by hand, a stick of lath being inside of the folded strip of rubber upon which to press the seam of the tube.

In this form, of course, the inner tube is a straight piece having two ends somewhat like a short length of thin rubber hose. In this condition it is slipped over long metal tubes or forms, and in order to facilitate sliding it over the tubes compressed air is applied to one end of the rubber tubing which tends, of course, to expand the latter and allows it to slip over the metal vulcanizing form or tube very easily. These long forms are then wrapped with cotton bandage cloth and put into vulcanizing tanks where, by the

application of heat by means of steam, the sulphur is again combined with the rubber gum, forming the well-known vulcanized rubber inner tube which is, however, still in the straight shape.

In order to make the tube endless a very ingenious device is used. Fig. 8 shows that the tubes have slipped over one of their ends a metallic sleeve. This sleeve is really double, and in the space between its inner and outer walls another sleeve fits very neatly. The rubber of the inner tube is folded down over the end of one of these short sections of metal tube, the surface of the rubber being treated with curing acid

to make it raw and easily cemented. Next, the other section of tube is slipped down into the first section, and by the application of compressed air the two sections are practically shot apart, causing the turned-back section of the rubber tubing to slide over the other end and lie flat upon it. By the application of rubber bands around the outside of the joined portion sufficient pressure is brought upon the parts to cause them to stick together. The metallic tubes are removed from the now endless rubber tube by sliding the rubber out through a groove which goes down one side of each one of the metal tubes.

A WATER BALLAST MOTOR ROLLER.

A NEW ENGLISH INVENTION.

BY FRANK C. PERKINS.

THE accompanying illustration shows the construction and method of operation of a novel motor roller provided with water ballast as constructed at Petersburg, England, and utilized for rolling race courses and training grounds, as at the jockey club at Newmarket. It is also employed at parks, golf links, and cricket grounds in Great Britain, as well as for road making with granite, tarmacadam, and asphalt.

This English water ballast motor roller is provided with a double-cylinder engine of 14-horse-power capacity and a kerosene carbureter. The motor is easily started with a few drops of gasoline. It is provided with a low-tension magneto, and also battery and coil in addition for ignition. The roller when loaded with water weighs about six tons, and is largely used in India as well as by some of the other colonial governments, also on several race courses in Japan.

In addition to the water circulating tank, a smaller tank is provided for carrying water to keep the surface of the front and back rollers wet when rolling tar macadam, so that this material or asphalt will not stick to the rollers. Water pipes are fitted to the car to sprinkle each of the rollers. It is stated that this arrangement has been found to work very satisfactorily, and to give excellent results for street work. The roller is 3 feet in diameter and 4½ feet wide, and weighs about 4 tons, and is provided with gearing giving two speeds. When running on the slow speed, it is claimed it will climb a hill with a gradient of 1 in 7. As to efficiency and economy of operation, it is maintained that the engine consumes on an average from 1/3 to 1/2 gallon of fuel per hour.

AN ENGLISH WATER BALLAST MOTOR ROLLER.

THE PRESERVATION OF ROADS.

TAR AS APPLIED TO SURFACE TREATMENT.

BY HERVEY J. SKINNER.

THE problem of preserving the surface of roads and highways and the prevention of dust has been given attention by highway engineers for many years, but not until the year 1905 was the question seriously considered in the United States. The increasing use of automobiles and motor vehicles about this time introduced a new condition to be considered in the building and preservation of roads. Reports from various parts of the United States, England, France and wherever the use of motor vehicles had become common showed that the automobile was exerting an extremely destructive effect upon road surfaces.

The macadam road has especially been subjected to this destructive action since it is the form of construction most commonly adopted for modern thoroughfares. The binder or fine material upon the surface of the road is removed by the constant passage of automobiles, thus exposing the larger stones, which become loose and which are either left on the surface or in windrows along the sides of the road. The roughened surface presents greater resistance to traction and allows water to percolate to the foundation of the road, thereby seriously injuring the whole structure.

Up to this time the macadam form of construction had been very satisfactory for the character of traffic for which it was designed, namely, that of iron-tired horse vehicles. In a perfectly constructed macadam road, the rock used is so adapted to the kind and

amount of traffic that the fine material worn off from the rock replaces that which is removed by atmospheric agencies. Under ordinary conditions it has been possible to maintain a hard and smooth surface at a moderate expense.

The advent of the automobile has changed very materially the character of the traffic. The action of the rubber tires is very different from that of iron tires, and practically no dust is worn off to replace that removed by ordinary wear. The great tractive force or shear exerted by the driving wheels of motor vehicles is the main cause of this injurious effect. It has been demonstrated by a series of experiments in which separate speedometers were connected to the front and rear wheels of automobiles that there is a very appreciable amount of slipping of the driving wheels on the surface of the road. This slipping effect throws into the air large quantities of the fine surface material, which is caught by the air currents generated by the car body and subsequently removed from the road by the wind.

