Sanitation.

Houses are generally overcrowded and unhygienic, as many as seven or eight people living in a single-roomed house.

Cholera Hospital.

An old caravanserai was set apart for this purpose. Only the poor and destitute were received as patients; it was of little real utility.

Breakdown of Precautions.

The sale of fruit in the bazaars was for a time prohibited by the Governor of the province. Measures which could have stopped the epidemic and have prevented its spreading to other provinces—such as cleaning the town, disinfecting the houses and clothing of patients and contacts, notification of cases, free distribution of medicines and disinfectants, etc.—although originally started, fell to the ground through weakness on the part of the Governor in supporting these measures because of the protests of a few bigoted and discontented persons against the innovations of the European doctors.

On April 20th and 21st a demonstration was made against the European medical officers who were entrusted with carrying out protective measures in Kermanshah, it being rumoured that the outbreak of cholera was a fiction and that the doctors had poisoned the town water supply. From this date onwards all sanitary precautions in the town were abandoned.

Origin of the Epidemic.

Cholera had practically disappeared, when Aga Fazel Mamegani, one of the leading high priests of Kerbela, who was proceeding on a pilgrimage to Meshed with a large following, broke through the cordon at Kasr-i-Shirin, and was allowed to enter, remain in, and leave Kermanshah without submitting to any quarantine regulations. On May 8th, the son of one of the Mullahs of Kermanshah having died from cholera, a sudden panic took place, and about one-third of the population left the town, camping under trees or in tents near villages. From this date the infection spread through the whole district, and whilst the mortality seems to have been very great in some villages, as in Hadjiabad, where out of a population of 250 souls 40 or 50 fatal cases occurred, in others it was limited to one or two deaths. Finding the district as bad as the town, people began to return on May 30th.

Aga Fazel again broke through the cordon at Kangavar, which had been isolated, being infected, and from the time of his passage through Kangavar one traces the spread of the contagion along the high road from Kangavar to Koom and Teheran, and along the road from Kangavar to Hamadan and towards Azerbaijan.

The first case of cholera in the town of Hamadan occurred shortly after the arrival of Aga Fazel, who preached against the faithful being prevented from visiting the sacred shrines, and described the quarantine measures as innovations of the "Feringees."

In Hamadan the disease broke out in the beginning of May, and in the village of Kabudrahang alone 80 cases and 50 deaths were reported during the space of sixteen days. The mortality in Hamadan is said to have reached at the end of June 100 a day. At about the same time a serious outbreak of cholera in Malayer, Tusirkan, Nehevend, Doaletabad, and Burujird was reported.

Kurdistan was for some time kept free from cholera, most stringent quarantine regulations having been enforced on the road from Kermanshah to Senneh, Kurdistan. The epidemic however, reached Senneh from Penjwin, in Turkish territory.

Quarantine.

Theoretically quarantine should be an efficient protection against cholera being introduced into a community; practically it is a failure, notably as carried out in the province of Kermanshah. Quarantine regulations can be of little use unless they are stringent and thoroughly carried out. Unfortunately the temptation to evade such regulations is in proportion to their stringency. It is impossible to secure the absolute honesty and efficiency of every individual in a large body of poorly-paid soldiers charged with the carrying out of the details of a system which entails great personal inconvenience, and loss to travellers and merchants. Therefore if the strength and usefulness of the quarantine chain is to be measured by its weakest link, a very slight acquaintance with its working will prove how very weak it is. Even if the utmost care, honesty, and intelligence succeed in excluding individuals suffering from or likely to suffer from cholera, there is no guarantee that the germ of the disease may not be introduced. It is impossible, short of absolute and complete

isolation, for any practicable system of quarantine to deal with such cases. Ordinary quarantine, in my opinion, instead of proving a defence, may actually increase the risks of an epidemic; it fosters a sense of false security and neglect of the first principles of public health—pure water, good food, etc. No attempt was made to isolate the different arrivals, or disinfect clothing and personal effects of cholera patients, pilgrims, and travellers; regulations were evaded and cases were concealed.

