobium* and vice versa and that this could explain the distribution pattern of these infections, for example the presence of *S. bovis* and /absence...
absence of *S. haematobium* from Sardinia and the reverse situation in Egypt. Nelson et al (1962) suggested that constant exposure to animal schistosome cercariae will modify schistosome infection in man by reducing the worm burden without necessarily affecting the prevalence rate, but in these areas the complications less would be severe. This type of heterologous immunity response in man was named 'Zooprophylaxis' which has been defined as the prevention or amelioration of disease in man as a result of previous exposure to heterologous infections of animal origin (Nelson, in press).

Apart from the epidemiological evidence most of which has been reviewed by Clarke (1966 a), there are numerous experimental studies on animals to support the view that acquired immunity plays an important role in schistosome infections. But only three experiments have been carried out on man (Fisher 1934; Gothe 1963; Clarke 1966 a) and the results have been inconclusive.

Experimental data shows that mice and hamsters can acquire a partial resistance to reinfection with *S. mansoni, S. japonicum* and *S. schistosomatum*...
Schistosomatium douthitti, and rat can develop partial immunity to 
S. mansoni and S. japonicum. Baboons and Cercopithecus monkeys can 
develop some resistance to S. mansoni and partial immunity has been 
induced in the horse, the dog and the rabbit after homologous immunisation 
with S. japonicum. Hamster can develop some resistance to reinfection with 
S. haematobium and rhesus monkeys can become completely resistant to 
reinfection with S. mansoni, S. japonicum, S. haematobium and Schistosomatium 
douthitti.

The experiments on heterologous immunity to schistosomes have 
recently been reviewed by Eveland et al (1969): mice can become partially 
resistant to S. mansoni after immunisation with S. rodhaini and S. bovis 
and S. mattheei and to Schistosomatium douthitti after immunisation with 
S. mansoni. Rhesus monkeys can acquire partial immunity to S. mansoni 
after exposure to S. japonicum, S. haematobium, S. bovis and S. mattheei, 
to S. haematobium after immunisation with S. bovis and to the 'J' strain 
of S. japonicum after immunisation with the 'CH' strain of S. japonicum, 
S. mansoni and Schistosomatium douthitti. Calves immunized with S. mansoni 
can partially resist challenge with S. mattheei and a chimpanzee with
a natural infection of *S. mansoni* strongly resisted challenge with
*S. japonicum*.

Studies on the mechanism of schistosome immunity have shown
that inoculation with dead parasite material has a slight protective
effect in mice but fails to induce any recognisable resistance in rhesus
monkeys. Exposure to cercariae which are prevented from maturing in the
host by previous irradiation will provoke some resistance in mice and
monkeys but only a partial resistance is developed in the rhesus monkey
even after exposure to very large numbers of such irradiated cercariae
( Smithers, 1962 ).

The experiments of Smithers and Terry (1967) and Smithers et al
(1969) on homologous immunity to *S. mansoni* in the rhesus monkey have
shed considerable light on the stimulation of resistance. They have
demonstrated that the adult worms provide the main immunogenic stimulus
and in a series of transplant studies using worms that have matured in
different hosts they have also shown that the adult worms are able to
/disguise....
disguise their presence in the host by incorporating host antigens in their cuticle. This produces a state of 'Concomitant' immunity where the adult worms are able to survive in an otherwise completely immune host. Recently Clegg and Smithers (1970) have demonstrated that in the presence of serum from highly immune rhesus monkey some schistosomula die within the first twenty-four hours in vitro and by the fourth day 95-100% have died. This suggests the presence of a lethal factor in immune serum; this appears to be a specific antibody which is dependent for its action on complement.

The purpose of the present study was to investigate possible cross reactions between the animal, and human schistosomes that are prevalent in Khuzestan. In the first experiments in mice _O._ _turkestanicum_ was used as the immunizing agent. In the second experiments calves and sheep were used for further investigation, using _O._ _turkestanicum_, _S._ _bovis_ and _S._ _haematobium_. The results were quite striking, especially in calves which are the main natural host of bovine schistosomiasis in the Khuzestan endemic area.
CHAPTER 2

MATERIAL AND METHODS,

Three species of experimental hosts were used in the present study:

1. Albino mice, 6-8 weeks old.
2. Calves, male 7-9 months old (local race).
3. Sheep, male 7-9 months old (local race).

Four species of schistosomes were used: the local strains of O. turkestanicum, S. bovis and S. haematobium, and a Puerto Rican strain of S. mansoni.

In mice each experiment was separately controlled and followed a similar design as that used by Nelson et al (1968): group A, immunized and challenged; group B, challenged control; and group C, immunized but not challenged. Immunisation consisted of a single or triple exposure to various doses of O. turkestanicum cercariae and the challenge at 9 weeks...
weeks was with 300 cercariae of *S. bovis* or *S. haematobium* or 150 cercariae of *S. mansoni*. The cercariae were all taken from the same suspension obtained from a large number of infected snails.

The calves and sheep were divided into groups of 2-3 animals. The challenge control group in one experiment served as the control for the other experiments. In the heterologous immunity experiments immunizing and challenging doses of cercariae in large animals consisted of a single exposure of 8,000 cercariae of *O. turkestanicum* or 5,000 *S. bovis* in calves and 5,000 cercariae of *O. turkestanicum* or *S. bovis* in sheep. Immunizing the calves with *S. haematobium* consisted of three inoculations of 7,000 cercariae in each inoculation with 4 weeks interval.

Autopsy was performed 9 weeks after the challenge exposure. The mean worm recoveries and tissue egg counts per gram were used as the criteria to evaluate the degree of resistance.

/ In homologous....
In homologous immunity experiments on calves the immunisation consisted of a single exposure of 1,000 cercariae of *S. bovis* or *O. turkestanicum*. The challenge was made with 4,000 cercariae of the same species, but the challenge control groups were exposed to 5,000 cercariae, which meant that each animal in the immunized and control groups finally received 5,000 cercariae.

The protective effect of immunity in schistosomiasis was measured by determining the effects on expected worm burden and egg counts of the challenge infection. Immunity may be complete in the sense that no developing or mature worms can be found or it may be partial in that the worms and eggs load of the immunized animals are reduced. Stunting of the worms with the production of fewer eggs by the females, is also considered as evidence of acquired immunity. Other criteria like distribution and viability of eggs and also eggs per female worm were considered.
RESULTS IN MICE.

A. Heterologous immunity studies.

Experiment 1: _O. turkestanicum_ (100 cercariae) challenged with _S. bovis_ (300 cercariae)

Analysis of the results of the schistosome recovery (Table 32) showed that the mean adult worm burden of _S. bovis_ in the immunized group A, was lower than that of the challenge control group B, being 12 and 16.8 respectively, with a percentage reduction of 28.5%.

_S. bovis_ egg counts in the liver, gut and the total egg counts per mouse showed a more defined effect with a marked reduction in group A as compared with group B, (49.8%). The differences between the means in the liver, gut and total egg counts were statistically significant (P < 0.05; P < 0.01 and P < 0.02 respectively). The total
number of eggs per female deposited in liver and gut was slightly lower in group A than in group B.

The mean adult worm burden of O. turkestanicum and eggs per mouse in the immunized group A was higher than that of group C, suggesting that the presence of the S. bovis stimulates a high egg output than occurs with the single infection. A similar phenomenon was reported by Taylor et al. (1969) with S. mattheei in the presence of S. mansoni.

Experiment 2: O. turkestanicum (50 x 3 150 cercariae) challenged with S. bovis (300 cercariae).

In this experiment immunisation was carried out by three repeated inoculation of 50, O. turkestanicum cercariae with 4 weeks interval between inoculations. The challenge exposure with S. bovis cercariae was carried out 4 weeks after the last exposure to O. turkestanicum cercariae.

/ As indicated....
As indicated in Table, 33, the mean recovery of *S. bovis* from the challenge infection was lower in group A than that in group B, with a reduction of 21.9%.

Analysis of the egg counts in the tissues showed a considerable reduction in liver, gut and the total number of eggs per mouse in group A as compared with group B (total 55.8%). The student t-test showed that the differences between the means of the eggs in liver, gut and the total eggs of these two groups were significant (P<0.05, P<0.02 and P<0.02 respectively). The total number of eggs per female was markedly lower in group A than in group B.

The mean burden of worms and eggs of *O. turkestanicum* in group A was again higher than group C but the differences were less marked than in the first experiment.

Experiment, 3: *O. turkestanicum* (200 cercariae) challenged with *S. bovis* (300 cercariae).

Analysis of the results of this experiment (Table, 34) showed that there was a reduction of 30.1% in worm burden of *S. bovis* ....
S. bovis in group A compared with group B. The egg counts in the tissues showed significant reductions in liver and total eggs per mouse (P<0.05 and P<0.05), but not in the gut. The number of eggs per female was also higher in non-immunized group B than that in group A.

Experiment, 4: Q. turkestanicum (50 x 3 = 150 cercariae) challenged with S. haematobium (300 cercariae).

Analysis of the results of this experiment (Table, 35) showed that although there were no significant differences between the means of adults of S. haematobium (the reduction was only 0.7%), the tissue egg counts in the liver were considerably reduced in challenge group A compared with control group B; a 41.1% reduction was observed. There was a significant difference between the means of the liver egg counts and total eggs per mouse in two groups A and B (P<0.01 and P<0.05).

The number of eggs per female worm were lower in group A than that in group B. There were considerably more eggs per mouse...
mouse in group A than that in group C.

Experiment, 5: *O. turkestanicum* (50 cercariae) challenged with *S. mansoni* (150 cercariae)

Analysis of the results of this experiment (Table, 36) showed that there was no marked differences observed between the mean number of either adults or tissue egg counts of *S. mansoni* in the immunized and non-immunized control groups A and B.

The mean tissue egg loads of *O. turkestanicum* per mouse in the immunized and challenged group A was markedly higher than that in control group C.

Experiment, 6: *O. turkestanicum* (200 cercariae) challenged with *S. mansoni* (150 cercariae).

Analysis of the results of this experiment (Table, 37) showed that although there was only a slight reduction in adult *S. mansoni* burden, there was a statistically significant difference in the means of the total tissue egg counts with a 37.9% reduction and P values of (P < 0.05, P < 0.05 and P < 0.02) in liver, gut and total eggs respectively. /B. Homologous...
Experiment, 7: *S. bovis* (100 cercariae) challenged with *S. bovis* (300 cercariae)

This experiment was designed to compare the immunizing effect of homologous infection with *S. bovis* in mice compared to the results previously obtained in calves. The analysis of the results in this experiment (Table, 38) showed a 66.0% reduction in the adult *S. bovis* burden (*P* < 0.001). Tissue egg counts in liver, gut and total eggs per mouse also showed considerable reductions (49.4%). *P* values in liver, gut and total egg counts per mouse were *P* < 0.2, *P* < 0.02 and *P* < 0.05 respectively.
Table 32

Experiment 1: Mice immunized with *O*. turkestanicum and challenged with *S*. bovis.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial exposure</th>
<th>No. of cercariae in <em>S</em>. bovis challenge exposure</th>
<th>Autopsy weeks after initial exposure</th>
<th>Mean Worms Recovery</th>
<th>Reduction of <em>S</em>. bovis %</th>
<th>Tissue egg counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of mice</td>
<td>P.</td>
<td>M.</td>
<td>total</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>10</td>
<td>300</td>
<td>19</td>
<td>8.2</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.5</td>
<td>10.3</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>9</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>7</td>
<td>2.3</td>
</tr>
</tbody>
</table>

*Egg per female*
Table 33

Experiment 2: Mice immunized with O. turkestanicum and challenged with S. bovis.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial exposure (infection)</th>
<th>No. of cercariae in S. bovis challenge exposure</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>No. of mice</th>
<th>Mean Worms Recovery</th>
<th>Reduction of S. bovis %</th>
<th>Tissue egg counts</th>
<th>Reduction in S. bovis egg load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50 x 3 150 x 21</td>
<td>300</td>
<td>30</td>
<td>111</td>
<td>4.5 6.7 6.4 10.8 10.9 17.5</td>
<td>621 11581 27 1223 648 12804 (1911)</td>
<td>55.8%</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>300</td>
<td>9</td>
<td>7</td>
<td>8.3 14.1 22.4 - 557</td>
<td>- 25630 3350 28980 (3492)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>50 x 3 150 x 24</td>
<td>-</td>
<td>30</td>
<td>7</td>
<td>6.7 6.6 12.3 - 557</td>
<td>- - 557 -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Egg per female*
Table 34

Experiment 3: Mice immunized with *O*. turkestanicum and challenged with *S*. bovis.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial O.t. exposure</th>
<th>Interval (weeks)</th>
<th>No. of cercariae in <em>S</em>. bovis challenge exposure</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>No. of Mice</th>
<th>Mean Worms Recovery</th>
<th>Tissue egg counts</th>
<th>% Induction of bovis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F.</td>
<td>M.</td>
<td>total</td>
</tr>
<tr>
<td>A</td>
<td>200</td>
<td>11</td>
<td>300</td>
<td>2010</td>
<td>20.1</td>
<td>5.5</td>
<td>24.3</td>
<td>6.8</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>96</td>
<td>6.3</td>
<td>6.3</td>
<td>10.3</td>
<td>17.6</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>24.6</td>
<td>24.6</td>
<td>49.2</td>
<td>-</td>
</tr>
</tbody>
</table>

* Egg per female
Table 35

Experiment 4: Mice immunized with O. turkestanicum and challenged with S. haematobium.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial O.t. exposure</th>
<th>Interval (weeks)</th>
<th>No. of cercariae in S.h. after challenge exposure</th>
<th>Autopsy No. of mice</th>
<th>Mean Worms Recovery %</th>
<th>Reduction of S. haematobium</th>
<th>Tissue Egg Counts</th>
</tr>
</thead>
</table>
### Table 36

Experiment 5: Mice immunized with *O. turkestanicum* and challenged with *S. mansoni*.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial <em>O. turkestanicum</em> exposure</th>
<th>Intervals of cercariae in <em>S. mansoni</em> challenge exposure (weeks)</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>No. of mice</th>
<th>Mean Worms Recovery</th>
<th>Tissue egg counts</th>
<th>Reduction in <em>S. mansoni</em> egg load %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Total</td>
</tr>
<tr>
<td>A</td>
<td>50</td>
<td>8</td>
<td>150</td>
<td>16</td>
<td>10</td>
<td>5.5</td>
<td>11.9</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>150</td>
<td>8</td>
<td>9</td>
<td>18.4</td>
<td>22.6</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>-</td>
<td>16</td>
<td>18</td>
<td>7.9</td>
<td>2.6</td>
<td>10.5</td>
</tr>
</tbody>
</table>

* Egg per Female
Table 37

Experiment 6: Mice immunized with *O. turkestanicum* and challenged with *S. mansoni*.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercariae in initial <em>O. turk.</em> exposure</th>
<th>Interval (weeks)</th>
<th>No. of cercariae in <em>S. mansoni</em> challenge exposure</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>No. of mice</th>
<th>Mean Worms Recovery</th>
<th>Tissue egg counts</th>
<th>Reduction in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Female  O.t. S.m. 0.t. S.m. O.t. S.m. 0.t. S.m.</td>
<td>Egg/Liver  O.t. S.m. 0.t. S.m. 0.t. S.m.</td>
<td>Egg/gut  O.t. S.m. 0.t. S.m. 0.t. S.m.</td>
</tr>
<tr>
<td>A</td>
<td>200</td>
<td>8</td>
<td>150</td>
<td>16</td>
<td>6 24.2 12.3 13.8 20.3 38 32.6</td>
<td>1370 1340 - 18660 1370 32100 (2610)</td>
<td>37.9</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>150</td>
<td>8</td>
<td>9 - 18.4 - 22.6 - 41</td>
<td>20.4 - 18600 - 13000 - 31700 (2872)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>7 26.7 - 21.1 - 47.8 -</td>
<td>2000 - 100 - 2100 -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Egg per Female
Table 38

Mice immunized with S. bovis and challenged with S. bovis.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of cercarize in initial S. bovis exposure</th>
<th>Interval (weeks)</th>
<th>No. of cercarize in S. bovis challenge exposure</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Mice no.</th>
<th>Mean worm recovery</th>
<th>Reduction of S. bovis mul. %</th>
<th>Tissue egg counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
<td>total</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>9</td>
<td>300</td>
<td>19</td>
<td>8</td>
<td>4.3</td>
<td>7.4</td>
<td>11.6</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>10</td>
<td>8</td>
<td>19.6</td>
<td>19.6</td>
<td>34.2</td>
</tr>
<tr>
<td>C</td>
<td>120</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>4</td>
<td>2.5</td>
<td>4.7</td>
<td>7.2</td>
</tr>
</tbody>
</table>

* Egg per female.
CHAPTER 4

RESULTS IN CALVES AND SHEEP,

1. CALVES,

A. Heterologous Immunity Studies,

Experiment 1: O. turkestanicum versus S. bovis

The calves were divided into three groups. Group I consisted of 3 calves which were each exposed to 8,000 oocarinae of O. turkestanicum but not challenged; they were killed 9 weeks after exposure to the oocarinae. Group II consisted of 3 calves each exposed to 8,000 oocarinae of O. turkestanicum and challenged 9 weeks later with 5,000 oocarinae of S. bovis; they were killed after further 9 weeks. Group III consisted of 2 calves each exposed only to 5,000 oocarinae of S. bovis, serving as the control for the calves in group II.