Aside from the disintegrating action on the road, the dust raised by automobiles is a menace to health and a source of great discomfort to those living near much-traveled highways, especially in residential sections. Another consideration of importance is the damage to property, and instances are recorded where country estates have been disposed of far below their value, and farms and orchards abandoned owing to the dust nuisance.

The increasing number of automobiles each year emphasizes their importance as a factor to be taken into consideration, and consequently highway engineers have given careful study to the necessity of making a change in the present practice of road construction, as well as evolving some method of preserving the surface of the enormous mileage of roads already built.

The increased cost of maintenance resulting from these changed conditions has resulted in a search for some method of surfacing other than that commonly used on macadam roads. Various materials have been proposed and used, some of which are temporary in their nature and are simply intended as dust preventives. Others are more permanent in character and are advantageous in actually binding the surface of the road together, thus becoming an integral part of the structure. Of this latter class, crude oil and tar are the most important, and numerous preparations of these materials have been used with varying degree of success.

Coal tar has been employed in road building for many years. Tar macadam roadways were constructed in Nottingham, England, as early as the year 1840, although under rather crude conditions. Coal-tar pavements have been tried in various parts of the United States, but as a rule the results have not been satisfactory, asphalt being found superior as a paving material. In more recent years, tar macadam roads have been quite successful, and this form of construction is now used to a considerable extent.

* Read before the American Gas Institute.

The application of tar to the surface of a completed macadam road, while comparatively new in this country, was tried in France about forty years ago. The results were rather unsatisfactory, but the practice has been carried on to some extent at intervals since that time, especially in Italy and France.

In the United States the first experiment which attracted the attention of road engineers was in the summer of 1905, when a series of careful experiments were made at Jackson, Tennessee, by the United States Office of Public Roads in co-operation with the city engineer of Jackson, to determine the value of coal tar in the treatment of broken-stone roads. The widespread interest created by these experiments led to similar ones in various parts of the country, particularly in Massachusetts, Rhode Island, New York, New Jersey and Pennsylvania.

The variation in the methods of application and the lack of attention to the quality of the tar and the condition of the road have led to a difference of opinion as to the real value of coal tar in surface treatment.

The methods of applying the tar have varied considerably, but perhaps the one more generally used, especially in the earlier experiments, is to remove the dust and all loose particles by thoroughly sweeping the surface of the road and then applying the tar from an open kettle mounted on wheels and fitted with a portable fire box. The tar is brushed over and into the surface with stiff brooms such as are ordinarily used for street work. The kettle is kept in advance of the workmen, and by using two kettles and heating one while the other is in use the process is made continuous. After allowing the tar to soak into the surface for at least ten hours, it is covered with a layer of sand or fine stone screenings. When several hours have elapsed, the road is completed by rolling with an ordinary steam road roller.

In some places, and particularly in Europe, mechanical means have been employed for applying tar. Some years ago, the Road Improvement Association held in England a competitive trial in which many of the machines were fitted with ingenious devices. Nearly all of them provided for heating the tar and applying it under pressure by means of compressed air. Some of them were designed for carrying on the whole operation with one passage of the vehicle. The dust and loose particles were first removed by suction and drawn up into a receiver. The tar was then applied by compressed air and spread over the surface of the road by means of automatic brushes. The fine material previously removed was again distributed over the surface and rolled by the steam-heated wheels of the machine. Some of these machines were drawn by horses, and others, the larger ones especially, were self-propelled.

The method most commonly used at the present time is a compromise between strictly surface application and tar macadam construction and is known as the penetration method. In this method the surface of the road is broken up by means of a scarifier, new material added to fill ruts or other depressions, and the road reshaped. After a slight rolling without the addition of water, the tar is applied and allowed to stand as in the previous method. A dressing of fine material is then spread over the surface and the road well rolled, with the result that a surface is formed in which all of the spaces between the hard stone are filled with a minimum amount of tar. A road treated in this manner is similar to one built by the tar macadam process, in which the stone and tar are mixed before being laid.

Many of the trials which have been made with tar as a surfacing material have failed because of a lack of appreciation of a number of important details. The structure of the road, its condition at the time of treatment, the traffic to which it is subjected, the character and amount of tar used, are all important factors which are necessary for successful results.

The structure of macadam roads varies according as each engineer has deviated from the original method of macadam construction to meet his own ideas. As a rule, however, the formation of the road is much the same and is of minor importance in comparison with the actual condition of the surface at the time the tar is applied. The road should be dry and as free from moisture as possible, since water and tar are not miscible in any sense, and if the tar is applied to a wet road, the latter is, so to speak, tar proof, and proper penetration is impossible. In such a case, peeling of the surface is very liable to result, owing to the tendency of the tar to remain on the surface as a crust. It is equally important that the road surface should contain as little dust or loose material as possible, as the latter will absorb the tar instead of allowing the tar to be absorbed by the road. This again results in the formation of a crust, which under certain conditions will peel off, leaving the exposed surface of the road comparatively free from tar.