The accompanying maps show how easily muleteers and travellers evaded the different quarantine posts. The march of the epidemic can be traced through the plain of Irak with its multitude of villages, on to the great shrine of Fatima at Koom, and so on to the capital. From Koom the epidemic worked its way south to Kashan and Ispahan. From the capital it gradually spread to Meshed in the east, Resht and Tabriz in the north-west. Dr. Vaume, of the Turkish Sanitary Board, who was entrusted with the supervision of the quarantine measures, succumbed to the disease. Nomadic tribes scarcely suffered, whilst villagers suffered heavily, which is not to be wondered at, as Persian villages are most insanitary. Trade was completely paralysed for a time, and the Customs receipts fell considerably. Every pilgrim carries a leather bottle containing water when on the road, and is never very particular where he fills the same. At Koom the bodies of cholera patients were washed in the river which flows close to the great mosque, the same water being used for domestic purposes. It is estimated that from 50,000 to 100,000 pilgrims pass Kermanshah yearly en route to Kerbela, Nejed, and Kazimein.

On entering Turkish territory at Khanekin pilgrims are subject to a quarantine tax of 10 piastres, gold. Corpses, of which a great number are annually sent to Kerbela for interment, pay a tax of 35 kranas to the Turkish authorities in Kermanshah, and a further tax of $\frac{1}{2}$ L. Turkish at Khanekin. A permanent quarantine post is maintained at Khanekin by the Turkish Sanitary Board to supervise the traffic and examine the bodies.

Statistics.

From figures supplied by the Minister of Customs and Posts the approximate mortality is given, and is generally conceded as much underestimated.

Provinces.			Provinces.		
Kermanshah	...	5,000	Mazanderan	...	2,000
Hamadan	...	3,000	Khorasan	...	5,000
Irak	...	1,000	Ispahan	...	2,000
Tusirkan	...	1,500	Shiraz	...	15,000
Koom	...	1,000	Arabistan	...	2,000
Teheran	...	20,000	Azerbaijan	...	8,000
Kazvin	...	200			
Gilan	...	3,000	Total	...	68,700

Recommendations.

In order to prevent further outbreaks and protect Persia against returning pilgrims, the following precautions are, I think, necessary:

The provision of a permanent camping ground at Kasr-i-Shirin, where pilgrims would be housed in large corrugated iron sheds, the ground being at some distance from village and oil works. Such a camp should be furnished with the latest sanitary arrangements; sufficient latrine accommodation should be provided, the water supply being pumped from the river bed and stored in a cistern, and from thence supplied by means of pipes on the tap system; in this manner the water supply would be safeguarded; a special washhouse provided and the ground drained. No great difficulty should attend the carrying out of the above measures, as Kasr-i-Shirin being a frontier Customs post, a permanent Customs staff already exists.

RATS IN RELATION TO PLAGUE.

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II.

THERE have been periods when in India rats have proved themselves most destructive to the crops; in ordinary seasons their destructive proclivities are sufficiently trying to the agriculturist, but in some years their depredations call for special remark. Thus, in the Bombay Agricultural Report for 1895-6 we read that rats were in such large numbers in Karachi and Hyderabad that rewards were offered for their capture (p. 24). But the most interesting among several

references to the damage worked by these rodents is the following:

The Bombay Agricultural Report for 1892-3, in recording the work done during that financial year, states on p. 32:

Rats have caused considerable anxiety, appearing first, as they did in the locality where they first appeared in 1878, that is in the Eastern talukas of Belgaum. They were reported also from Sind and the Deccan, but they did most harm in the Karnatak (Bijapur, Belgaum, and Dhárwár).

The numbers, however, never became very numerous. But again, as in 1879, the plague* was stayed by opportune heavy rain and by an enormous increase of ticks, which appear to be ordinary cattle ticks. It is still doubtful whether this parasite infested healthy rats, or whether it attacked them when weakened by the heavy rain. A recommendation was made by this Department that the subject of rat plagues* should be recommended for study by the Imperial bacteriologist in the hope that inquiry may show a means by which rats may be inoculated with a contagious disease not communicable to man or to domesticated stock.