The results of this experiment are given in Table 39 and 40. There was a reduction of 37.7% adult S. bovis in the immunized calves compared with their challenge control group. The corresponding reductions in tissue egg counts were also considerable...
considerable, showing a reduction of 71.3 %, 65.6 % and 76.2 % in the liver, small intestine and large intestine respectively compared with the egg counts in control group III.

Experiment 2: *S. bovis* versus *O. turkestanicum*.

The design of this study was the same as the previous experiment; there were 3 animals in each group except for group I which had 2 calves. The number of *immunising S. bovis* cercariae was 5,000, challenged by 8,000 cercariae of *O. turkestanicum*.

The results of this experiment are shown in Tables 41 and 42. The mean number of *O. turkestanicum* adults was reduced to 29.7 % of those in the challenge group II, and reduction of tissue egg counts per gram of liver and small intestine were 61.3 % and 77.0% respectively.

Experiment 3: *S. haematobium* versus *S. bovis*.

The calves were divided into a non-immunised group I and immunised group II. In group I, calves were first immunised...
with cercariae of *S. haematobium* and then challenged with cercariae of
*S. bovis*. Immunisation of calves group I was by 7,000 *S. haematobium*
cercariae for each exposure at 4 weeks interval giving a total of
21,000 cercariae per calf.

It was found that the mean worm recovery of *S. bovis* in
immunized group I was much lower than that in the control group II,
with a reduction of 42.3% (Table, 43). Distinguishing *S. haematobium*
from *S. bovis* was easy, since all the *S. haematobium* worms were very
small and immature with undeveloped internal organs.

*S. bovis* egg counts in the liver, small intestine and large
intestine were very reduced in group I compared with control group II:
reduction of the 30.3% in the liver, 45.0% in the small intestine
and 90.8% in the large intestine (Table, 44).

Experiment, 4: *S. haematobium* versus *O. turkestanicum*.

The details of this experiment are given in Tables, 45 and 46.
The mean recovery of adult *O. turkestanicum* was 31.4% lower in
challenge group I than that in control group II. The corresponding reduction in tissue egg counts per gram of liver and small intestine was 17.5% and 82.5% respectively.

The results of the above experiment on calves showed that there is a strong interaction and cross-protection between *S. bovis*, *O. turkestanicum* and *S. haematobium*. This suggests that the immune phenomenon will occur in endemic areas like Khuzestan and that under natural condition this might reduce the severity of the disease in livestock.

B. Homologous Immunity Studies,

Experiment 1: *O. turkestanicum* versus *O. turkestanicum*,

In this experiment 2 groups each of 2 calves were used. The results are given in Tables 47 and 48. The mean number of *O. turkestanicum* adult worms recovered in group I was 1,400 while in the non-immunized control group II the mean recovery of adult worms were 2,434. The reduction in the immunized group was 42.4%. Further evidence of /protection...
protection can be seen in the tissue egg counts. In the immunized group I, the number of eggs in the liver was the same as in the non-immunized control group II, but in the small intestine there was a considerable reduction of egg densities (72.8%).

Experiment 2: *S. bovis* versus *S. bovis*.

Calves were divided into immunized and non-immunized groups.

Analysis of the results (Tables 49 and 50) showed that there was no reduction in the worm recovery in the immunized group, but the tissue egg counts were reduced in the immunized group I animals compared with the non-immunized control group II by 21.2% in liver, 46.9% in small intestine and 76.0% in large intestine.
2. SHEEP.

Heterologous Immunity Studies,

Experiment 1: O. turkestanicum versus S. bovis.

The results of this experiment are given in Tables 51 and 52. The reduction of worm burden was 8.2% and the reduction of tissue egg counts was 19.8% in liver, 15.4% in small intestine and 26.3% in large intestine.

Experiment 2: S. bovis versus O. turkestanicum.

Analysis of the results of this experiment (Tables 53 and 54) showed a reduction of 43.6% in adult worms of O. turkestanicum burden and a reduction of tissue egg counts of 87.4% in liver and 22.1% in small intestine. The effect of immunisation in sheep in group II was variable: in sheep no. 2 low numbers of adult O. turkestanicum (432 worms) and no eggs were found in the liver digestion, with very low egg counts....
counts of 350 eggs per gram of small intestine, whereas sheep no.1 in the same group had 1569 worms and 13,475 eggs per gram of small intestine.
Table 39

Experiment 1. Immunisation against *S. bovis* with cercariae of *O. turkestanicum* in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Worms Recovery</th>
<th>Average number of <em>S. bovis</em> adults</th>
<th>Reduction in <em>S. bovis</em> adult loads %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>O. turk.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>S. bovis</em></td>
<td>0.f.</td>
<td>S.b.</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1022</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1824</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>2377</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>972</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>921</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>821</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 40

Experiment 1. Immunisation against *S. bovis* with cercariae of *O. turkestanicum*

in calves: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>S. bovis</em> egg/gram</th>
<th>Reduction in <em>S. bovis</em> egg load (mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>O. turk.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>S. bovis</em></td>
<td>Liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>116</td>
</tr>
<tr>
<td>only</td>
<td>3</td>
<td>8,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>816</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>404</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td><em>O. turk.</em> &amp; <em>S. bovis</em></td>
<td>2</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>170</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>8,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>112</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td><em>S. bovis</em> only</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
</tbody>
</table>

Reduction of *S. bovis* egg per gram of tissues %
Table 41

Experiment 2. Immunisation against *O. turkestanicum* with cercariae of *S. bovis*

in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf No.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Worms Recovery</th>
<th>Average number of <em>O. turke</em> adults</th>
<th>Reduction in <em>O. turke</em> adult loads %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>O. turke</em></td>
<td>Female S.B.</td>
<td>Female O.t.</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1250</td>
</tr>
<tr>
<td><em>S. bovis</em> only</td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1661</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1455</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>8,000</td>
<td>18</td>
<td>1357</td>
</tr>
<tr>
<td><em>S. bovis</em> x <em>O. turke</em></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>8,000</td>
<td>18</td>
<td>1541</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5,000</td>
<td>9</td>
<td>8,000</td>
<td>18</td>
<td>1397</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1491</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td><em>O. turke</em> only</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1411</td>
</tr>
</tbody>
</table>
Table 42

Experiment 2. Immunisation against *O. turkestanicum* with cercariae of *S. bovis*

in calves: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy weeks after initial exposure</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>O. turk.</em> egg/gram</th>
<th>Reduction in <em>O. turk.</em> egg load (Mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>O. turk.</em></td>
<td>Liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>3597</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>2556</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>3076</td>
<td>2138</td>
<td>4721</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>8,000</td>
<td>18</td>
<td>3530</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>8,000</td>
<td>18</td>
<td>1760</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>2133</td>
<td>156</td>
<td>1266</td>
<td>4001</td>
<td>943</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>404</td>
<td>17567</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction of <em>O. turkestanicum</em> egg per gram of tissues %</td>
<td>61.3</td>
<td>77.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experiment 3. Immunization against *S. bovis* with cercariae of *S. haematobium* in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks)</th>
<th>Worms Recovery</th>
<th>Average number of <em>S. bovis</em> adults</th>
<th>Reduction in <em>S. bovis</em> adult loads %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. haem.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>S. bovis</em></td>
<td>Female S. haem.</td>
<td>Female S. bovis</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>21,000</td>
<td>15</td>
<td>5,000</td>
<td>22</td>
<td>251</td>
</tr>
<tr>
<td>S. haem. x <em>S. bovis</em></td>
<td>2</td>
<td>13</td>
<td>5,000</td>
<td>22</td>
<td>111</td>
<td>794</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>181</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td><em>S. bovis</em> only</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1455</td>
</tr>
</tbody>
</table>
Table 44

Experiment 3. Immunisation against *S. bovis* with cercariae of *S. haematobium* in calves: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>S. bovis</em> egg/gram</th>
<th>Reduction in <em>S. bovis</em> eggload (mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>1</td>
<td>Initial exposure to <em>S. haem.</em>: 21,000 (7000 x 3)</td>
<td>13, 5,000</td>
<td>22</td>
<td>Liver: 0, 2990, 0; Small intestine: 0, 1690, 0; Large intestine: 0, 380</td>
<td>1232</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>13, 5,000</td>
<td>22</td>
<td>Liver: 0, 1400, 0; Small intestine: 0, 750, 0; Large intestine: 0, 480</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Liver: 2150, 1175; Small intestine: 1175, 430</td>
<td></td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>Liver: 3597, -; Small intestine: -; Large intestine: 7312</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>Liver: 2556, -; Small intestine: -; Large intestine: 2130</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Liver: 3076, 2138; Small intestine: 2138, 4721</td>
<td></td>
</tr>
<tr>
<td>Reduction of <em>S. bovis</em> egg per gram of tissue %</td>
<td>30.1</td>
<td>45.0</td>
<td>90.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 45

Experiment 4: Immunisation against *O. turkestanicum* with cercariae of *S. haematobium* in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks)</th>
<th>Worms Recovery</th>
<th>Average number of <em>O. turke</em> adults</th>
<th>Reduction in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. haem.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>O. turke.</em></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>21,000 (7000x3)</td>
<td>13</td>
<td>8,900</td>
<td>22</td>
<td>186</td>
</tr>
<tr>
<td>S. haem. x O. turke.</td>
<td>2</td>
<td>-</td>
<td>13</td>
<td>8,000</td>
<td>22</td>
<td>43</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>21,000</td>
<td>13</td>
<td>8,400</td>
<td>22</td>
<td>114</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>O. turke. only</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 46

Experiment 46. Immunisation against *O.* turkestanicum with cercariae of *S.* haematobium: Effect on tissue egg counts (in calves).

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf no.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>O.</em> turk. egg/gram</th>
<th>Reduction in <em>O.</em> turk. eggload (Mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>1</td>
<td>21,000</td>
<td>13</td>
<td>8,000</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>S. haem.</td>
<td>(700 x 3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0. turk.</td>
<td>13</td>
<td>8,000</td>
<td>22</td>
<td>0</td>
<td>212</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>333</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>O.</em> turk. only</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>404</td>
<td>17567</td>
</tr>
<tr>
<td>Reduction of <em>O.</em> turk. egg per gram of tissue %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17.5</td>
<td>82.4</td>
</tr>
</tbody>
</table>
Table 47

Experiment 1. Immunisation against *O. turkestanicum* with cercariae of *O. turkestanicum* in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf No.</th>
<th>Number of cercariae</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Worms recovery</th>
<th>Average number of <em>O. turk.</em> adults</th>
<th>Reduction in <em>O. turk.</em> adults load %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>O. turk.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>O. turk.</em></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>707</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>481</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>594</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O. turk. only</td>
<td></td>
<td>1</td>
<td>1000</td>
<td>-</td>
<td>5000</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td></td>
<td>9</td>
<td>1272</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1042</td>
</tr>
</tbody>
</table>
Experiment 1. Immunisation against _O. turkestanicum_ with cercariae of _O. turkestanicum_
in calves: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf No.</th>
<th>Number of cercariae</th>
<th>Autopsy weeks after initial exposure</th>
<th>Tissue egg counts/gram</th>
<th>Average number of <em>O. turk.</em> egg/gram</th>
<th>Reduction in <em>O. turk.</em> eggs lost % (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>O. turk.</em></td>
<td>Interval (weeks)</td>
<td>challenge exposure with <em>O. turk.</em></td>
<td>Liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>76</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>113</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td>9</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>5000</td>
<td>9</td>
<td>80</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>110</td>
</tr>
<tr>
<td>Reduction of <em>O. turk.</em> egg per gram of tissue %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Table 49

Experiment 2. Immunisation against *S. bovis* with cercaricide of *S. bovis*

in calves: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf No.</th>
<th>Number of cercaricide</th>
<th>Autopsy weeks after initial exposure</th>
<th>Worms recovery</th>
<th>Average number of <em>S. bovis</em> adults</th>
<th>Reduction in <em>S. bovis</em> adults load %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>Interval (weeks)</td>
<td>challenge exposure with <em>S. bovis</em></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>1242</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>1508</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1376</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td>9</td>
<td>1343</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td>9</td>
<td>1380</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1361</td>
</tr>
</tbody>
</table>
Table 50

Experiment 2. Immunisation against *S. bovis* with ceralazine of *S. bovis* in calves: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Calf</th>
<th>Number of ceralazine</th>
<th>Autopsy weeks after initial exposure</th>
<th>Tissue egg counts/gram</th>
<th>Average number of <em>S. bovis</em> egg/gram</th>
<th>Reduction in <em>S. bovis</em> eggload %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>Interval (weeks)</td>
<td>challenge exposure with <em>S. bovis</em></td>
<td>Liver</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>1466</td>
</tr>
<tr>
<td><em>S. bovis</em></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. bovis</em></td>
<td>2</td>
<td>1000</td>
<td>9</td>
<td>4000</td>
<td>18</td>
<td>870</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1168</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td>9</td>
<td>886</td>
</tr>
<tr>
<td><em>S. bovis</em></td>
<td>only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>only</em></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5000</td>
<td>9</td>
<td>2080</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1483</td>
</tr>
<tr>
<td>Reduction of <em>S. bovis</em> egg per gram of tissue %</td>
<td>21.2</td>
<td>46.9</td>
<td>76.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 51

Experiment 1. Immunization against *S. bovis* with cercarase of *O. turkestanicum* in sheep: Effect on adult worm counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sheep no.</th>
<th>Number of cercarase</th>
<th>Autopsy (weeks after initial exposure)</th>
<th>Worms Recovery</th>
<th>Average number of <em>S. bovis</em> adults</th>
<th>Reduction in <em>S. bovis</em> adult loads %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>O. turkestanicum</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>S. bovis</em></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>514</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>965</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>630</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>5,000</td>
<td></td>
<td></td>
<td></td>
<td>703</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>551</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>415</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>483</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1044</td>
</tr>
</tbody>
</table>
Table 52

Experiment 1. Immunisation against *S. bovis* with cercariae of *O. turkestanicum*

in sheep: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sheep no.</th>
<th>No. of cercariae</th>
<th>Autopsy weeks after initial exposure</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>S. bovis</em> egg/gram</th>
<th>Reduction in <em>S. bovis</em> egg load (mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial exposure to <em>O. turk.</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>S. bovis</em></td>
<td>Liver <em>O. t.</em></td>
<td><em>S. b.</em></td>
<td>Liver <em>O. t.</em></td>
</tr>
<tr>
<td>Group I</td>
<td>1</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1458</td>
</tr>
<tr>
<td>only</td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>1197</td>
</tr>
<tr>
<td>3</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>630</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1095</td>
</tr>
<tr>
<td>Group II</td>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>570</td>
</tr>
<tr>
<td><em>O. turk.</em></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>877</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>723</td>
</tr>
<tr>
<td>Group III</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td><em>S. bovis</em></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9757</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9757</td>
</tr>
<tr>
<td>Reduction of <em>S. bovis</em> egg per gram of tissues %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19.8</td>
</tr>
<tr>
<td>Group</td>
<td>Sheep no.</td>
<td>Number of cercariae</td>
<td>Autopsy (weeks after initial exposure)</td>
<td>Worms Recovery</td>
<td>Average number of 0. turk. adults</td>
<td>Reduction in %</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>---------------------</td>
<td>----------------------------------------</td>
<td>----------------</td>
<td>----------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Group I</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. bovis</td>
<td>1</td>
<td>5,000</td>
<td>-</td>
<td>9</td>
<td>1191</td>
<td>1305</td>
</tr>
<tr>
<td>only</td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>9</td>
<td>897</td>
<td>909</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1044</td>
<td>1107</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. bovis x O. turkestanicum</td>
<td>1</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>1086</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
<td>815</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>950</td>
<td>369</td>
</tr>
<tr>
<td>Group III</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O. turkestanicum</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>only</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>5,000</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>703</td>
<td>1071</td>
</tr>
</tbody>
</table>
Table 54

Experiment 2. Immunisation against *O. turkestanicum* with cercariae of *S. bovis*

in sheep: Effect on tissue egg counts.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sheep no.</th>
<th>Number of cercariae</th>
<th>Autopsy weeks after initial exposure</th>
<th>Tissue egg counts per gram</th>
<th>Average number of <em>O. turkestanicum</em> egg/gram (mean) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial exposure to <em>S. bovis</em></td>
<td>Interval (weeks)</td>
<td>Challenge exposure with <em>O. turkestanicum</em></td>
<td>Liver</td>
</tr>
<tr>
<td>Group I</td>
<td></td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>9757</td>
<td></td>
<td>4635</td>
<td>5005</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5,000</td>
<td>9</td>
<td>5,000</td>
<td>18</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>24073</td>
<td>138</td>
<td>14752</td>
<td>6912</td>
</tr>
<tr>
<td>Group III</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>1095</td>
<td></td>
<td>8860</td>
<td></td>
</tr>
<tr>
<td>Reduction of <em>O. turkestanicum</em> eggs per gram of tissues %</td>
<td>87.4</td>
<td>21.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

The results of the experiments on mice are summarized in Table 55. Initial single or multiple exposures to *O. turkestanicum* cercariae induced a moderate partial protection against the challenge infection with *S. bovis* and *S. haematobium*, but to a less extent against *S. mansoni*. The immunity was evident from both the reduction of worm burdens and the tissue egg counts. Initial doses of 100 cercariae or more produced partial protection, but 50 cercariae produced very poor resistance. It seems likely that with this parasite there is a minimum immunizing exposure as was reported by Smithers and Terry (1965) for *S. mansoni* in the rhesus monkey. This threshold in *O. turkestanicum* is less than 100 cercariae.

A single exposure to *O. turkestanicum* cercariae produced immunity as effectively as repeated exposures. Furthermore, the degree of resistance in mice showed no correlation with the number of cercariae...
of cercariae used since 100 cercariae of _O.turkestanicum_ produced
the same degree of protection as 200 cercariae or 150 cercariae in
3 inoculations. Hunter et al (1962) also found that with _S.mansoni_
in albino mice multiple exposure was no more effective in producing
immunity to a challenge infection than a single exposure to the same
total number of cercariae. On the other hand Kagan (1952), Thompson
suggested that resistance to schistosome infections is increased by
repeated immunisation.

The experiment on homologous immunity in mice with _S.bovis_
showed that there was a moderate protection against the subsequent
infection after immunisation with this species.

The results of the heterologous immunity studies in calves
are summarized in Table, 56 and show reductions of 29.7 % to 42.4 %
in adult worms load and 50.2 % to 81.0 % in tissue egg counts per
/gram....
gram of tissues in immunized groups compared with the non-immunized control groups. A strong reciprocal protection was demonstrated between *S. bovis* and *O. turkestanicum* in calves, the natural host of these parasites. The immunity in sheep (Table 56) was less effective.

Results from calves together with the previous study which show some degree of 'self cure' in *S. bovis* and *O. turkestanicum* infections in calves suggests calves are useful animals for studying immunity in schistosomiasis particularly as they are the natural hosts of these parasites.

The only previous report of heterologous studies in calves was by Hussein et al. (1970) who reported a high degree of partial protection in calves immunized with *S. mansoni* against challenge with *S. mattheei*.

*S. haematobium* in the calves failed to develop to maturity. Nevertheless immunisation with 3 inoculations of *S. haematobium* cercariae...
cercariae produced very strong cross-protection against *S. bovis* and *O. turkestanicum*. This experiment was the reverse of those reported by Hsu et al. (1966) who immunized rhesus monkeys repeatedly with Iranian *S. bovis* cercariae and then challenged them with Iranian *S. haematobium* and produced a strong protection.

In our homologous immunity experiment in calves with *S. bovis* no reduction in worm burden was observed in the immunized group compared with the non-immunized group, but in homologous immunity with *O. turkestanicum* in calves a 42.4% reduction of worms load was observed. There was a considerable reduction in tissue egg counts in the immunized groups, 50.2% in *S. bovis* and 72.3% in the *O. turkestanicum* experiments. In our observations on cattle naturally infected with *O. turkestanicum* the worms load and tissue egg counts also declined with increasing age, which could be attributed to the development of some degree of natural acquired immunity either homologous or heterologous.

/We conclude....
We conclude from these experiments that natural heterologous and homologous immunity between both the bovine parasites and the human parasite S. haematobium could be of great importance in protecting the animals from the severe effects of subsequent reinfections. A similar effect may be of general importance in schistosomiasis of domestic animals in many endemic areas.
Summary of work done on heterologous and homologous immunity between schistosome species in albino mice, percentage of reduction in worm load and tissue egg counts.

<table>
<thead>
<tr>
<th>Immunized Species</th>
<th>Challenged Species</th>
<th>No. of cercarize</th>
<th>S. bovis</th>
<th>S. haem.</th>
<th>S. mansoni</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. tunk.</td>
<td></td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(49.8)</td>
<td></td>
<td></td>
<td>(7.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>28.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(50x3)</td>
<td>(55.6)</td>
<td>(41.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>21.9</td>
<td>8.7</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(50x3)</td>
<td>(51.3)</td>
<td>(37.9)</td>
<td></td>
</tr>
<tr>
<td>S. bovis</td>
<td></td>
<td>200</td>
<td>30.1</td>
<td>-</td>
<td>20.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(49.4)</td>
<td></td>
<td></td>
<td>(37.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>66.1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

( ) Reduction of the mean egg counts per gram of tissues.
Table 56

Summary of work done on heterologous and homologous immunity between schistosome species in calves and sheep, percentage of reduction in worm load and tissue egg counts.

<table>
<thead>
<tr>
<th>Immunized Species</th>
<th>Challenged Species</th>
<th>Calves</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q. turkei</td>
<td>S. bovis</td>
<td>Q. turkei</td>
</tr>
<tr>
<td>Q. turkei</td>
<td>42.4 (72.8)</td>
<td>37.7 (72.5)</td>
<td>-</td>
</tr>
<tr>
<td>S. bovis</td>
<td>29.7 (76.8)</td>
<td>0 (50.2)</td>
<td>43.6</td>
</tr>
<tr>
<td>S. haem.</td>
<td>31.4 (81.0)</td>
<td>42.3 (62.2)</td>
<td>-</td>
</tr>
</tbody>
</table>

( ) Reduction of the mean egg counts per gram of tissues.
ADDENDUM

THE FIRST RECORD OF EXPERIMENTAL INFECTION OF

CALVES WITH S. HAEMATOBIIUM

INTRODUCTION,

In the above study on heterologous immunity calves were
exposed to a large number of S. haematobium cercariae; at autopsy, 22
weeks after initial exposure immature worms were present. There are
no previous records of S. haematobium infection in cattle. Kunts and
Malakatis (1955) exposed goats to S. haematobium cercariae and only a
very few small worms were recovered; Leiper (1915); MacHattie (1933);
Saeed (1970) failed to infect sheep with S. haematobium.

In the present experiments 4 calves 7-9 months old from
Khuzestan were exposed to a total of 21,000 cercariae of S. haematobium
each, in 3 inoculations at 4 weeks intervals (in each inoculation
7,000 cercariae were used). For each inoculation, cercariae were
/pooled....
pooled from 20-30 Bulinus truncatus which were infected from a human source in the laboratory.

After 18 weeks from initial exposure the calves were challenged with S. bovis or O. turkestanium cercariae to study the cross-immunity against animal schistosomes.

RESULTS,

The red papules on the skin of the legs showed that the cercariae had penetrated, when the animals were killed 22 weeks after initial exposure to S. haematobium cercariae it was found that all the 4 calves had developed limited S. haematobium infections (Table, 55).

The number of worms recovered by perfusion varied from 250 to 640 (378 ± 99), the percentage of worms recovered was 3.0%, 0.9%, 1.9% and 1.2% with a mean of 1.8%.

In tissue digestion for egg counts only calf no. 1 revealed a few deformed, rudimentary black eggs with no miracidia (Table, 55).
Most of the worms were found in the portal veins, but in calf no. 1 some large worms with deformed intra-uterine eggs were recovered from the lower mesenteric veins of the large intestine, but no worms or eggs were found in the vesicleal plexus or bladder wall. The immature *S. haematobium* worms were easily distinguished from *O. turkestanicum* and *S. bovis* worms because they were smaller in size and the females had undeveloped vitellaria.

**DISCUSSION,**

Not only domestic animals but also various species of rodents have been known as reservoir of great epidemiological importance for *S. japonicum*, one of the three principal species of the schistosoma parasite of the man. As for the other two species *S. haematobium* and *S. mansoni*, it was believed until recently that man was the only host of epidemiological importance. A wide variety of rodents have been found naturally infected with *S. mansoni* but it is generally considered that they are unlikely to be of any significance as maintenance hosts.

/But recently...
But recently it has been shown that baboons in East-Africa act as a reservoir host for *S. mansoni* (Nelson et al., 1962; Fenwick, 1966, 1969). Barbosa et al. (1962) found adult *S. mansoni* in cattle slaughtered in an abattoir in Brazil and Saeed et al. (1969) successfully infected calves with *S. mansoni* but their significance as natural maintenance host is still unknown.

Records of *S. haematobium* infections in animals are rare. Nelson (1960) reported two cases in East Africa one in a baboon and the other in a *Cercopithecus* monkey. A natural infection of *S. haematobium* in a West African chimpanzee was reported by De Paoli (1965).

Recently one baboon out of 24 from West Africa was found to be naturally infected with *S. haematobium* and was passed viable eggs in both the faeces and urine (Taylor, 1971 personal communication).

Kunts and Malakatis (1955) exposed 3 goats to about 200,000 cercariae of *S. haematobium* each, and succeeded in infecting 2 of them, /however...
however, the number of parasites recorded was extremely small.

Leiper (1915), MacHattie and Chadwick (1932), MacHattie et al. (1933); Saeed (1970) were unable to infect sheep with *S. haematobium*. Saoud (1966) also failed to infect pigs with *S. haematobium* cercariae in laboratory and disputed the report by Hill and Omaamraco (1960) who claimed to have found a natural *S. haematobium* infection in a pig in Nigeria.

Our experiments with *S. bovis* and *S. haematobium* and *O. t. turkestanium* show that success in experimentally infecting calves depends largely on the technique used. Using an efficient technique, calves were shown to take *S. haematobium* infection but the worms recovered were immature. This may also happen to calves in nature in endemic areas, since they live in very close contact with infected natural waters. The immune response which developed in calves with *S. haematobium* infection was considerable and was discussed in the previous chapter.
Table, 55

Recovery of adults and eggs of *S. haematobium* in calves infected with total 21,000 cercariae in 3 inoculations at 4 weeks intervals.

<table>
<thead>
<tr>
<th>No. of calves</th>
<th>No. of cercariae</th>
<th>Duration of infection (weeks)</th>
<th>Worms Recovery</th>
<th>Tissue egg counts/gram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1.</td>
<td>7000 x 3 (21000)</td>
<td>22</td>
<td>186</td>
<td>454</td>
</tr>
<tr>
<td>2.</td>
<td>&quot;</td>
<td>22</td>
<td>43</td>
<td>161</td>
</tr>
<tr>
<td>3.</td>
<td>&quot;</td>
<td>22</td>
<td>251</td>
<td>167</td>
</tr>
<tr>
<td>4.</td>
<td>&quot;</td>
<td>22</td>
<td>111</td>
<td>139</td>
</tr>
<tr>
<td>Mean (S.E.)</td>
<td></td>
<td></td>
<td>148</td>
<td>230</td>
</tr>
</tbody>
</table>
PART IV
FIELD AND LABORATORY OBSERVATIONS ON LYMNAEA GEDROSIANA

THE INTERMEDIATE HOST OF ORNITHOBILHARZIA TURKESTANICUM

IN KHUZESTAN

INTRODUCTION,

*L. gedrosiana* (Annandale & Prasad) is a molluscan host of 2 important parasites of domestic animals (*O. turkestanicum* and *Fasciola gigantica*) in Khuzestan. Therefore, control measures against the snail are of great economic importance. Detailed biological and ecological studies are necessary before control measures can be directed against *L. gedrosiana*. This approach has been used in other parts of the world against the snail hosts of human schistosomiasis (*Pesigan et al.*, 1958; *Shiff*, 1964; *Webbe*, 1962 and *Chu et al.*, 1968).

The present study records observations on the transmission of *O. turkestanicum*, the biology and ecology of the principal molluscan host, seasonal fluctuations in snail population densities and associated *O. turkestanicum* infection rates and laboratory experiments designed to study the "vector" potential of *L. gedrosiana*.

/Chapter, 1...
CHAPTER 4

OBSERVATIONS ON THE GEOGRAPHICAL DISTRIBUTION
OF L. GEDROSIANA IN KHUZESTAN

The L. gedrosiana survey was started in 1967 in conjunction with the B. truncatus survey. L. gedrosiana was found to be distributed all over the irrigation systems of Khuzestan. Most of the primary and secondary canals, water-sheds, isolated breeding sites such as ponds, swamps and ditches were visited. Map 1 shows that B. truncatus and L. gedrosiana were mostly found in the same areas. The following accounts give detail of the study area:

The Main Focus:

This area is the largest and agriculturally the richest plain and the best irrigated area in the Khuzestan; it is bordered in the north by the slopes north of Dezful and Andimeshk, and in the west and east by the Karkheh and Karun rivers, respectively, and /terminates....
terminates in the south near Ahwaz. For convenience of description, the area has been divided into 3 namely, the northern area, the sugar cane area and the southern area.

The Northern Area (Map, 2)

The distribution of snails in this area during the period from 1959 to 1961 was described by Gaud et al (1962) and Chu et al (1968). In the centre covering an area of 22,000 ha, is a new irrigation system which was installed between 1962 and 1964; water is drawn only from the Dez river. Previously there had existed an old system of earth canals and flow of water in them was rapid. The new irrigation system includes main canals, lateral and tertiary canals; some of the canals are cement lined. The old canals are still used to distribute water to farming land and fruit gardens and as drains to collect water from the field and to discharge it into new large drains which finally empty themselves into the Abjirob stream and the Dez river. A number of canals are not in use and some of them dry out from time to time.

The snails....
Map 2

Details of rivers, streams, canals and villages, etc., in the Northern part of the main foci of *Lymnea cedrosiana* and *Bulimus truncatus* in Khuzestan.
The snails were mostly found in canals, drains, swamps, ricefields, ponds and springs. From 1965 onwards, many new habitats were found—consisting of swamps and sidepools along new canals and new highways. The increased use of water in the ricefields may account for the further spread of the snails.

Between the lower ends of the new irrigation area and the Lureh area is the Abjirob area where a chain of irrigation canals has existed for some 20 years, the source of water here is the Abjirob stream, which also collects water from the new irrigation area and discharges through a dam into Dés river. *B. truncatus* and *P. gedrosiana* were found in most canals at their terminal ends in swamps adjoining the canals. The Lureh area is located in the north part of the Abjirob area between the Shuruh stream and the Abjirob stream. The Lureh stream is the only water source for this area. Schistosome infections in man and animals were wide spread.

In the west is an area receiving water from several sources: from the Karkheh river (*Hermoni* canals); from the Dés river; from /the Shahur....
the Shahur stream which also crosses this area. Snails were found in swamps, way-sidepools and canals. Recently, the Greater Dez Project was begun to install a new irrigation system in this area, with water taken from the Dez river.

The Sugar Cane Area,

This area located in the South part of Pilot Project Area and separated by wire mesh from the adjoining areas. It is a new irrigation system with numerous newly built canals, large water reservoirs and a deep drainage network, the water source is from the Dez river. B. truncatus and L. gedrosiana were widespread all over the area. The slow water flow in the canals and the large water reservoirs with plenty of vegetation gave ideal conditions for snail breeding.

The Southern Area,

This area is bounded in the north by the Sugar Cane Area, in the east by the Dez-Karun river, in the west by the Karkheh river.
and the Ahwaz-Desful Highway and in the south it extends to Ahwaz.

The water in this area is derived from the Shahur river which divided into two branches. The upper branch (Maleh) is wide, meandering and overgrown with heavy vegetation; during the dry season (summer and autumn) this branch becomes broken up into several swamps. During the wet seasons (winter and spring) snails are therefore carried to down stream areas. The lower branch of the Shahur river is about 60 km. long; it is the main branch and the water flows fast. In the course of the lower branch there are several small and large marshy swamps and snails were spread all over the area; man and animal schistosomes were abundant in this area.

Other Important Areas,

The lower Karkheh Area (Dasht-Mishan),

This area is bounded in the west by the Iraq frontier, in the north by the dry Dehloran area, in the east by Ahwaz and in the south by a desert. A dam was established at Hamidieh where a main irrigation channel feeds water to some canals in the east and south / part of....
part of this area. The lower Karkheh river divides into two branches at Kut Naim. The southern branch was empty of water for 7 km; below that point it receives water from the main Hamidieh channel. The northern branch further divides at Susangird and discharges into a large marsh (Susangird swamp) adjoining the Iraq border.

The area north of the northern branch of the Karkheh river was completely dry. On the south side, the water was pumped from the river into short irrigation canals along the bank. L.gedrosiana flourished in irrigation canals, but E.trumeatus was found only in ponds and tertiary canals around a village called Ghadir. In the large swamp (Susangird swamp) between the Iran and Iraq border only dead shells of Lymnaea, Cirulus and few live Viviparus and Melanoides were found.