It is a most unfortunate fact that the Imperial bacteriologist was that year transferred to another department, and no record can be traced which will afford a clue to any attempt at the elucidation of rat plagues.* With regard to the reference to the years 1878 and 1879, we find in the Report¹ of the Indian Famine Commission presented to Parliament in 1881:

The autumn crop of 1878 and the spring crop of 1879 were both below average, especially in Guzerat and Katiawar, and a great portion of what was then produced was destroyed by an extraordinary plague of rats which infested the Southern Deccan and South Mahratta districts; rewards were given for their extermination, and over 12 millions have been destroyed.

Perhaps others may be able to give a reference to the source whence the information was obtained that on this occasion likewise the rats were affected by cattle ticks. A responsible Government official would not have made the statement without substantial evidence. We therefore accept it as a fact that rats died on both those occasions while infested by cattle ticks, and perhaps owing to a disease produced by the ticks. It is to be hoped that further investigation will demonstrate the importance of this neglected record.

If this disease were plague we should expect to find some evidence of its occurrence among the people, at any rate in 1893, were there any reliable means of diagnosis. There were not any such means, neither were the figures, which show an increased fever mortality in 1893, reliable; those who furnish the figures recognize their unsatisfactory value.[†] It is not until the Bombay epidemic of 1895 that the pestilence is recognized; it is then also realized that the disease must have been in existence for some time in the Presidency. There is, however, no definite evidence that plague existed in the Bombay Presidency before 1896; it can only be presumed.

Starting on the presumption that plague was present in 1893 among rats, and perhaps among men, how did the rats contract the disease? But before proceeding it may be not amiss to follow the account of the first recorded plague epidemic found in the Bible.

In the first place the ark captured by the Philistines was taken to Azotus and placed near an idol. On two consecutive nights the idol was overthrown; we may not unfairly assume that an earthquake may have been the cause of this catastrophe. The people of Azotus next suffered from emerods. There was a great mortality in the city, and an invasion of mice (or rats) in the villages and fields.

The people of Azotus attributed their misfortune to the captured ark, which they proceeded to remove. As it was carried from city to city the plague went with it. The perigrination of the ark being marked by plague breaking out at each fresh spot where it rested led the Philistines to determine on returning it to the Israelites from Ekron, where it had finally arrived bringing with it "deadly destruction." Thereupon they placed the ark on a cart drawn by two kine and let them take it where they pleased. Five of the lords of the Philistines followed the cart, which was taken to Bethshemesh, territory of the Israelites, after seven months—Josephus² says four months—in Philistia. The Philistines having noted the reception of the ark by the Israelites, who were at that time reaping their wheat, returned to Ekron. They are not reported as having held any communication with their enemies; they were not sent for that purpose, but merely to report whether the ark had returned to its original owners.

Judging by this record, the only living things which served as a link for the carriage of the plague were the kine. The

latter the Israelites slew and burnt with the wood of the cart as an offering. They, however, contracted plague, from which some 70 men and 50,000 of the people died. The ark was then removed to another place, but apparently without any further extension of the epidemic.

This epidemic has been accepted by modern writers as having been one of bubonic plague. Josephus says "they died of a dysentery or flux." Further, he says that when the ark reached Bethshemesh, and the Israelites approached the ark, 70 of them died of the plague. He does not mention the "50,000 of the people" recorded by the Christian Bibles as victimized by a "great and holy God." Keeping, however, to the account in the Bible, we have here a graphic description of a plague epidemic setting forth the various special points noticeable in similar epidemics to-day. The period of the epidemic in Philistia corresponds with that of its duration in India—some seven months before the wheat harvest, when rats are out in the fields. The only point hitherto unrecognized about this story is the part taken by the cattle. These constitute the only living connexion between the plague-stricken Philistines and the Israelites, who had no sooner received the ark and the attached cattle than they became plague-stricken, although the cattle appear to have been slain and burnt on the day of their arrival.