The Shushtar Area,

The water in this area is drawn partly from the Karun river and partly from natural streams which finally join the Karun river.
Lymnaea was abundant in canals and ponds around market gardens and irrigation canals, B. truncatus was found in a marshy drain near Boneh Arabba. Animal schistosomes was prevalent in this region.

Other Areas,

The area south-east of Ahwas (Ramhormoz) is suitable for snail breeding, but only L. gedrosiana was found and no B. truncatus. In Shadegan area where the dry Jarahi river ends there is a shallow large saline swamp and no live snails. In the Khorramshahr area, dead shells of B. truncatus were found in the field channel of date farms but in the canals and ponds L. gedrosiana was found. The Dehloran area north of Dasht-Nishan is a vast and dry area.
CHAPTER 2

A GENERAL DESCRIPTION OF THE SPECIAL STUDY AREA

Studies on the seasonal population trends of *L. pedrosiana* and its relation to transmission of *Q. turkestanium* in animals were carried out from 1967-1970 in the special area (Pilot Project Area) located in the northern part of Khuzestan (Map, 3). This area lies mainly south of Andimeshk-Dezful, within an irregular quadrilateral of a somewhat rhomboidal shape. It is bordered in the west by the Karkheh river and crossed by the Teheran-Alwas highway and railroad, in its north-east part by the Dezful-Shushtar road, in the east by the Shureh stream. In the south it is bordered by the Sugar Cane Area (Haft-tapeh) and Ahudasht steppe. The great axis north-west from the Karkheh river down to the south-east (railway station of Ahudasht) measures 73 km. The small axis north-east to south west measures 45 km. from Sarbisheh village down to the intake of the great canal of the south Agricultural Company in the Karkheh river.

/ The Pilot.../
The Pilot Irrigation Area with its new system of irrigation canals is entirely included in the study sector. It almost covers the axial part of the area and represents approximately one-sixth of the total study area. On the Dez river 25 km. north of the old city of Dezful, the first of a series of multiple-purpose dams, the Mohamad Reza Shah Pahlavi Dam (the highest dam in the Middle-East) was dedicated in March, 1963. A pilot demonstration of approximately 50,000 acres (22,000 hectares) was selected to receive the first waters of the dam. A system of canals and laterals was constructed in this area which extends generally southward from the city of Dezful, which was to be known as the Dez Pilot Irrigation Area. The construction of the irrigation network works for the undeveloped balance of 250,000 acres known as the Greater Dez Irrigation Project, which is included in the Study Area is to be completed by the end of 1972.

The whole study area occupies 1,000 km²; the main watercourse in this area is the Dez river which divides the area from north to south into equal parts and collects water from the west, / east of...
east of Bala Rud. The Bala Rud, a torrent which completely dries up in summer. The Karkheh river runs along the western edge of the area. From these rivers a great number of irrigation canals branch off. The excess irrigation water finds its way to the natural drains. These, which naturally flow north-southwards are: The Shahur and its tributary, the Attidj between Karkheh and Dez. The Abjirob, the Lureh and the Shureh, east of the Dez. The Shureh borders the eastern side of the study area. Down streams, before flowing into the Dez river these give rise to new irrigation network.

The flood plains have very different aspects; those of the northern and eastern part of the area (Bala Rud, upper Dez, Lureh and Shureh) are vast areas dry and covered with a thick layer of pebbles; those of the Karkheh and of the southern part of the Dez are mostly covered with a shrubby vegetation (Tamarix) in a relatively wet soil; The flood plains of the Shahur are much narrower and are swampy, with herbaceous vegetation.

/ Chapter 3, .....
CHAPTER 3

FIELD OBSERVATIONS ON SEASONAL POPULATION TRENDS
OF L. GEDROSIANA AND THEIR RELATION TO THE TRANSMISSION
OF O. TURKESTANICUM IN VARIOUS HABITATS IN THE STUDY
AREA

METHODS,

Selection of Sampling Areas,

Studies on the L. gedrosiana population dynamics and
seasonal infections with O. turkestanicum were started in January 1967.
Twenty different types of snail habitats (canals, swamps, ponds and
drains) were selected for monthly study of natural infections of
L. gedrosiana with O. turkestanicum cercariae (group A).

In October 1969 another series of observations were designed
to study the population dynamics and bionomics of L. gedrosiana by
fortnightly survey. Eight different types of habitats were selected
(group B).

/Sampling....
Sampling of Snail Populations,

Snails were collected monthly at fixed sites in each habitat. The habitats sampled included 11 canals in different parts of the study area (6 canals in Abjirob area, 3 canals in Lureh area and 2 canals in Pilot Irrigation Area), 3 swamps, 4 ponds and 2 drains. In an attempt to detect seasonal fluctuations of snail populations, as well as cercarial infection rates, snails were collected in as uniform a manner as possible by using the methods of Oliver and Schneiderman (1956). The area selected for study was first measured and marked. If the body of water was a canal a portion 100 to 150 metres long was chosen, whereas if the habitat was a small pool the whole area was used. In large bodies of water, a segment of the margin was marked as the collecting area. For snail sampling one man carried out a dip-net in the marked area systematically and uniformly for 10 minutes.

Collected snails were brought to the laboratory, after separating the species, the size distribution of the collected snails...
was determined by measuring the length of all snail shells (the
distance from base to apex). Snails were divided into 3 size groups
(0-6 mm., 6-10 mm. and 10-14 mm.).

The snails were crushed individually between 2 slides and
examined under a dissecting microscope for cercarial infection. Proof
of the identification of _O. turkestanica_ cercariae was obtained by
exposing a local wild rodent (_Tatera indica_) which is susceptible
to _O. turkestanica_, to the cercariae obtained by crushing more than
2 infected snails. The exposed rodents were sacrificed 3 months later,
the worms and the eggs deposited in the liver of the host were observed
for identification of the species of parasites.

In addition, the water level of the habitats was recorded
on each occasion. The highest water level was designated "5" and
"0" was recorded when the habitat was near drying or dry. This
study continued for 12 months from January to December 1967.

/ A. Standing....
A. Standing Waters,

Ponds,

A total of 4 ponds in different part of the Study Area was surveyed: the Bayatian pond, populated with a variety of snails, was 2 metres in depth and was overgrown by submerged vegetations. The Khanabad Ghotb pond was in the east side of the Study Area with shallow water. The Sardarabad pond was in the Pilot Irrigation Area and was a small pond surrounded with trees and a large amount of decayed tree leaves and vegetation. The Dehbar pond was small and shallow and was located against a garden wall and received water from the garden drainage. The snail data from monthly surveys from Jan-Dec. 1967 are given in Table, 57 and Fig. 2. During the observation period the peak of snail population occurred mostly from April to June with a small peak also in autumn. Infected snails were most abundant in March and April and also in September, October and November.

/ Swamps....
Swamps

Three swamps were selected in different parts of Study Area for monthly observations: the Deylam Sofla swamp which was a large swamp located in the Pilot Irrigation Area with dense vegetation and varieties of snails. Animal and human contact with this swamp was abundant. The Khanabad Ghotb swamp in the east side of the Study Area, was very large and shallow, had numerous tributaries. The Boneh Jawas swamp in the Abjirob Area was very large and deep, *Typha* vegetation was grown all over the swamp making a dense bush in the central parts.

The snail data from the monthly observations are given in Table, 58 and Fig. 3. The peak density of snail populations differed in each swamp, *L. gedrosiana* was most abundant in April and May with low density in summer. The Khanabad Ghotb swamp dry in July and August. Infected snails were found from April to November 1967.
Bq Running Water

Drains,

Two newly made irrigation drains were selected in the Pilot Irrigation Area: the Sardarabad and the Boneh Rahimsh drains characterised by their long course, dense vegetation and low water velocity.

The data from the monthly snail collections from Jan.-Dec. 1967 are presented in Table, 59 and Fig. 4. L. edrosiana densities were moderate with a peak in May and June. A few infected snails were found in the Sardarabad drain in May and September and in Boneh Rahimsh drain in March, April and August.

New Canals,

Boneh Charry and Boneh Yakub canals were located in the Pilot Irrigation Area, and were newly constructed irrigation canals.

/ The Boneh....
The Boneh Charry canal terminated in many ponds and water depressions which were mostly populated with *L. gedrosiana* and *B. truncatus* snails. Data from monthly collections are given in Table 59. In the Boneh Charry drain the peak of the *L. gedrosiana* population density was in May and June but in the Boneh Yakub canal it was irregular during the observation period. Infected *L. gedrosiana* were collected in the Boneh Charry canal from July to October; in the Boneh Yakub canal from August to December.

**Old Canals (Lureh Area)**

Three old canals in the Lureh Area were surveyed monthly. The Farash-abad canal; this canal passes through the village creating many ponds and water depressions. The Shongor Sofla canal, with low velocity and dense submerged vegetations. The Shongor Olia canal, with tortuous course and a shallow spread side drain running along the canal.

/ The data....
The data from monthly observations are given in Table, 60. The *L. gedrosiana* densities were more or less constant throughout the observation period, only low density were found in June and July. The infected snails were found irregularly, in the Farash-abad canal from April to December, in the Shongor Sofla canal all over the year and in the Shongor Olia canal in winter and late autumn.

**Old Canals (Abjirob Area)**

Six canals in the Abjirob Area were surveyed monthly; the canals received water from the main Abjirob canal which branched off from the Abjirob stream above a dam built some 20 years ago. The flow of water in these canals was lower in winter than in summer. In summer the ricefields adjoining the canals used much of the water which continued to run into the tertiary canals.

The most prevalent snail was the *L. gedrosiana*. The results on Table, 61 show that the *L. gedrosiana* population was rather high with peak densities in most of the canals in April and May and low densities in summer and winter. The summer decline was due to very high water level in the canals and the winter decline presumably was
due to cold temperatures.

Infected snails were found in most of the canals during the whole period except in the Boneh Jawaz canal where infected snail were found only from January to May 1967. Human and animal schistosomes were prevalent in the Abjirob Area and it is likely that infested canals played a major role in transmission of schistosomes in this area.

In general snail densities in the canals in different parts (Fig. 5) showed a major peak in spring and a minor peak in autumn with a decline in summer. The infection rate of L. gedrosiana was high in summer from June to October, and low in winter.
CONCLUSIONS,

1. Seasonal transmission potential of various types of habitats,

Canals were permanent transmission sites of O.turkestanicum throughout the year. Infectivity of swamps also continued throughout the year with a peak in the summer season but a very low level in winter. In ponds the number of infected L.gedrosiana was very low in summer and winter with peaks in spring and autumn. Drains played a very minor role in transmission, with very low and irregular infectivity (Table, 62 and Fig. 6).

2. Size-frequency of infected snails,

The prevalence of infection in large snails was higher than small size snails, presumably due to their having more chance to contact miracidia during their longer life-span comparing with young snails. The Percentage of infected snails in different size groups was 0.1 %, 0.5 % and 1.1 % in 0-6 mm, 6-10 mm and 10-14 mm height of shell...
shell of *L. gedrosiana* respectively (Table, 63).

3. *Infection rates in snails from different habitats,*

The infection rates of *L. gedrosiana* in different type of habitats was 0.68% in canals, 0.38% in swamps, 0.25% in ponds and 0.15% in drains. The highest rate of infection was observed in the canals (Table, 64).

4. *Snail infection rate in different parts of Study Area,*

The infection rate of *L. gedrosiana* with *O. turkestanicum* cercariae in different parts of the Study Area was 0.66% in Pilot Irrigation Area, 0.54% in Abjirob Area and 1.0% in the Lureh Area (Table, 65).

The full pattern of seasonal fluctuation of the infection rate of *L. gedrosiana* with *O. turkestanicum* cercariae in the different type of habitats is shown in Table, 62 and Fig. 6.

/ Addendum...
**ADDENDUM:**

Non-schistosome parasite larval stages found in *L. gedrosiana*.

1. *Fasciola gigantica*. *L. gedrosiana* is an intermediate host for *Fasciola gigantica* on the Khuzestan plain and in fact the infection rate of *L. gedrosiana* with *F. gigantica* cercariae was higher than with the *O. turkestanicum* cercariae. The prevalence of *F. gigantica* in cattle and sheep was also higher than that of *O. turkestanicum*.

2. There was an unknown cercariae more or less like the *F. gigantica* cercariae but smaller in size and very active; this cercariae did not encyst on vegetation, the infection rate of this cercariae in *L. gedrosiana* was much higher than the other cercariae. It may be that this cercariae is the same species that Miriam Rothschild (1936) described from *Lymnaea tenora ephratisa* in Iraq, as belonging to the Cynnocephalidae group.

/ 3. There....
3. There was also an apharyngeal longifurcate cercariae much longer than the brevifurcate cercariae of _O. turkestanicum_. Laboratory animals exposed to these cercariae developed no infections. The infection rates of this distome in _L. gedrosiana_ was very low and it was seen only occasionally in certain canals.
Table 57  

Numbers of *L. gedrosiana* collected monthly from 4 ponds in Khuzestan and numbers infected with *Q. turkestanium*.

<table>
<thead>
<tr>
<th>Month</th>
<th>Beyatian</th>
<th>Khan-abad</th>
<th>Sardar-abad</th>
<th>Dehbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>0/ 52</td>
<td>0/ 34</td>
<td>0/ 69</td>
<td>1/ 67</td>
</tr>
<tr>
<td>Feb.</td>
<td>0/ 91</td>
<td>0/ 63</td>
<td>0</td>
<td>0/103</td>
</tr>
<tr>
<td>March</td>
<td>0/ 10</td>
<td>0/ 90</td>
<td>1/ 24</td>
<td>2/185</td>
</tr>
<tr>
<td>April</td>
<td>0/ 68</td>
<td>3/166</td>
<td>0/ 72</td>
<td>0/1111</td>
</tr>
<tr>
<td>May</td>
<td>0/191</td>
<td>0/175</td>
<td>0/745</td>
<td>0/1138</td>
</tr>
<tr>
<td>June</td>
<td>0/ 66</td>
<td>1/307</td>
<td>0/390</td>
<td>0/263</td>
</tr>
<tr>
<td>July</td>
<td>1/179</td>
<td>0/305</td>
<td>0/102</td>
<td>0/ 13</td>
</tr>
<tr>
<td>Aug.</td>
<td>0/110</td>
<td>0/ 5</td>
<td>1/554</td>
<td>0/ 2</td>
</tr>
<tr>
<td>Sept.</td>
<td>2/210</td>
<td>0/ 7</td>
<td>3/764</td>
<td>0/ 20</td>
</tr>
<tr>
<td>Oct.</td>
<td>0/ 44</td>
<td>2/152</td>
<td>0/227</td>
<td>0/ 50</td>
</tr>
<tr>
<td>Nov.</td>
<td>0/90</td>
<td>9/ 78</td>
<td>0/254</td>
<td>0/214</td>
</tr>
<tr>
<td>Dec.</td>
<td>0/250</td>
<td>0/ 12</td>
<td>0/106</td>
<td>0/136</td>
</tr>
</tbody>
</table>

Numerators—number of snails with *Q. turkestanium* infections.

Denominators—total number of snails collected.
Table 58

Numbers of *L. pedrosiana* collected monthly from 3 swamps in Khuzestan and numbers infected with *O. turkestanicum*.

<table>
<thead>
<tr>
<th>Month</th>
<th>Deylam Sofla</th>
<th>Khan-abad Ghutb</th>
<th>Boneh Jawaz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>1/104</td>
<td>0/433</td>
<td>0/61</td>
</tr>
<tr>
<td>Feb</td>
<td>0/131</td>
<td>1/343</td>
<td>0/69</td>
</tr>
<tr>
<td>March</td>
<td>1/148</td>
<td>0/250</td>
<td>0/41</td>
</tr>
<tr>
<td>April</td>
<td>3/300</td>
<td>0/237</td>
<td>0/205</td>
</tr>
<tr>
<td>May</td>
<td>1/41</td>
<td>1/1171</td>
<td>2/110</td>
</tr>
<tr>
<td>June</td>
<td>3/41</td>
<td>0/74</td>
<td>0/104</td>
</tr>
<tr>
<td>July</td>
<td>0/24</td>
<td>dry</td>
<td>1/124</td>
</tr>
<tr>
<td>Aug</td>
<td>0/29</td>
<td>dry</td>
<td>1/40</td>
</tr>
<tr>
<td>Sept</td>
<td>6/31</td>
<td>0/4</td>
<td>0/74</td>
</tr>
<tr>
<td>Oct</td>
<td>1/52</td>
<td>0/42</td>
<td>1/101</td>
</tr>
<tr>
<td>Nov</td>
<td>1/65</td>
<td>0/16</td>
<td>0/101</td>
</tr>
<tr>
<td>Dec</td>
<td>0/46</td>
<td>0/53</td>
<td>0/162</td>
</tr>
</tbody>
</table>

Numerator—number of snails with *O. turkestanicum* infection.