In the Biblical account the plague among the men of Bethshemesh is attributed to their having looked into the ark (in the Douay Bible "because they had seen the ark"). This view of its origin was calculated to cause enhanced respect for the sacred coffer among a superstitious people. This point is, however, only a matter of opinion, superadded to a record of facts which otherwise is curiously in accord with what is known of plague to-day. If, therefore, we omit this speculation, which would endow the ark with the attributes of a Pandora's box, we find ourselves in face of the probability that the kine, the only living connexion between the plague-stricken Philistines and the Israelites across the border, were the vehicles of the plague. And that they may have been the source of the disease does not, when it is realized that plague is caused by inoculation, appear to be unlikely, were there any evidence that the kine were themselves suffering from any disease.

The only point which can be regarded as such evidence is that the kine of their own free will took a road which led in a direction directly away from their calves—an unnatural proceeding which can only be accounted for by the presumption that their milk had run dry. A subsidiary point is that the Philistines would not have handed over healthy kine to the Israelites so long as they had diseased ones available for the purpose.

This is but slender evidence to adduce in a scientific paper were it not supported by the fact already recorded that in 1893 there was in certain parts of Bombay an enormous increase of cattle ticks which assisted in staying the "plague"—that is, the devastating effects—of rats. This leads, naturally, to the consideration of cattle diseases, and to the possibility of the extension of any cattle disease causing plague to rats, and also to man, by the agency of ticks.

The study of cattle diseases in India can only be said to be a modern development. The Agricultural Department began its reports in 1884, while the Veterinary Reports have only taken definite shape within the last decade. The earlier returns of cattle diseases are acknowledged to be unreliable, but even so they furnish evidence of the principal cattle diseases which is borne out by more recent and increasingly accurate returns. Omitting surra, with which the name of Dr. Lingard is associated, we find the principal cattle diseases to be rinderpest, foot and-mouth disease, and anthrax. From anthrax has recently been differentiated ghotwa. Quarter-ill and pleuro-pneumonia also are frequent cattle diseases.

Rinderpest, or steppe murrain, is endemic and rampant in India and in the Steppes of Russia, from which it has periodically invaded Europe. It was not known in South Africa previous to 1864. It is only too well known in South Africa in the present day. The micro-organism of this murrain is not known; nevertheless inoculation causes the disease. It may therefore be spread by ticks.

"It is amenable to the repressing effect of heavy and sustained rain."³

"Cattle disease is as well known in Kumáon as small-pox among human beings," and also in Garhwal. Cattle disease is here called máu, and is the same as rinderpest.^{4 5}

The last extension of rinderpest to England was in 1872. It did not then or in 1866 cause plague among human beings, though ticks abound in this country. At that period rats

* Not pestis, but devastating swarms of rats.

[†] See the previously-quoted Famine Commission Report, and the Report of the Indian Plague Commission, 1898 and 1899.

were not under suspicion—if there had been increased mortality among them it would, probably have escaped record and perhaps observation.

Foot and mouth disease is endemic in the same localities, whence it spreads to Europe. This disease was specially prevalent in the districts in which the rats referred to above died with cattle-ticks on them.⁶ The diagnosis of this and other cattle diseases did not formerly rest on a very satisfactory basis. It is only of recent years that the efforts of the Veterinary Service in India have led to more accurate returns from places coming under the immediate supervision of experts.

Quarter-ill, or charbon symptomatique, has a well-marked bacillus bearing no resemblance to that of plague.

Pleuronpneumonia and anthrax possess their own specific bacillus, about which there is no reason to doubt.

Ghotwa, or ghotu, or galghotu has been described by Veterinary-Captain W. T. Pease⁷ as corresponding to buff-senche in Hungary, and very nearly resembling glos-anthrax. He first reported the occurrence of this as a distinct disease in 1896. Galghotu was previously reported⁸ as being the same as glos-anthrax (in 1883 by Veterinary-Colonel J. A. Nunn). "This disease is most prevalent in the rains, but may appear at other time of the year and specially following the Christmas rains." This disease is caused by inoculation, but it may be introduced by ingestion, probably through wounds on the lips and tongue. The characteristic bacillus is described on p. 5 of the paper. "It attacks most commonly young buffaloes which are in good condition, but older animals also get it. Cattle and swine also take the disease spontaneously. Besides the means of natural infection described by Captain Pease on p. 2 of his paper, it is obvious that this disease is one which might be spread by ticks or mites.

Here we have well-marked cattle diseases whose existence in India can be traced at least as far back as the records of Europeans go. They have been present from season to season in some part or other of the country. There would appear to be no obvious reason why any one of them, even if pathologically related, should be the source of pestilence among men, unless it can be shown that there is present another factor, and that is a vehicle from cattle to men and rats.

There are certain meteorological and telluric conditions which become appreciable to man by their results in the plant and animal world. "A good year for stone fruit," or "a bad year for blight," are expressions indicative of our ignorance of the intimate causes which favour the development of stone fruit or the predominance of blight. Ignorant of the causes, we have to remain content with the facts which force themselves on our perception. Similar ignorance at present hangs round the bearing of the connexion between earthquakes and certain plague epidemics. The atmospheric and telluric conditions attending earthquakes we may be allowed to presume to be conditions favouring the development of the vehicle of plague. Such a presumption will be in keeping with the known fact that earthquakes have been frequently recorded as preceding and attending outbreaks of plague, while certain species of insects and plants may find in earthquake years the favourable conditions necessary for their propagation in such numbers as to defy the control of man, to his ruin, and even to his destruction.

At least the fact remains that the spread of the lower organisms is dependent upon their finding in new countries conditions favourable to their existence—conditions which are periodic in their occurrence, otherwise, if permanent, the organism would have been established.

We have next to find the agent which periodically assumes such importance as to be able to cause plague epidemics. From what has already been stated, this agent flourishes in India in comparatively dry weather, is virulent in hot dry weather, and is dormant during rains or very cold weather, except under such artificial conditions as will counteract rains and extreme cold.

We have reason to believe that rats may die through the agency of cattle ticks, and these animals fulfil the above conditions.

Probably the best-known ticks are those which have been found to infect animals with the piroplasma.

The cattle tick of India appears to be of the same species as that which carries the piroplasma of Texas, or red-water fever.⁹ This tick is described by Colonel A. E. Queripel,¹⁰ under the name of *Ixodes bovis*. Neumann¹¹ classifies it as *Rhipicephalus annulatus*, but does not mention its occurrence in India. Other species¹² of tick have since been shown to convey the piroplasma.

Texas fever does not appear as yet to have become epizootic in India, while "cattle ticks" are to be found throughout the country. But the mere presence of cattle ticks will not present a solution of the problem, for ticks which infest cattle are world-wide in their distribution. It is obvious that either the cattle disease which furnishes the *materies morbi* of pestilence must be of localized and unusual occurrence, or the tick or mite which spreads the disease must be one whose distribution area corresponds only to the endemic areas of plague, whence it spreads on occasions specially favourable to its temporary existence in other regions. In Burmah, for instance, there are numerous varieties of ticks, but as up to the present plague is rare in that country whereas cattle diseases are common, these ticks are not of themselves at present the vehicles of pestis.

It is not likely that *Rhipicephalus annulatus* is the originator of plague. Were it the originator, the areas in which it is indigenous would be endemic plague areas. They are not endemic plague areas. Were that species of tick the vehicle from cattle to man, we should expect to find the reverse order occur, and plague to become endemic in Australia and South Africa.

The distribution of ticks and mites is a science which like many others is of comparatively recent growth, and such knowledge as has been acquired has not been completely systematized as yet. It is therefore impossible to state with exactitude what ticks were present in the Indian plague areas before the present plague epidemics occurred. It is consequently at present impossible to say whether any special variety of tick has lately appeared and become responsible for the carriage of pestilence to man, unless it can be shown that *Hyalomma aegyptium* has spread from Bombay into other plague-infected areas.

What may be suggested as required is a tick with a distribution such as that of *Ornithodoros savignyi*¹³ (Egypt, East Africa, and "even in Asia") or *Dermacentor reticulatus*¹⁴ (Europe, Caucasus, Turkestan, Persia, Amur, Siberia) or *Hyalomma aegyptium*¹⁵ (Southern Europe, probably whole of Africa, Asia Minor, Persia, Turkestan, Mongolia, Bombay). A tick such as one of the above, normally inhabiting endemic plague areas, and extending its borders during favourable years, would satisfactorily account for the extension of plague during periods favourable to its existence in a new station.