Denominator—number of snails collected.
Table, 59

Numbers of *L. gedrosiana* collected monthly from new irrigation system (2 canals and 2 drains) in Khuzestan and numbers infected with *O. turkestanium*

<table>
<thead>
<tr>
<th>Month</th>
<th>Boneh Canal</th>
<th>Bonsh Yakub Canal</th>
<th>Sardar-abad Drain</th>
<th>Boneh Rahimeh Drain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>0/417</td>
<td>3/120</td>
<td>0/ 25</td>
<td>0/ 32</td>
</tr>
<tr>
<td>Feb.</td>
<td>3/125</td>
<td>0/304</td>
<td>0/199</td>
<td>0/561</td>
</tr>
<tr>
<td>March</td>
<td>0/ 73</td>
<td>0/516</td>
<td>0/ 33</td>
<td>1/228</td>
</tr>
<tr>
<td>April</td>
<td>0/270</td>
<td>0/227</td>
<td>0/165</td>
<td>1/223</td>
</tr>
<tr>
<td>May</td>
<td>2/490</td>
<td>2/320</td>
<td>1/424</td>
<td>0/1067</td>
</tr>
<tr>
<td>June</td>
<td>0/447</td>
<td>0/320</td>
<td>0/ 38</td>
<td>0/437</td>
</tr>
<tr>
<td>July</td>
<td>4/217</td>
<td>2/271</td>
<td>0/ 19</td>
<td>0/182</td>
</tr>
<tr>
<td>Aug.</td>
<td>3/452</td>
<td>2/ 88</td>
<td>0/27</td>
<td>3/534</td>
</tr>
<tr>
<td>Sept.</td>
<td>9/195</td>
<td>4/ 78</td>
<td>2/ 66</td>
<td>0/570</td>
</tr>
<tr>
<td>Oct.</td>
<td>2/247</td>
<td>1/ 30</td>
<td>0/143</td>
<td>0/179</td>
</tr>
<tr>
<td>Nov.</td>
<td>0/133</td>
<td>0/118</td>
<td>0/ 73</td>
<td>0/ 66</td>
</tr>
<tr>
<td>Dec.</td>
<td>0/198</td>
<td>1/74</td>
<td>0/ 22</td>
<td>0/ 25</td>
</tr>
</tbody>
</table>

Numerator - number of snails with *O. turkestanium* infections.
Denominator - total number of snails collected.
Table 60

Numbers of L.gadrosiana collected monthly from 3 canals in Khuzestan (Lureh Area) and numbers infected with O.turkestanicum.

<table>
<thead>
<tr>
<th>Month</th>
<th>Shongor Olim</th>
<th>Shongor Sofla</th>
<th>Farash-abad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>3/145</td>
<td>2/358</td>
<td>0/ 59</td>
</tr>
<tr>
<td>Feb.</td>
<td>2/206</td>
<td>3/155</td>
<td>0/349</td>
</tr>
<tr>
<td>March</td>
<td>0/ 24</td>
<td>0/ 13</td>
<td>0/ 83</td>
</tr>
<tr>
<td>April</td>
<td>1/181</td>
<td>7/152</td>
<td>0/473</td>
</tr>
<tr>
<td>May</td>
<td>0/202</td>
<td></td>
<td>0/285</td>
</tr>
<tr>
<td>June</td>
<td>0/ 24</td>
<td>1/ 28</td>
<td>2/448</td>
</tr>
<tr>
<td>July</td>
<td>0/ 76</td>
<td>0/ 34</td>
<td>4/ 50</td>
</tr>
<tr>
<td>Aug.</td>
<td>0/260</td>
<td>3/ 36</td>
<td>3/122</td>
</tr>
<tr>
<td>Sept.</td>
<td>0/359</td>
<td>3/ 76</td>
<td>3/270</td>
</tr>
<tr>
<td>Oct.</td>
<td>0/208</td>
<td>8/283</td>
<td>0/ 27</td>
</tr>
<tr>
<td>Nov.</td>
<td>1/121</td>
<td>6/285</td>
<td>0/ 61</td>
</tr>
<tr>
<td>Dec.</td>
<td>1/138</td>
<td>2/265</td>
<td>1/ 42</td>
</tr>
</tbody>
</table>

Numerators - number of snails with O.turkestanicum infections.
Denominators - number of snails collected.
Table, 61

Numbers of *L. gedrosiana* collected monthly from 6 canals in Khuzestan (Abjirob Area) and numbers infected with *O. turkestanicum*.

<table>
<thead>
<tr>
<th>Month</th>
<th>Seyed Nur</th>
<th>Seyed Majid</th>
<th>Seyed Janfar</th>
<th>Boneh Ayesh</th>
<th>Boneh Hajat</th>
<th>Boneh Jawaz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>1/152</td>
<td>1/ 74</td>
<td>0/ 88</td>
<td>1/ 78</td>
<td>0/ 92</td>
<td>1/491</td>
</tr>
<tr>
<td>Feb.</td>
<td>2/324</td>
<td>1/179</td>
<td>1/209</td>
<td>0/244</td>
<td>0/100</td>
<td>1/184</td>
</tr>
<tr>
<td>March</td>
<td>0/ 54</td>
<td>3/193</td>
<td>0/ 66</td>
<td>0/107</td>
<td>0/ 70</td>
<td>2/367</td>
</tr>
<tr>
<td>April</td>
<td>3/601</td>
<td>1/391</td>
<td>0/336</td>
<td>4/481</td>
<td>0/ 87</td>
<td>5/188</td>
</tr>
<tr>
<td>June</td>
<td>7/131</td>
<td>0/305</td>
<td>1/207</td>
<td>1/121</td>
<td>0/ 10</td>
<td>0/ 52</td>
</tr>
<tr>
<td>July</td>
<td>0/74</td>
<td>1/269</td>
<td>0/ 5</td>
<td>0/ 2</td>
<td>0/ 22</td>
<td>0/334</td>
</tr>
<tr>
<td>Aug.</td>
<td>0/230</td>
<td>4/259</td>
<td>0/ 10</td>
<td>0/ 4</td>
<td>1/ 39</td>
<td>0/ 53</td>
</tr>
<tr>
<td>Sept.</td>
<td>0/196</td>
<td>3/149</td>
<td>1/ 57</td>
<td>0/ 54</td>
<td>3/ 96</td>
<td>0/111</td>
</tr>
<tr>
<td>Oct.</td>
<td>0/231</td>
<td>2/ 68</td>
<td>1/ 59</td>
<td>1/ 59</td>
<td>1/298</td>
<td>0/ 32</td>
</tr>
<tr>
<td>Nov.</td>
<td>3/294</td>
<td>3/ 74</td>
<td>0/59</td>
<td>0/51</td>
<td>0/140</td>
<td>0/51</td>
</tr>
<tr>
<td>Dec.</td>
<td>0/138</td>
<td>3/ 49</td>
<td>0/ 75</td>
<td>0/ 68</td>
<td>0/ 80</td>
<td>0/ 37</td>
</tr>
</tbody>
</table>

Numerators - number of snails with *O. turkestanicum* infections.

Denominators - total number of snails collected.
Table 62

**O. turkestanicum** infection rate of *Lymnaea gedrosiana* in different habitats in Khuzestan.

1967

<table>
<thead>
<tr>
<th>Month</th>
<th>11 canals</th>
<th>3 swamps</th>
<th>2 drains</th>
<th>4 ponds</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Jan.</td>
<td>11/2084</td>
<td>0.5</td>
<td>1/598</td>
<td>0.1</td>
<td>0/56</td>
</tr>
<tr>
<td>Feb.</td>
<td>13/2171</td>
<td>0.6</td>
<td>1/543</td>
<td>0.1</td>
<td>0/760</td>
</tr>
<tr>
<td>March</td>
<td>5/1354</td>
<td>0.3</td>
<td>1/419</td>
<td>0.2</td>
<td>1/261</td>
</tr>
<tr>
<td>April</td>
<td>28/3209</td>
<td>0.8</td>
<td>1/742</td>
<td>0.1</td>
<td>1/388</td>
</tr>
<tr>
<td>May</td>
<td>18/3937</td>
<td>0.4</td>
<td>4/1322</td>
<td>0.3</td>
<td>1/1491</td>
</tr>
<tr>
<td>June</td>
<td>12/2093</td>
<td>0.5</td>
<td>3/219</td>
<td>1.3</td>
<td>0/475</td>
</tr>
<tr>
<td>July</td>
<td>11/643</td>
<td>1.7</td>
<td>1/148</td>
<td>0.6</td>
<td>0/201</td>
</tr>
<tr>
<td>Aug.</td>
<td>16/1553</td>
<td>1.0</td>
<td>1/69</td>
<td>1/5</td>
<td>3/561</td>
</tr>
<tr>
<td>Sept.</td>
<td>26/1631</td>
<td>1.5</td>
<td>0/109</td>
<td>0</td>
<td>2/636</td>
</tr>
<tr>
<td>Oct.</td>
<td>16/1559</td>
<td>1.0</td>
<td>2/195</td>
<td>1.0</td>
<td>0/322</td>
</tr>
<tr>
<td>Nov.</td>
<td>13/1395</td>
<td>0.9</td>
<td>1/182</td>
<td>0.5</td>
<td>0/169</td>
</tr>
<tr>
<td>Dec.</td>
<td>8/1164</td>
<td>0.7</td>
<td>0/261</td>
<td>0</td>
<td>0/47</td>
</tr>
</tbody>
</table>

**Numerator**—number of snails infected with *O. turkestanicum*.

**Denominator**—total number of snails collected.
Table 63

Size frequency of *L. edrosiana* and infection rate of *O. turkestanium* collected from 11 canals, 4 ponds, 3 swamps and 2 drains in Khuzestan.

<table>
<thead>
<tr>
<th>Size Distribution of Snails (mm.)</th>
<th>0 - 6</th>
<th>6 - 10</th>
<th>10 - 14</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of snails collected</td>
<td>18858</td>
<td>14660</td>
<td>10799</td>
<td>44317</td>
</tr>
<tr>
<td>No. of snails infected</td>
<td>26</td>
<td>74</td>
<td>125</td>
<td>225</td>
</tr>
<tr>
<td>Rate of infection %</td>
<td>0.14</td>
<td>0.5</td>
<td>1.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Table 64

Infection rates of *L. edrosiana* with *O. turkestanicum* cercariae in different type of habitats in Study Area.

<table>
<thead>
<tr>
<th></th>
<th>Canals</th>
<th>Swamps</th>
<th>Ponds</th>
<th>Drains</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of snails collected</td>
<td>25718</td>
<td>4687</td>
<td>8690</td>
<td>5224</td>
</tr>
<tr>
<td>No. of snails infected</td>
<td>177</td>
<td>18</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>Rate of infection</td>
<td>0.68%</td>
<td>0.38%</td>
<td>0.25%</td>
<td>0.15%</td>
</tr>
</tbody>
</table>
### Table 65

Infection rates of *L. sedrosiana* with *O. turkestanicum* corcario in canals in different parts of Study Area.

<table>
<thead>
<tr>
<th></th>
<th>New Irrigation Area</th>
<th>Abjirob Area</th>
<th>Lureh Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of snails collected</strong></td>
<td>5718</td>
<td>13992</td>
<td>6008</td>
</tr>
<tr>
<td><strong>No. of snails infected</strong></td>
<td>38</td>
<td>76</td>
<td>63</td>
</tr>
<tr>
<td><strong>Rate of infection</strong></td>
<td>0.66 %</td>
<td>0.54 %</td>
<td>1.0 %</td>
</tr>
</tbody>
</table>
Fig. 2
Numbers of *Lymanee缎esiana* collected monthly under uniform conditions in observation area (4 ponds) and numbers infected with *Ornithobilharzia turkestanicum* and fluctuations of water level.
Fig. 3

Numbers of *Lymnaea edrosiana* collected monthly under uniform conditions in observation area (3 swamps) and numbers infected with *Omnithobilharzia turkestanicum* and fluctuations of water level.
Fig. 4

Numbers of *Lymnaea adrosiana* collected monthly under uniform condition in observation area (2 drains) and numbers infected with *Opisthobilharzia turkestanica* and fluctuations of water level.
Fig. 5
Numbers of *Lymnaea pedrosiana* collected monthly under uniform conditions in observation area (11 canals) and numbers infected with *Ornithobilharzia turkestanica* and fluctuations of water level.
Infection rate of *L. sedrosiana* with *O. turkestanicum* in different type of habitats (canal, swamp, pond) in Khuzestan.
CHAPTER 4

DETAILED STUDIES ON THE POPULATION DYNAMICS
OF L.GEDROSIANA IN SELECTED HABITATS.

METHODS,

Eight different types of habitats (2 canals, 2 swamps and 4 ponds) were selected for observation of the population dynamics of L.gedrosiana. The above habitats were highly populated with snails and for convenience in each habitats only 10 dip-nets were used on each occasion once fortnightly from October 1969 to September 1970.

The size of each snail was determined and allocated to one of the following groups: 0-4 mm, 4-6 mm, 6-8 mm, 8-10 mm, 10-12 mm, 12-14 mm, and over 14 mm.

The number of eggmasses was counted at each visit and all the snails were returned to their respective sites within 24 hours, to

/avoid...
avoid any disturbance of snail densities due to survey collections. Water level index, water temperature and other ecological information of the habitats was recorded occasionally.

RESULTS,

A. Snail density fluctuation in various habitats,

Habitat, 1. Balengun Pond,

This shallow pond was connected to an irrigation canal with moderate vegetation. The data from fortnightly observations are shown in Table, 66 and Fig. 7. Egg masses were collected from September to November and April to August (Table, 67). Snail densities were high from October to January.

Habitat, 2. Sardarabad Pond,

This pond also was connected to a canal and shaded with trees and was all the time exchanging water with the adjoining canal. / The data....
The data from fortnightly observations are given in Table, 66 and Fig. 8. The reproduction of *L. gedrosiana* stopped only in the winter season (Table, 67). The peak of snail densities were observed in August and September.

**Habitat, 3. Nahr-Khan Pond,**

This was a pond with heavy vegetation and was elongated in shape and had a more constant water level. The data from fortnightly collection are given in Table, 66 and Fig, 9. The eggmasses were abundant from October to December 1969 and from June to September 1970. The first peak of snail densities occurred from October to December and a second peak from April to July.

**Habitat, 4. Shams-abad Pond,**

This was a smaller pond permanently fed from the Market-gardening excess water, with dense vegetation. The data from fortnightly observations are given in Table, 66 and Fig. 10. indicating that
major peaks of snail densities and egg production were in autumn and spring.

Habitat 5. Ghaleh Sheikh Swamp,

This swamp was irregular with dense vegetation and a high water fluctuation rate, water some from a nearby garden. The data given in Table, 66 and Fig. 11 indicate that the first peak of snail densities was in October and November, the second peak occurred in June and July.

Habitat 6. Ghaleh Seyed Swamp,

This was a very large and rich swamp, suitable for snail colonies throughout the year. Vegetation particularly *Typha* was abundant. The data collected from fortnightly observations from October 1969 to September 1970 are given in Table, 66 and Fig. 12. The *L. pseudosiana* population and egg production showed 2 major peaks...
one in autumn with a sharp decline in winter, the second peak was
from May to August 1970.

Habitat, 7. Chagha Saba Canal,

This was newly built secondary irrigation canal in the
Pilot Irrigation Area, with high submerged vegetation and slow water
flow. The data collected fortnightly are shown in Table 66 and
Fig. 13. The snail densities and egg production first peak was in
autumn and the second peak was from May to July with a sharp decline
in winter.

Habitat, 8. Main Canal No. 80,

This canal was a large and main new irrigation system with
large amounts of water and high submerged vegetation. The velocity
of water flow was high in middle part of the canal but low at the
bank, with many cement barriers for water diversion to the secondary
canals. The main peak of L. sedrosiana densities and egg production
was from October to December 1969, declined in winter with second minor
peak from April to June 1970 (Tables 66, 67 and Fig. 14).
B. Reproduction Rate of *L. gedrosiana*.

In appearance the eggmasses of the *L. gedrosiana* were elongated and their length varied from 5-15 mm. Eggmasses were transparent and contained some 7-108 egg sacs with an average of 60 egg sacs in 112 eggmasses collected in a snail habitat in April.

The number of eggs collected in a series of samples on any day represents the eggs laid by the adult snails present in the same samples. Table 68 shows the reproduction rates of *L. gedrosiana* obtained by estimating the egg production per adult snail per day during successive time-intervals calculating by dividing the number of eggs collected from each sampling by the number of adult snails over 6 mm length. It was clear that the reproduction capacity of *L. gedrosiana* was highest in running water systems, possibly due to high aeration. The peak reproduction rate was observed in autumn and spring in all habitats and it was nil in the winter season in swamps and ponds, though some fresh eggmasses were obtained from the / canal ....
canal No. 80. In summer egg laying activity continued but at lower 
level, whereas the snail densities did not decline very much in 
summer compared with the marked decrease in winter (Tables, 66 and 67).