Another factor in the problem is that of the active period of ticks and mites. These Acaridea pass their parasitic period either on animals or plants, in some cases during their whole career; in others, during one phase of their existence. For instance, the Trombididae pass the mature stage on plants. From the eggs come larvae, which attach themselves to animals, from which they fall off as pupae, which in temperate climates hibernate, living during this period on the juices they have extracted from their animal host. After hibernation they become mature forms. The Ixodidae, on the other hand, lay their eggs or produce their young in the earth. When hatched, the young attack their future hosts, only dropping off when the period of delivery of the female is at hand.

During the period when these young or eggs are in contact with the soil, they are liable to be washed away or rendered inactive by heavy rain. This may be assumed to constitute sufficient reason for the comparative quiescence of plague during the monsoon in India; while in temperate climates a similar inactivity would be evident during hibernation. Artificial conditions would modify this natural process; such conditions as protection from rains or cold if the eggs were deposited in a house. This would explain the occurrence of cases of plague during the rains in India, or during the winter in Russia and Europe.

The carriage of plague in ships (hitherto attributed to pest-bacillus in the cargo finding an inoculable spot in the victim) would become more readily explicable were it clear that the eggs of a plague-infected species of the Ixodidae were present in cargoes of wheat, the larvae on birth finding occasional hosts during the voyage, or when the cargo was unloaded. Further, if the climatic changes of the country where the cargo was discharged were unsuited to the tick its reproduction and the concomitant spread of plague should cease. On the other hand, the arrival of plague in a country usually unsuited to the plague tick would only become epidemic when meteorological and perhaps telluric conditions were such as to favour invasion by that particular species.

The knowledge of the distribution of ticks requisite for the demonstration of the above is not yet available. But what is possible of demonstration is whether pestilence may be com-

municated to rats by inoculation with the *materies morbi* of a cattle-disease.

Lieutenant-Colonel Leishman has throughout taken an interest in this subject and has now joined in the investigation of this point, regarding which we hope to make a further communication. In the meantime what has been written above may lead to fruitful investigation in plague areas, especially by officers of the Veterinary Services in India.

At the same time it has to be borne in mind that the tick may be the medium by which infection is conveyed from the soil to both man and beast, as well as from beast to man.

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⁶ Bombay Agricultural Report for 1892-3, p. 22. ⁷ *Agricultural Ledger*, 1897, Special Veterinary Series, No. 3. ⁸ *Ibid.*, 1893, No. 8, containing a Review of Official Reports. ⁹ *Ibid.*, 1895, No. 7, p. 6. ¹⁰ *Ibid.*, 1897, No. 2, p. 4.
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AN INVESTIGATION ON THE REGENERATION OF NERVES,

WITH REGARD TO THE TREATMENT OF CERTAIN PARALYSES.

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[PART II.]

In a previous communication, published in the *BRITISH MEDICAL JOURNAL* of April 29th, 1905, it was shown that the central end of one nerve is capable of establishing connexion with the distal ends of two and presumably more than two nerves. The nerves used were the external and internal popliteals which innervate antagonistic muscles. It was shown that a very useful function could be obtained in this way. As the result of counting the fibres in the regenerated nerves it was seen that a single axis cylinder in the central nerve split up into two or more branches at the place of section, and each of these could establish a connexion with a fibre in a distal nerve. It seems probable—and especially where a small nerve is used—that the nerve fibres do not reach the normal number, and presumably the function of the muscles cannot be quite as efficient as in the healthy state. It was also evident from the axon reflex phenomenon that some of the fibres which come from the splitting of a single axis cylinder may supply antagonistic muscles. It is impossible to say what proportion of fibres do this, but from the very vigorous axon reflex obtained it seems that a considerable number have this arrangement.

When a nerve is divided and immediately sutured, the fibres of the central end are described as dividing and forming a kind of brush. These have a wavy course, and ultimately one branch from each axis cylinder joins with or grows down a fibre in the distal nerve.