C. Size distribution of snail populations,

The size-frequency (Tables, 69 and 70) show that most of 
the snails in different habitats were young snails less than 6-8 mm. 
L. gadrosiana is very sensitive to environmental changes and their 
tolerance to drought is very poor compared with other snails (see 
Chu et al, 1967). Because of this sensitivity and short life-span 
of L. gadrosiana it was difficult to draw a synchronized growth rate 
curve for this snail as has been done for Bulinid and Biomphalaria 
snails.
Table, 66

Number of *L. gedrosiana* collected fortnightly from 2 canals,
2 swamps, 4 ponds in Khuzestan for 12 months.

<table>
<thead>
<tr>
<th>Months</th>
<th>No.80 canal</th>
<th>Chagha Sabz Swamp</th>
<th>Q. Seyed Swamp</th>
<th>Shams-abad Pond</th>
<th>Nahr-Khanabad Pond</th>
<th>Sardar-abad Pond</th>
<th>Jalengan Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct.</td>
<td>352</td>
<td>209</td>
<td>3641</td>
<td>409</td>
<td>469</td>
<td>480</td>
<td>563</td>
</tr>
<tr>
<td></td>
<td>1732</td>
<td>757</td>
<td>1707</td>
<td>260</td>
<td>312</td>
<td>391</td>
<td>699</td>
</tr>
<tr>
<td>Nov.</td>
<td>1100</td>
<td>1730</td>
<td>1494</td>
<td>469</td>
<td>426</td>
<td>368</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>323</td>
<td>-</td>
<td>786</td>
<td>70</td>
<td>533</td>
<td>416</td>
<td>-</td>
</tr>
<tr>
<td>Dec.</td>
<td>422</td>
<td>-</td>
<td>1311</td>
<td>89</td>
<td>230</td>
<td>280</td>
<td>302</td>
</tr>
<tr>
<td></td>
<td>398</td>
<td>272</td>
<td>978</td>
<td>212</td>
<td>535</td>
<td>159</td>
<td>271</td>
</tr>
<tr>
<td>Jan.</td>
<td>45</td>
<td>128</td>
<td>589</td>
<td>126</td>
<td>32</td>
<td>210</td>
<td>196</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>52</td>
<td>393</td>
<td>95</td>
<td>3</td>
<td>104</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>84</td>
<td>123</td>
<td>109</td>
<td>3</td>
<td>32</td>
<td>37</td>
</tr>
<tr>
<td>Feb.</td>
<td>47</td>
<td>1</td>
<td>58</td>
<td>20</td>
<td>0</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2</td>
<td>38</td>
<td>130</td>
<td>0</td>
<td>34</td>
<td>40</td>
</tr>
<tr>
<td>March</td>
<td>33</td>
<td>14</td>
<td>35</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>43</td>
</tr>
<tr>
<td>April</td>
<td>83</td>
<td>13</td>
<td>22</td>
<td>46</td>
<td>200</td>
<td>16</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>50</td>
<td>375</td>
<td>96</td>
<td>444</td>
<td>68</td>
<td>191</td>
</tr>
<tr>
<td>May</td>
<td>91</td>
<td>504</td>
<td>711</td>
<td>121</td>
<td>237</td>
<td>102</td>
<td>407</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>236</td>
<td>619</td>
<td>139</td>
<td>303</td>
<td>58</td>
<td>540</td>
</tr>
<tr>
<td>June</td>
<td>35</td>
<td>127</td>
<td>826</td>
<td>57</td>
<td>156</td>
<td>162</td>
<td>431</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>489</td>
<td>588</td>
<td>547</td>
<td>231</td>
<td>133</td>
<td>482</td>
</tr>
<tr>
<td>July</td>
<td>10</td>
<td>365</td>
<td>605</td>
<td>879</td>
<td>225</td>
<td>104</td>
<td>676</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>214</td>
<td>800</td>
<td>125</td>
<td>222</td>
<td>51</td>
<td>365</td>
</tr>
<tr>
<td>Aug.</td>
<td>17</td>
<td>112</td>
<td>639</td>
<td>14</td>
<td>233</td>
<td>39</td>
<td>396</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>148</td>
<td>567</td>
<td>14</td>
<td>123</td>
<td>117</td>
<td>610</td>
</tr>
<tr>
<td>Sept.</td>
<td>45</td>
<td>76</td>
<td>310</td>
<td>5</td>
<td>132</td>
<td>117</td>
<td>608</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>76</td>
<td>140</td>
<td>6</td>
<td>41</td>
<td>82</td>
<td>600</td>
</tr>
</tbody>
</table>
Table, 67

Numbers of *L. gedrosiana* egg masses collected fortnightly from 2 canals, 2 swamps and 4 ponds in Khuzestan for 12 months

(10 deep nets)

<table>
<thead>
<tr>
<th>Months</th>
<th>No.30 canal</th>
<th>Chagha canal</th>
<th>Seyed canal</th>
<th>Swamp</th>
<th>Shams-abad Pond</th>
<th>Nahr-Khan Pond</th>
<th>Sardar-abad Pond</th>
<th>Balengun Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct.</td>
<td>37</td>
<td>68</td>
<td>51</td>
<td>18</td>
<td>55</td>
<td>131</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>30</td>
<td>23</td>
<td>10</td>
<td>23</td>
<td>89</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Nov.</td>
<td>8</td>
<td>20</td>
<td>22</td>
<td>21</td>
<td>22</td>
<td>28</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>0</td>
<td>25</td>
<td>3</td>
<td>53</td>
<td>14</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Dec.</td>
<td>14</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>20</td>
<td>8</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Jan.</td>
<td>7</td>
<td>36</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Feb.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>29</td>
<td>0</td>
<td>17</td>
<td>2</td>
<td>23</td>
<td>5</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0</td>
<td>49</td>
<td>6</td>
<td>11</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>May</td>
<td>15</td>
<td>6</td>
<td>23</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>15</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>24</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>July</td>
<td>0</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>7</td>
<td>12</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>16</td>
<td>9</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Aug.</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>14</td>
<td>4</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Sept.</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 68
Reproductive rates (eggs per adult snail per day) of *L. gedrosiana* in different habitats at fortnightly intervals from Oct. 1969 to Sept. 1970.

<table>
<thead>
<tr>
<th>Month</th>
<th>interval (weeks)</th>
<th>Canals</th>
<th>Swamps</th>
<th>Ponds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okt.</td>
<td>2</td>
<td>18.0</td>
<td>3.0</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>16.8</td>
<td>3.0</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>30.0</td>
<td>5.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Nov.</td>
<td>8</td>
<td>49.2</td>
<td>11.4</td>
<td>9.0</td>
</tr>
<tr>
<td>Dec.</td>
<td>10</td>
<td>33.6</td>
<td>1.8</td>
<td>20.4</td>
</tr>
<tr>
<td>Dec.</td>
<td>12</td>
<td>31.8</td>
<td>0.4</td>
<td>10.8</td>
</tr>
<tr>
<td>Jan.</td>
<td>14</td>
<td>60.0</td>
<td>0</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>180.0</td>
<td>0</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>5.4</td>
</tr>
<tr>
<td>Feb.</td>
<td>20</td>
<td>16.2</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>25.2</td>
<td>4.8</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>24</td>
<td>5.4</td>
<td>6.6</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>262</td>
<td>108.6</td>
<td>87.6</td>
<td>52.8</td>
</tr>
<tr>
<td>April</td>
<td>28</td>
<td>450.0</td>
<td>60.0</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>10.2</td>
<td>2.4</td>
<td>9.0</td>
</tr>
<tr>
<td>May</td>
<td>32</td>
<td>16.2</td>
<td>0.3</td>
<td>3.6</td>
</tr>
<tr>
<td>June</td>
<td>34</td>
<td>12.6</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>18.0</td>
<td>4.2</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>15.0</td>
<td>4.8</td>
<td>3.0</td>
</tr>
<tr>
<td>July</td>
<td>40</td>
<td>5.4</td>
<td>4.2</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>6.0</td>
<td>1.8</td>
<td>5.4</td>
</tr>
<tr>
<td>Aug.</td>
<td>44</td>
<td>30.0</td>
<td>0.6</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>4.2</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Sept.</td>
<td>48</td>
<td>7.8</td>
<td>0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Table: 69

Observations on the reproductive capacity of *L. gedrosiana* in different habitats.

<table>
<thead>
<tr>
<th>Name</th>
<th>Type of habitats</th>
<th>Total no. of mature snails over 6 mm.</th>
<th>Total no. of eggmasses</th>
<th>No. of eggmasses per snail</th>
<th>No. of eggs per snail</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 80</td>
<td>Canal</td>
<td>677</td>
<td>213</td>
<td>0.3</td>
<td>18</td>
</tr>
<tr>
<td>Chagha Sabz</td>
<td>Canal</td>
<td>562</td>
<td>223</td>
<td>0.4</td>
<td>24</td>
</tr>
<tr>
<td>Ghaleh Seyed</td>
<td>Swamp</td>
<td>9375</td>
<td>271</td>
<td>0.02</td>
<td>1.2</td>
</tr>
<tr>
<td>Ghaleh Sheikh</td>
<td>Swamp</td>
<td>1320</td>
<td>85</td>
<td>0.06</td>
<td>3.6</td>
</tr>
<tr>
<td>Shams-abad</td>
<td>Pond</td>
<td>2626</td>
<td>298</td>
<td>0.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Sardar-abad</td>
<td>Pond</td>
<td>2748</td>
<td>334</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>Nar-Khan</td>
<td>Pond</td>
<td>932</td>
<td>135</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>Balengun</td>
<td>Pond</td>
<td>242</td>
<td>25</td>
<td>0.1</td>
<td>6</td>
</tr>
</tbody>
</table>

Mean number of eggs in one eggmass is 60.
Table 70

Size-Frequency of *A. gedrosiana* collected fortnightly from the snail habitats during the period of 12 months.

<table>
<thead>
<tr>
<th>Type of habitat</th>
<th>Size-Frequency of collected snails (mm.) shown:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-4</td>
</tr>
<tr>
<td>Canal No. 80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2944</td>
</tr>
<tr>
<td>Cal al Chagha sabz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3673</td>
</tr>
<tr>
<td>Swamp Ghaleh Seyed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6217</td>
</tr>
<tr>
<td>Swamp Ghaleh sheikh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1558</td>
</tr>
<tr>
<td>Pond Shams abad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1911</td>
</tr>
<tr>
<td>Pond Sardar abad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2923</td>
</tr>
<tr>
<td>Pond Nahr-Khan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1461</td>
</tr>
<tr>
<td>Pond Balengun</td>
<td></td>
</tr>
<tr>
<td></td>
<td>424</td>
</tr>
</tbody>
</table>
Fig. 7

Fortnightly densities of *Lymanea edroiana* adults, eggs, water temperature and fluctuations of water level in a Balengun Swamp.
Fig. 8
Fortnightly densities of *Lymnaea sedrosiana*, adults and eggs, fluctuation of water level and water temperature in a Sardar Abad pond.
Fig. 9. Portulacaria densis of *Lymnaea caroliniana*, adults, eggs, water temperature and fluctuations of water level in a Hair-Than pond.
Fig. 10

Fortnightly densities of *Lymnaea edosiana*, adults, eggs, water temperature and fluctuations of water level in a Shams-Abad pond.
Fig. 11
Fortnightly densities of *Lymnaea sedrosiana* adults, eggs, water temperature and fluctuations of water level in a Shaleh Sheikh Swamp.
Fig. 12

Fortnightly densities of *Lymnaea edrosiana* adults, eggs, water temperature and fluctuation of water level in a Ghaleh Seyed Swamp.
Fig. 14

Fortnightly densities of *Lymnae acerosiana* adults, eggs, water temperature and fluctuations of water level in a new irrigation system canal no. 30.
Fortnightly densities of *Lymnaea sedrosiana* adults, eggs, water temperature and fluctuations of water level in a new irrigation system canal No. 40.
DISCUSSION,

Seasonal Fluctuation in Population Dynamics,

*L. gedrosiana* was found only in permanent water bodies. According to Gaud *et al.* (1962) drought and flooding are the two main factors limiting snail populations in Khuzestan. The size of a snail population is controlled by the physical, chemical and biological factors in the habitat, especially temperature and competition with the other species of snails as well as the activities of natural predators. It has been noticed many times in Khuzestan that following mollusciciding that when snails have reappeared the population has built-up very rapidly and after some while the snail densities have reached a peak, the controlling factors having produced a natural balance again.

/ Effect of.....
Effect of Drought,

Drought may occur in every season in Khuzestan but the summer drought is very severe and most of the *L. gedrosiana* population in dry habitats are eliminated. Previous studies concerning the adaptation of *B. truncatus*, *B. alexandrina* and *L. gedrosiana* to drought in the laboratory have been presented by Chu, Massoud and Arfaa (1967). We found that *B. truncatus* was able to burrow into mud in response to the disappearance of water, while *L. gedrosiana* was unable to do so and had only a slight tolerance for dessication, because of the wider aperture of its shell and inability of withdrawing the body far into shell. Cawston (1929) in South Africa also concluded that *Lymnaea natalensis* was less able than allied species to survive in drying conditions. McCullough (1965) observed that *L. natalensis* the intermediate host of *Fasciola gigantica* in Ghana shows the least resistance to drought of all the local species of fresh water gastropods. Other factors, such as a wider range of distribution in water bodies and a high rate of reproduction,
ensure that this species outnumbers *B. truncatus* in most of the snail habitats of Khuzestan. Only in habitats where drought is frequent and prolonged are larger *B. truncatus* population found.

**Effect of Rainfall.**

Rainfall has a significant effect on the ecological changes of the habitats and provides suitable condition for snail breeding. As shown in Fig. 1, the rainfall from October to December 1969 in the study area was high and the *L. gedrosiana* population densities were also high, but in the following months in 1970 there was low rainfall and the snail densities decreased in all habitats in the area from February to September 1970. Mosley (1939) working in Tansania recorded that *B. (p). globosus* breed rapidly during and after the rainfall. Webbe (1962) showed that major seasonal fluctuation in *B. (p). nasutus productus* density in Tanganika mainly depends upon rainfall, temperature and the ecological changes brought about by them.

/ Effect of temperature.
Effect of Temperature,

In the present observations it appears that temperature has some influence on the population dynamics of *L. gedrosiana*. The low water temperature (14°C - 15°C) in winter stopped egg production and the population density declined to the minimum level; high temperatures above 30°C in July and August also decreased the egg production and snail densities in shallow ponds.

The snail population densities varied in different types of habitats. In standing waters, the peaks of snail populations occur in 2 periods one from May to July and the other from October to December. In flowing waters, snail colonies were collected mostly in autumn and spring and to some extents in summer when the water temperature is suitable for snail breeding. The winter was the most unfavourable season for *L. gedrosiana* breeding in the different types of habitats, when snail densities fell to a very low level in cold temperatures. Our previous observations (Chu, Massoud & Arfaa, 1968) on the *B. truncatus* population curve in the same area showed / that the....
that the yearly peak of *B. truncatus* population may occur twice or only once a year.

**Transmission Potential of Different Type of Habitats,**

The present results suggest that in Khuzestan, canals are permanent transmission sites of *O. turkestanicum* throughout the year, ponds play a rather minor role in transmission, but swamps also are important sites and transmission can occur in late spring, summer and autumn. Drains in general are unlikely to be of importance as transmission sites for *O. turkestanicum*. Chu, Massoud & Arfaa (1969) reported the importance of canals and ponds as the main transmission sites of *S. haematobium* in the same area of Khuzestan.

The prevalence of infection in large snails was much higher than in those of smaller size. *L. edrosiana* serves as the molluscan intermediate host for *O. turkestanicum*, *Fasciola gigantica* and other unknown flukes in the Khuzestan area, but there was no evidence of mixed cercarial infection.

/In our...
In our previous observations (Chu et al., 1968) we showed that the optimum transmission seasons of *S. haematobium* and *S. bovis* were mainly spring and autumn. In the present observations we concluded that transmission of *O. turkestanicum* in Khuzestan was likely throughout the year particularly from June to November, when there are more infected snails and more animals in contact with infected water. The differences in transmission of *O. turkestanicum* compared with *S. haematobium* and *S. bovis* were mostly due to different patterns of distribution and dynamics of the molluscan intermediate hosts.

**Implication for the Planning of Control Campaigns,**

A sound knowledge of the bionomics of *L. gedrosiana* is essential for the precise understanding of the epidemiology and control of *O. turkestanicum* and Fasciolasis. In particular, if snail control measures are to be undertaken, the seasonal population fluctuations must be understood. Our observations show that the population densities increase in autumn and spring and decline towards cold winter months. The observations suggest that the application...
of molluscicides would be most effective if first applied in April to June and repeated at the early autumn (October to December).