The remainder of the branches from the central fibre gradually disappear. But if a more than corresponding number of fibres be present in the distal end some of these branches instead of disappearing remain permanently and have a definite use. I attach considerable importance to this splitting of the axis cylinder. If a single motor cell is supplying antagonistic muscles, it is evident that there is a certain amount of waste of nerve and muscular energy. Accurate dissociated movements will be impossible, or at any rate only possible by ceasing to use such muscular fibres as are thus innervated. This is a very serious drawback to nerve crossing. That this is no theoretical objection I hope to show, and suggest a very simple remedy. Most of the nerve suturing has up to the present been done with the facial and spinal accessory which are quite analogous to the motor nerves of the limb. After facio-spinal-accessory anastomosis any movement of the face has been associated with elevation of the shoulder and bending of the neck, owing to simultaneous contraction of the trapezius and sterno-mastoid muscles. This improves to some extent with time as the result of re-education of the cortical and other centres, but seems never quite to disappear. Ballance and Purves Stewart¹ have reported 7 cases (in one the hypoglossal and facial were used) and say: "So far in our series of facio-accessory cases, we have not observed any independent movement of the face unassociated with that of the trapezius and sterno-mastoid, although in several cases

minimal innervation of the trapezius is sufficient to cause facial contraction."

The following experiment in a dog gave the best functional results I have seen, and single axis cylinders dividing to supply antagonistic muscles were not present.

Dog V. Left leg operated on January 17th, 1905. About one inch of the external popliteal nerve was excised. The internal popliteal was separated into two parts. The separation was made between the fascicular bundles, and as little damage as possible was done to the nerve tissue. These were then cut transversely across, and the smaller part was sutured to the distal end of the external popliteal. The larger one was then fixed by a single suture to the distal end of the entire internal popliteal (see Fig. 1). Union of the wound took place by first intention.

Fig. 1.

Fig. 2.

March 7th, 1905. Dog walked fairly well and nearly always on the plantar surface of the foot; no ulcers had formed on the dorsum. The original wound was opened up. Two small bulbs had formed at xx, where the suturing had been done, but these were not in contact with one another.

June 7th, 1905 (141 days). The function was practically perfect, and it was almost impossible to tell which leg had been operated on. Scratching, which I regard as the best test of accurate co-ordination in the dog, was done nearly perfectly. The animal was anaesthetized and electrical stimulation performed. The internal popliteal was cut across at A, and stimulation here produced a vigorous response in the muscles at the front and back of the leg. The internal popliteal was then divided across at B, and stimulation at A now produced only contraction of the extensors of the toes. Stimulation at B gave no contraction of the extensor muscle. This showed the axon reflex was absent, and none of the axis cylinders had split to give branches to antagonistic muscles. The anterior and posterior sets of muscles were now dissected out; they were well developed and nearly as bulky as on the opposite side.

Dog VI. The left leg operated on February 17th, 1905. The same operation was performed as on the previous dog, a little over $\frac{3}{4}$ in. of external popliteal being excised. Union took place by first intention.

March 10th. Animal up to the present has always kept the leg raised off the ground.

April 25th. It was noticed that the function was not quite so good as it had been a week or two previously. The animal very often walked on the dorsum of the foot and a small ulcer had formed here. The wound was reopened, and it was found that the bulbs at xx had fused considerably. The narrow popliteal space in the dog renders this difficult to avoid. The bulbs were separated by cutting between them and the wound sutured.

June 20th. The function had greatly improved, but was not by any means perfect; the animal, however, rarely went over on the dorsum of the foot, and the ulcer here had healed.

CONCLUSIONS.

Both clinical and theoretical considerations point to nerve splitting being preferable to suturing two distal nerves directly to the central end of one of them. The functional result in Dog V was the best I have obtained up to the present. Dog VI is of special interest. Where the bulbs fused, fibrils from one axis cylinder presumably grew down into the two distal nerve trunks. The separation of the bulbs, even though it destroyed a good many fibres, resulted in a rapid and considerable improvement. In facio accessory anastomosis it would be wise to split the latter nerve into two strands, injuring the actual nerve fibres as little as possible.