The control measures against *L. gedrosiana* are rather different from the campaign against *B. truncatus* in Khuzestan, because *B. truncatus* has a patchy and discontinuous pattern of distribution, while *L. gedrosiana* has a permanent and continuous type of distribution. Mollusciciding which seems to be the only feasible way of control measures against this snail host should be applied in each water body in the area. Focal application has no value, because as was observed in mollusciciding against *B. truncatus* in Khuzestan (Massoud et al., 1969) the *L. gedrosiana* population is re-established in treated habitats in a very short period due to rapid introduction of the snails from up-stream.
CHAPTER 6

LABORATORY STUDIES ON THE HOST-PARASITE RELATIONSHIP: THE EFFECTS OF VARIATIONS IN MIRACIDIAL EXPOSURE DOSAGE

INTRODUCTION,

At present our knowledge concerning the host-parasite relationship of *L. gedrosiana* and *Q. turkestani*cum is very meagre. Because this knowledge may be necessary for effective control measures, experimental studies on various aspects of the problem are of importance. The effect of the exposure dosage of miracidia on the biology of the snail host and on the subsequent development of the larval stages of the parasite is interesting problem involving the host-parasite relationship of *L. gedrosiana* and *Q. turkestani*cum. The similar topic of study made by Pesigan et al (1958) on *S. japonicum*, Najarian (1961), and Chu, Massoud and Sabbaghian (1966) on Bulinus truncatus and *S. haematobium*.

/ The present....
The present study describes some research on the host parasite relationship and larval development of *O. turkestanicum* in *L. gedrosiana* under laboratory condition.

**MATERIAL AND METHODS,**

Laboratory bred *L. gedrosiana* 5-7 mm long were used. The snails were divided into six groups, each group consisting of 35 to 50 snails. Snails in group I were used as non-infected controls.

Each individual snails in group II to VI was exposed to 1, 2, 5, 10 and 20 miracidia respectively. The miracidia were counted carefully under a dissecting microscope and transferred with a fine pipette to a watch glass. One snail was added to each glass and left there for at least 4 hours, after which the snails in each group were maintained in separate plastic tanks at 25° C - 27° C.

The mortality of snails was recorded every day and from day 15 after exposure snails were examined for cercaria-shedding in separate.....
separate test-tubes. The snails in each group were examined every other day for cercariae shedding after 3 hours exposure to light in a 50 mL beaker. After 3 hours the snails removed from beaker and the number of cercariae were counted with the ninhydrin staining technique (Mc Clelland, 1961). The total number of cercariae divided by the number of snails in each group gave the average number of cercariae shed per snail per day. The cercarial counting was continued during the whole cercarial shedding period which was usually the life-span of the infected snails.

RESULTS,

Prepatent periods (Table, 71),

On day 17 after exposure 4 snails in group III and 3 snails from group VI were found to be shedding cercariae. The last snail from group IV started to shed cercariae on the 24th day after exposure. All the negative snails at 30 days after exposure were crushed between /two slides...
two slides and searched for cercariae under a dissecting microscope; they were all uninfected. The average length of the cercarial prepatent period from the snails in groups II-VI was 21, 18, 20, 21, and 18 days respectively. Thus, was observed no marked differences between the different groups.

Infection rates (Table 72)

The infection rates of snails in groups II-VI were 54.5 %, 57.1 %, 62.5 %, 84.0 % and 100 % respectively. This result indicates that the infection rate increased with the exposure dosage of miracidia.

Number of cercariae shed by the infected snails (Table 73)

The mean daily number of cercariae shed by the snail from groups II-VI during their entire infection life-span was: 62; 225; 799; 172 and 565 respectively. Thus the snails in group II exposed
to one miracidium and group III exposed to 2 miracidia shed fewer
cercariae than those in the other groups. The difference between
the number of cercariae shed in group II=III and the other groups was
statistically significant ( P<0.02 and P<0.05 ).

Cercaria-shedding curve,

Beginning from the day of the first shedding of the cercariae,
the average number of cercariae shed per snail per day was at first
low, it then gradually increased. In group II and III the peak of
cercaria-shedding was reached at 25 days after the first shedding,
then the snails died; in group IV the peak was at about 27 days after
first shedding remaining high until the snails died; in group V the
peak was recorded at about 22 days; in group VI peak was at 32-34 days
after the first shedding.

Survival rates of the exposed snails. (Table, 74)

At the time of exposure to miracidia there were 50 snails
in group II, 40 snails in groups III, IV, VI and 35 snails in groups
I and V...
I and V. At the end of the shortest cercarial prepatent period (17 days) the number of the surviving snails in the control group was 35, and the number of surviving snails in groups II, III, IV, V and VI were 44, 35, 24, 25 and 12 respectively. The survival rates of snails in group IV, V and VI which were exposed to the larger numbers of miracidia were thus considerably lower than the other groups.

The mean survival periods of the cercaria-shedding snails were 39, 45, 36, 40 and 34 days from the time of exposure to miracidia for groups II to VI respectively, and the maximum survival periods were 50, 45, 60, 40 and 55 days after exposure respectively. Comparison with the maximum survival period of non-infected control group I, where 28 live snails out of 35 with 80% survival rate in 60 days observation period showed that the differences between the mean life-span of the infected snails and non-infected snails in the control group were statistically highly significant (P 0.001).

/ Discussion....
DISCUSSION,

Cerearial output rates,

Cerearial output varied greatly, both from snail to snail and from day to day. In general, few cerearias were produced at the beginning of the shedding period, then the number increased over a period of days or weeks until it reaches a more or less constant level, which was maintained until a few days before the termination of shedding by death or self-cure.

Some snail species produced only small numbers of cerearias and remain infected for a short period. For example cerealial output figures for *B. haematobium* are reported to be low up to 1500 from a single *B. (p). africans* (Porter 1920) and 50-400 from *B. (p). globosus* (Gordon et al 1934) and up to 790 from *B. truncatus* (Chu et al 1966) whereas with *S. mansonii* in *B. glabrata* as many as 1000 to 5000 cerearias per snail per day is not unusual and individual snail may shed for many weeks. *L. pedrosiana* with cerearias production of only 62 to

/799...
799 maximum in 4-5 weeks is therefore a poor shedder.

The daily pattern of output of the cercariae shedding corresponds with the temperature and intensity of illumination, particularly with animal schistosome cercariae which are more susceptible to temperature and light. Thus, *S. bovis* and *O. turkestanicum* cercariae are very susceptible to sunlight and cercaria-shedding usually takes place in the morning, particularly in the case of *O. turkestanicum*.

With regard to the effect of the exposure dosage of miracidia on the number of cercariae shed by the infected snails, Pesigan *et al.* (1958) reported that *Oncomelania quadrasi* exposed to one miracidium of *S. japonicum* shed twice as many cercariae per day as the snails exposed to 2-5 miracidia. Conversely Chu *et al.* (1966 a) found *B. truncatus* exposed to 2 or more miracidia of *S. haematobium* shed more cercariae than those snails exposed to one miracidium.
Our present studies coincide with those of Chu et al. (1966 a).

L. gedrosiana infected with one or two miracidia shed markedly less cercariae than those snails infected with 5 to 20 miracidia each.

**Cercarial prepatent periods.**

Chu et al. (1966 a) found that the cercarial prepatent periods in *B. truncatus* exposed to various numbers of miracidia of *S. haematobium* were inversely proportional to the exposure dosage.

Conversely Pesigan et al. (1958) studied the prepatent period of *S. japonicum* in *O. quadraspi* and found that there was no difference in the length of the cercariae-prepatent period between the snails exposed to one miracidium and those to 2-5 miracidia. The results of our studies on the cercarial-prepatent period in *L. gedrosiana* exposed to various numbers of miracidia of *O. turkestanicum* were at variance in this respect with those obtained by Chu et al. (1966 a) and coincide those obtained by Pesigan et al. (1958). The mean prepatent period in *L. gedrosiana* in our experiments was 18-21 days in different groups at water temperature of 25°C., but Azimov et al. /1968.....
(1968) reported that development of *O. turkestanicum* cercariae in *Radix auricularia obliquata* took 22-25 days in Uzbekistan (SSR).

**Infection rate,**

Investigating the infection rate of snails to miracidia, Shreibar and Shubert (1949 b) found an increasing percentage of snails shedding cercariae as a result of exposure to increasing numbers of miracidia. Similarly Etges (1963) found that *B. glabrata* was 100% susceptible to *S. mansoni* infection if snails were exposed to a sufficiently large number of miracidia and the failure to achieve 100% infection of the snails is attributable to deficient infectivity of the miracidia rather than to innate resistance of the snails.

Chu et al. (1966 a) achieved 100% infection rates in *B. truncatus* exposed to 20 miracidia of *B. baematobium*. Similarly we obtained a 100% infection rate in *L. medoziana* with 20 miracidia of *O. turkestanicum*.

/ Lengy...
Lengy (1962 a) found that summer-winter variations in temperature have little effect on the success of infection and that *B. truncatus* become infected with *S. bovis* miracidia equally well at 14°C. and 30°C. However, Chu et al (1966 b) found that the infection rate of *B. truncatus* exposed to *S. haemaphysium* miracidia at temperature of 10°C.-20°C. was low, although the longevity of miracidia in cold water was increased. In the present study we found *L. gedrosiana* infected with *O. turkestanicum* in field conditions all around the year which average water temperature varied from 14°C. in winter to 30°C. or more in summer. From our studies on the life-span of *L. gedrosiana* infected in the laboratory which show a maximum of 65 days after exposure to miracidia it seems unlikely that under natural condition snails infected during the summer would survive into the winter period.

**Snail mortality rates.**

Snail mortality subsequent to infection was high, all the snails in different groups were dead 65 days after exposure to /miracidia...
miracidia. Similarly Lengy (1962 a) observed high mortality rates (50 %) in B. truncatus infected with S. bovis over a period of 2 months. After 2 months the infections in the surviving snails had died out and the snails ceased shedding cercariae. In our experiments infected L. gedrosiana always died and no self-cures were ever observed.
Table 71

Effect of dosage of miracidia on the cercarial-insemination period of *O. turkestanicum* in *L. gedrosiana*.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of miracidia used to infect each snail</th>
<th>Total number of cercariae-shedding snails</th>
<th>Number of snails shedding cercariae for the first time on the following days after exposure</th>
<th>Length of cercarial-insemination period in days (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>1</td>
<td>24</td>
<td>0 0 0 0 15 4 0 5 0</td>
<td>20-23(21)</td>
</tr>
<tr>
<td>III</td>
<td>2</td>
<td>20</td>
<td>4 10 0 6 0 0 0 0 0</td>
<td>17-20(18)</td>
</tr>
<tr>
<td>IV</td>
<td>5</td>
<td>15</td>
<td>0 0 0 5 10 0 0 0 0</td>
<td>20-21(20)</td>
</tr>
<tr>
<td>V</td>
<td>10</td>
<td>21</td>
<td>0 0 4 7 5 0 0 0 5</td>
<td>19-24(21)</td>
</tr>
<tr>
<td>VI</td>
<td>20</td>
<td>12</td>
<td>3 7 2 0 0 0 0 0 0</td>
<td>17-19(18)</td>
</tr>
<tr>
<td>Group</td>
<td>Number of miracidia used to infect each snail</td>
<td>Number of snails exposed to infection</td>
<td>Number of snails surviving at the time of first shedding of cercariae</td>
<td>Number of surviving snails cercaria-positive</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>50</td>
<td>44</td>
<td>24</td>
</tr>
<tr>
<td>III</td>
<td>2</td>
<td>40</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>IV</td>
<td>5</td>
<td>40</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>V</td>
<td>10</td>
<td>35</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>VI</td>
<td>20</td>
<td>40</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
Table, 73

Cercarial production of *L. gedrosiame*, infected with different number of *O. turkestanum* miracidium in the laboratory at temperature 25°C - 27°C.

<table>
<thead>
<tr>
<th>Number of days' after first shedding of cercariae</th>
<th>Group II (1 miracidium)</th>
<th>Group III (2 miracidium)</th>
<th>Group IV (5 miracidium)</th>
<th>Group V (10 miracidium)</th>
<th>Group VI (20 miracidium)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of cercariae per snail (mean)</td>
<td>No. of cercariae per snail (mean)</td>
<td>No. of cercariae per snail (mean)</td>
<td>No. of cercariae per snail (mean)</td>
<td>No. of cercariae per snail (mean)</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>17</td>
<td>7</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>16</td>
<td>25</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>16</td>
<td>282</td>
<td>3</td>
<td>430</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>16</td>
<td>155</td>
<td>3</td>
<td>200</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>16</td>
<td>218</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>13</td>
<td>15</td>
<td>16</td>
<td>100</td>
<td>1</td>
<td>198</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>17</td>
<td>140</td>
<td>1</td>
<td>196</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>14</td>
<td>136</td>
<td>1</td>
<td>126</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>12</td>
<td>693</td>
<td>1</td>
<td>1740</td>
</tr>
<tr>
<td>22</td>
<td>5</td>
<td>10</td>
<td>123</td>
<td>1</td>
<td>998</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>8</td>
<td>560</td>
<td>1</td>
<td>2460</td>
</tr>
<tr>
<td>Mean</td>
<td>62</td>
<td>223</td>
<td>799</td>
<td>180</td>
<td>565</td>
</tr>
<tr>
<td>Time since exposure (day)</td>
<td>Surviving snails group I (non-infected)</td>
<td>Surviving snails group II 1 miracidium</td>
<td>Surviving snails group III 2 miracidia</td>
<td>Surviving snails group IV 15 miracidia</td>
<td>Surviving snails group V 10 miracidia</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------</td>
<td>---------------------------------------</td>
<td>---------------------------------------</td>
<td>---------------------------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>No.</strong></td>
<td>%</td>
<td><strong>No.</strong></td>
<td>%</td>
<td><strong>No.</strong></td>
</tr>
<tr>
<td>12</td>
<td>35a</td>
<td>100.0</td>
<td>18a</td>
<td>100.0</td>
<td>17a</td>
</tr>
<tr>
<td>25</td>
<td>35</td>
<td>100.0</td>
<td>18</td>
<td>100.0</td>
<td>16</td>
</tr>
<tr>
<td>30</td>
<td>35</td>
<td>100.0</td>
<td>16</td>
<td>88.8</td>
<td>16</td>
</tr>
<tr>
<td>35</td>
<td>35</td>
<td>100.0</td>
<td>15</td>
<td>83.3</td>
<td>14</td>
</tr>
<tr>
<td>40</td>
<td>33</td>
<td>94.2</td>
<td>10</td>
<td>55.5</td>
<td>12</td>
</tr>
<tr>
<td>45</td>
<td>30</td>
<td>82.9</td>
<td>1</td>
<td>5.5</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
<td>82.9</td>
<td>1</td>
<td>5.5</td>
<td>0</td>
</tr>
<tr>
<td>55</td>
<td>28</td>
<td>80.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>28</td>
<td>80.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>65</td>
<td>28</td>
<td>80.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- number of snails used when experiment was started.
SUMMARY AND CONCLUSIONS

Geography and freshwater ecology of Khuzestan,

1. Khuzestan is a semi-arid plain extending over 157,000 square kilometres in the south-west of Iran. The maximum temperatures are very high in the summer (over 50°C) and minimal winter temperatures are around 0°C.

2. Five major water courses drain the south-west slopes of the Zagros Range and transverse the plain of Khuzestan. These are the Hindijan, the Jarahi, the Karum, the Karkheh and the Dez rivers. The northern and central parts of Khuzestan are important endemic areas for the human and animal schistosomiasis.

3. The aquatic molluscan fauna is limited in species and B. truncatus and Lymnaea snails are the only medically and veterinary important snails.

4. The human activities: agriculture, rice fields market gardening, cattle breeding and clay pits are more or less directly connected with the ecology of the snails.

/ 5. S. haematobium....
5. *S. haematobium* is the only 'human' schistosome and *S. bovis* and *O. turkestanicum* are the only 'animal' schistosomes occurring in Khuzestan. The molluscan host of the *S. haematobium* and *S. bovis* is *B. truncatus* whereas *O. turkestanicum* is transmitted by *L. gedrosiana*.

The high prevalence of animal schistosomiasis in Khuzestan and the economic importance of the parasites in ruminants prompted the present detailed studies on different aspects of two bovine parasites in various laboratory and domestic animals and the studies on *L. gedrosiana*, the snail intermediate host of *O. turkestanicum*.

**Studies on *O. turkestanicum***

**Morphology,**

Most of the species in the genus *Ornithobilharzia* are parasites of birds but a few occur in large animals. *O. turkestanicum* is restricted to mammals and is a parasite of ruminants in which it is common. The morphological characteristics of *O. turkestanicum* which distinguish this species from the genus *Schistosoma* are the smaller...
smaller size of the adult worms (21-10^mm.), the larger number of
testes in the male worm (50-90) and the spiral shape of ovary in the
girl worms. The eggs are much smaller than eggs of bovine schistosomes
(76^um 26^um) and are oval with a blunt spine at one pole and a nipple-
shaped appendage at the other end.

Observations on naturally infected domestic animals,

1. The wide distribution of _L. pedrosiana_ in the irrigation system in
Khuzestan has provided an excellent opportunity for the dissemination
of this parasite. _O. turkestanicum_ infection is uniformly distributed
in the northern and central parts of Khuzestan, but in the southern
part the infection rate is very low. Other workers have found this parasite
in Isfahan and Babolsar in the central and northern parts of Iran.

2. The prevalence of _O. turkestanicum_ in cattle (30.3%) was higher
than sheep (15.6%), and goats (6.7%) or in buffaloes (2.1%). In
other types of animals the infection rate of _O. turkestanicum_ was
very low.

3. The intensity of infection (worm burden and tissue egg loads)

/ in naturally....
in naturally infected cattle declined with increasing age. In contrast in sheep the intensity apparently increased with age. The intensity of *O. turkestanicum* infection in nature was much higher in cattle than in sheep and goats.

**Laboratory experiments in domestic animals,**

1. Eight calves, 5 sheep, 2 goats, one buffalo-calf and one young wild pig were exposed to *O. turkestanicum* in the laboratory; autopsies were performed either 9 or 10 weeks after exposure to cercariae. A new technique was devised for exposing large animals to cercariae by leg immersion in a cercarial suspension in a polythene bag and good infection rates were obtained by this method.

2. The prepatent period in *O. turkestanicum* infection in different type of animals varied from 43-46 days.

3. The adult worms recovery rates were 37.6 % in calves, 33.9 % in sheep, 22.5 % in goats and 9.6 % in a buffalo.

4. The distribution pattern of adult worms was characteristic. Very few worms recovered from the hepatic veins (3.1 % in calves; 8.3 % in sheep....
in sheep and 5.2% in goats) compared with the large numbers of adult worms recovered from the mesenteric veins, particularly the veins of the duodenum (96.9% in calves, 91.7% in sheep and 94.8% in goats).

No worms were found in the inferior mesenteric veins of the large intestine.

5. The distribution of the eggs in different organs was similar to the distribution of the adult worms. The duodenum was most intensely involved in _O. turkestanicum_ infections. The density of eggs declined gradually in the jejunum and few eggs were found in the ileum. The large intestine was entirely free from eggs. The liver showed very low egg counts (1-2.3% in calves, 9-11% in sheep and 20.6% in goats). Other organs (lung, spleen, rumen, reticulum, omasum and abomasum) were free from any eggs. In the buffaloes only a few non-viable eggs were detected.

6. The mean daily egg output per gram of faeces was higher in calves than in sheep or goats being 179, 37, and 59 respectively. The daily egg output in faeces per individual female worm was also higher in calves than in sheep or goats, being 283, 52 and 82 respectively when estimated 9 weeks after exposure to cercariae.

/Susceptibility...
Susceptibility of small mammals and birds,

1. *O. turkestanicum* showed very little infectivity to small mammals: *Tatera indica* (a wild local rodent) produced a few viable eggs after 62 days, but other rodents including laboratory rodents produced only a few immature worms with non-viable eggs. The susceptibility of *Tatera indica* to *O. turkestanicum* was rather low and laboratory maintenance of this parasite in *Tatera indica* was difficult as this wild rodent will not breed easily in the laboratory and stocks had to be provided by trapping wild animals. It is more practical to maintain this parasite in calves or sheep.

2. The dog, mongoose, domestic duck and chicken were insusceptible to infection and no worms were recovered at autopsy.

3. Surveys of mammals in Khuzestan and the above laboratory studies show that *O. turkestanicum* has very little infectivity to the small mammals and that birds are probably completely resistant to the parasite. The main natural hosts of *O. turkestanicum* are the large domestic animals, particularly ruminants.
Studies on *S. bovis*.

**Prevalence.**

1. Observations on the prevalence of *S. bovis* infection in Khuzestan showed that only 0.8% of the cattle were infected with *S. bovis* and among sheep the infection rate was nil.

2. The dramatic reduction in the *S. bovis* infection rate in ruminants in Khuzestan from 20.8% to 0.8% in cattle and from 14.0% to nil in sheep from 1964 to 1970 is due to the successful snail control measures against *B. truncatula*, the snail intermediate host of *S. bovis* and *S. haematobium* during this period.

3. This observations shows that prevalence studies on bovine schistosomiasis before and after snail control measures may be used as a criteria for the evaluation of the effectiveness of control measures directed against human schistosomiasis where the snail hosts of the human and animal schistosomes are the same.

**Laboratory experiments on *S. bovis* in large animals.**

1. Seven calves, 5 sheep, 2 goats and one buffalo-calf were exposed to *S. bovis* cercariae in the laboratory; autopsies were performed 9 or 18 weeks...
18 weeks after exposure to cercariae.

2. The prepatent periods varied from 44-45 days in calves, 47-50 days in sheep and 47-48 days in goats. The differences between the prepatent periods in calves and sheep or goats were statistically significant.

3. The recovery rates of adult worms were 62.1% in calves, 41.4% in sheep and 67.3% in goats. These infection rates were much higher than those obtained by previous workers, possibly because of the improved infection technique in the course of the present studies.

4. A buffalo-calf exposed to *S. bovis* cercariae showed no signs of infection. Studies in slaughter houses also showed no infections in buffaloes in nature suggests that they may be insusceptible to the Iranian strain of *S. bovis*.

5. The distribution of adult worms in the liver was 14% in calves, 7.6% in sheep and 24% in goats. The adult worms in the mesenteric veins were evenly distributed in superior and inferior mesenteric veins. This was a quite different picture from *O. turkestanicum* infection where the parasites mainly were concentrated in the veins of duodenum.
6. The pattern of egg distribution also differed from *O. turkestanicum* as the eggs were uniformly distributed between the small and large intestine. A few eggs were also found in the abomasum.

7. The mean daily egg output per gram of faeces was 75 in calves, 60 in sheep and 75 in goats. The daily egg output in faeces per individual female was 106 in calves, 52 in sheep and 48 in goats 9 weeks after exposure to cercariae. The number of eggs passed in the faeces decreased in calves and increased in sheep as the duration of infection was prolonged.

8. Similarly the egg counts expressed as eggs per gram of tissue increased as the duration of infection was prolonged in sheep, whereas in calves these counts declined considerably with duration of infection. The pathological and clinical manifestations in sheep also become more serious with longer infection, and in some cases *S. bovis* produced a fatal infection in sheep. It thus seem that there is some tendency in calves to self-limit infections with the parasite but no such effect was observed in sheep.

/ Comparative....
Comparative pathology of *S. bovis* and *O. turkestanicum* in ruminants,

1. Severe pathology was observed in one cow with a chronic natural infection of *S. bovis*; there was blockage and thrombus formation in the mesenteric veins with numerous dead worms and acute superficial haemorrhagic ulcerations in the small intestine.

2. In the experimental infections sheep and goats were more severely affected with *S. bovis* than calves. The gross appearance of the liver showed numerous minute greyish nodules and some large lymphoid nodules.

3. The different ruminants showed different histopathological responses to *S. bovis*. Calves had pronounced medial hypertrophy of portal veins; sheep had proliferative endophlebitis and thrombophlebitis with abundant eosinophil infiltration; goats had a large number of eggs surrounded by stellate-shaped accumulation of eosinophilic antigen-antibody material (the Hoepli phenomenon).

4. *O. turkestanicum* produced a milder pathological response in ruminants than *S. bovis*. The liver showed mild or moderate pathological changes with minute greyish nodules all over the surface and deep in tissue substances in sheep and goats but not in cattle.

/5. In the ....
5. In the intestine *O. turkestanicum* eggs were found chiefly in the mucosa and lumen of duodenum.

6. In sheep with natural heavy infection of *O. turkestanicum* inflammatory reactions and eosinophile infiltration in the mucosa and villi of duodenum were striking.

7. Infection of *O. turkestanicum* and *S. bovis* in ruminants in Khuzestan is probably of considerable economic importance. The damage to the intestine produces inadequate nutrition and fattening of such animals becomes difficult. Furthermore, damage in the intestines makes them useless for processing as sausage skins and cause economic loss, and porous intestines or 'sprinklers' are discardable.

Control measures to combat the economic loss caused by schistosomes of domestic animals should concentrate on snail control programs and the provision of safe water supply.

/ Immunity....
Immunity experiments,

1. Immunity experiments on bovine and human schistosome species were carried out in mice, calves and sheep using heterologous and homologous systems. Heterologous immunity experiments in albino mice immunizing with 100, 150 and 200 cercariae of *O. turkestanicum* produced the same level of partial protection against *S. bovis* and *S. haematobium*. Immunisation with 200 cercariae of *O. turkestanicum* produced lower protection against challenge infection of *S. mansoni* and 50 cercariae of *O. turkestanicum* produced very little protection against *S. mansoni*. Homologous immunity experiment in albino mice with *S. bovis* produced a moderately high protection against the subsequent challenge infection with the same parasite.

2. In albino mice immunized with *O. turkestanicum* there was a minimum threshold value for the immunizing exposure which was less than 100 cercariae.

3. A single exposure of albino mice to *O. turkestanicum* cercariae produced as effective an immunity as repeated exposure.

/ 4. A high...
4. A high degree of reciprocal heterologous and homologous immunity was produced with *O. turkestanicum*, *S. bovis* and *S. haematobium* in calves but the effect was poor in sheep. Calves could be partially protected against bovine schistosomiasis by previous exposure to *S. haematobium* cercariae. Cattle have advantages in experimental and field studies on schistosome immunity as one is observing the effect on their natural parasites.

5. Homologous immunity and heterologous immunity between bovine and human schistosomes could be of great importance in protecting animals in Khuzestan from the severe effects of subsequent reinfections.

6. It was shown that calves can develop *S. haematobium* infection but only immature worms are produced. In nature in the endemic areas this must occur since cattle are in very close contact with *S. haematobium* infested waters. This may help to protect them against subsequent infection with the bovine schistosomes. The reciprocal effects of immunisation of man against *S. haematobium* by *S. bovis* and *O. turkestanicum* may also occur.

/ Field studies....
Field studies on *L. gedrosiana* the molluscan host of *O. turkestanicum*,

1. A study on the distribution and population dynamics of *L. gedrosiana* in relation to the transmission of *O. turkestanicum* in various habitats was carried out in Khuzestan. *L. gedrosiana* is the most common aquatic snail in Khuzestan and occurs throughout the year in different types of water courses. It is the intermediate host of *Fasciola gigantica* as well as *O. turkestanicum*.

2. Populations of *L. gedrosiana* were higher in canals and swamps than in ponds, with peaks in spring and autumn, and low densities in summer and winter. The winter decline was more marked than in summer. *L. gedrosiana* is soon killed by exposure to drought and other environmental changes. In summer the populations of *L. gedrosiana* were larger in canals and deep swamps than in small and shallow habitats.

3. The reproductive capacity of *L. gedrosiana* was higher in running water than in stagnant water. The peak reproduction rate was in spring and autumn and continued at low levels in summer but it was nil in winter.

/ 4. The size.....
4. The size-frequency studies of *L. gedrosiana* showed that most of the snails in different habitats were young snails less than 6-8 mm in height.

5. The prevalence of infection in large size *L. gedrosiana* with *O. turkestanicum* was higher than in small snails, being 0.1 %, 0.5 % and 1.1 % in snails measuring 0-6 mm, 6-10 mm and 10-14 mm respectively.

6. Transmission of *O. turkestanicum* occurred through the year in canals with a peak in late summer. Infectivity of swamps also continued in spring, summer and autumn with a peak in early summer. In ponds most of the transmission probably occurs in spring and autumn. Drains played a very minor role in the transmission of *O. turkestanicum* in Khuzestan.

7. The infection rates of *L. gedrosiana* in canals was higher than in other habitats, being 0.68 % in canals, 0.36 % in swamps, 0.25 % in ponds and 0.15 % in drains.

8. Non-schistosome parasite larval stages found in *L. gedrosiana* were:
   a. *Fasciola gigantica* cercariae.
   b. *Cercariae* of the heterogeneous Gymnocephalic group.
   c. *An unknown apharyngeal longifurcate cercariae*.

/ Laboratory...
Laboratory experiments on *L. gedrosoëna*.

1. In the laboratory infection of *L. gedrosiana* with 1, 2, 5, 10 and 20 miracidia of *O. turkestanicum* the following results were obtained:

2. The infection rates in different groups increased with the dosage of miracidia, being 54.5%, 57.1%, 62.5%, 84.0% and 100% from 1, 2, 5, 10 and 20 miracidia respectively.

3. The mean prepatent period varied from 16-21 days in the different groups but the differences between the groups were not significant.

4. The mean numbers of cercariae shed daily by single snails exposed to one miracidium or 2 were significantly fewer than those exposed to 5, 10 or 20 miracidia.

5. Few cercariae were shed per snail during the early patent period but the number increased with the duration of infection. All the infected snails died at the peak of cercarial shedding, and no infected snails survived more than 60 days after exposure to miracidia. The differences between the mean life-span of the infected snails and non-infected snails in the control group were statistically significant.

/6. Mollusciciding...
6. Mollusciciding seems to be the only practical way of controlling *L. gedrosiana*. Our previous works on mollusciciding in the Khuzestan showed that *L. gedrosiana* is more susceptible to the molluscicides than Bulinus snail. Since *L. gedrosiana* is wide-spread and has a permanent and continuous type of distribution, molluscicides should be applied throughout the water bodies of the area.
REFERENCES

Abdussalam, M. and Sarvar, M.M. (1952)
Occurrence of *Ornithobilharzia turkastanioum* in Pakistan. Proc. 4th Pakistan Sci. Conf. 3, 143

Ale-Dawood, N. (1963)

Alves, W. (1949)
The eggs of *Schistosoma bovis*, *Schistosoma mattheei* and *Schistosoma haematobium*. J. Helminth. 23, 127-134


Anderson, Ch. and Cobert, E. (1934)
Note sur la présence en Tunisie du *Schistosoma bovis*, infection naturelle de *E. contortus*. Bull. de la Soc. Path. Exotique. 27, 850-853
Arfaa, F., Sabbaghian, H. and Bijan, H. (1965)

Arfaa, F. Sabbaghian, H. and H. Ale-Dawood (1965)
Studies on Ornithobilharzia turkestanica (Skrjabin 1913)
Annales. de Parasit. Hum. et Comp. 40, 45-50

Azimov, D.A. (1965)

Azimov, D.A. (1966)
Epidemiology of Ornithobilharzia turkestanica infection in ruminants. Veterinaria Moscow 43, 50-52

Azimov, D.A. and Murmukhamedov, Kh. N. (1968)
New data on the biology of trematoda Ornithobilharzia turkestanica. Zool. Zhurnal. 48, 1471-1478

Azim, M.A. and Watson, E.H. (1948)
Comparative efficiency of various methods of infecting mice with Bilharzia mansoni. J. Egypt. Publ. Hlth. Ass. 24, 121-140
Barbosa, F.S., Barbosa, I. and Arruda, F. (1962)

_Schistosoma mansoni:_ Natural infection of cattle in Brazil. Science, 139, 831

Bertolini, G. (1908)

La clinica veterinaria. 1, 1. (cited by Hussein, 1969).

Bhalerao, G.D. (1932)

On the intensity of the schistosome found in cases of bovine nasal granuloma and some observations on a few other members of the schistosomatidae. Indian J. Vet. Sci. 2, 338-355

Bijan, H., Arfaa, F. and K. Mousavi (1958)


Blanc, C. and Desportes, G. (1936)

_c.r. Sanno. Soc. Biol. Paris_ 123, 466

Blair, D.M. (1966)

The occurrence of terminal eggs other than those of _Schistosoma haematobium_ in human beings in Rhodesia. C. Afr. J. Med. 12, 103-109

Boev, C.H. (1944)


Lency, J. (1962b). Studies on *Schistosoma bovis* in Israel. II. The intramammalian phase of the life-cycle. Ibid. 10 E, 73-96.


Smithers, S.R. and Terry, R.J. (1965). Natural acquired resistance to experimental infection of *Schistosoma mansoni* in the rhesus monkey (*Macaca mulata*).
*Parasitology*, 55, 701-710.


Smithers, S.R. and Terry, R.J. (1967). Resistance to experimental infection with *Schistosoma mansoni* in rhesus monkeys induced by the transfer of adult worms.


ADDENDUM

Progress towards the control of bilharziasis in Iran.

Fairley, N. H., P. P. Machie and P. Jasudasan (1930)

Sabbaghian, H., Arefa, F. and H. Bijan (1964)
Studies on animal schistosomiasis. (in Persian)
J. Veterinary College, Teheran.