The kind and amount of traffic to which different roads are subjected is very variable, and in cases where the traffic is particularly heavy or excessive,

ruts and hollows are sure to exist. These irregularities in the surface make even rolling impossible, and unless repaired previous to tarring water will collect in them and soon exert a detrimental effect upon the tarred surface. In many instances traffic has been allowed on the road too soon after treatment, and this alone has been the cause of a number of failures.

The character of the tar is of almost equal importance as the condition of the road. Tars vary widely in composition even when produced by the same process. The character of the coal used, the method of carbonization and the temperature of distillation all have a decided influence on the composition of the tar. The value of coal tar in the surface treatment of roads depends almost entirely upon the binding power of its heavy bitumens. Besides these bitumens there are present other substances such as water, ammoniacal liquor, oily constituents including the light oils and the creosote or "dead" oil, naphthalene, anthracene and similar compounds, and free carbon, the proportion of which varies according to the manner in which the distillation process has been carried out.

The presence of water in coal tar has a similar effect as moisture in the road. If a tar containing water is applied to a dry road, the latter absorbs the water more readily than the tar, producing the tar-proof effect to which reference has already been made. Difficulty is also experienced in handling tar containing an appreciable amount of water since the water causes foaming, and if the vessel is heated by direct fire the danger of the tar going over the side of the vessel and taking fire is great.

Ammonia is another undesirable constituent, it being alkaline in nature and having a tendency to form with the oil constituents soluble compounds which are easily washed out by the action of the rain.

Naphthalene and anthracene, while they exert no particularly harmful effect as in the cases of water and ammonia, have no binding power, and their presence simply reduces the amount of bitumens which may be present.

Free carbon, like naphthalene, has no detrimental effect, but, on the other hand, it is a useless constituent so far as road treatment is concerned, and its presence reduces the binding power and waterproofing effect since it possesses none of these qualities itself.

The oily constituents of the tar are valuable to some extent since they act as diluents. The light oils are more or less volatile and are probably evaporated soon after the tar is applied to the road, but their presence makes the tar thinner and consequently renders their application easier. The creosote oils are also of some advantage, as it is claimed they add life to the tar and prevent its becoming too brittle.

The amount of tar is another important detail, and if more is applied than the road can properly absorb it will remain on the surface and be taken up by the top dressing with the resulting formation of a crust. Another objection to an excessive amount of tar is that it has a tendency to become sticky in warm weather and slimy in wet weather.

Sand or fine stone screenings have been used as a top dressing in the majority of the trials with coal tar, although occasionally the fine material removed from the road previous to tarring has been used. Stone screenings are probably the best material to use on a macadam road since they furnish a dressing of the same material as the road itself.

A comparison of coal tar with other road binders and dust preventives is somewhat difficult in the absence of really comparative experiments. Some few trials have been made in which different materials were used on the same stretch of road, but in most cases these experiments using such materials have been on different sections of roadways, and consequently the results are not truly comparable.

Another cause for lack of comparative data lies in the great diversity of materials which have been used. As we have seen, the efficiency of a dust preventive is in proportion to its binding power, and therefore a comparison of only those materials of approximately the same binding power is justifiable. The various dust preventives really form a series from water, which has no binding power, up to coal tar and the heavy asphaltic oils, which have the maximum binding power of any of the materials yet proposed.

Water, salt solutions and light oil emulsions are of the nature of temporary binders and are not to be compared with the more permanent ones such as coal tar and oils having an asphalt base.

The use of oil has been confined largely to the United States, and by far the greater portion of the work has been done in the West, owing to the proximity of the oil fields which supply oils with an asphalt base. In the eastern portion of the United States the cost of transportation has been so great that comparatively little experimenting has been done with oil. Tar has been used quite extensively abroad, especially in England and France. In the United States, its use has been confined very largely to the eastern and

northern States, although the park authorities of the larger cities have used tar to quite an extent.

Experiments have pretty clearly demonstrated that tar is not adapted for the treatment of gravel or soft earth roads owing to the fact that it does not amalgamate sufficiently well with these materials to bind them together. For roads of this class, therefore, oil has been more successful than tar. The use of tar has been and must be confined almost entirely to macadam or broken-stone roads, and for roads of this nature it is probably more suitable than oil.

Oil, as a rule, has greater power of penetration than tar, but its value is dependent in a large measure on its asphalt base, and before its maximum binding power is reached the more volatile constituents of the oil must be allowed to evaporate. This evaporation is a slow process, and until it is complete the disagreeable odor of the crude oil will be apparent and more or less objectionable. The use of oil has also received considerable criticism owing to the damaging effect which it has upon clothes and the paint and varnish of vehicles, especially in damp weather, when a greasy, disagreeable mud is formed.

Tar, on the other hand, solidifies quite completely as soon as it is cold and does not depend except to a small degree on the gradual evaporation of its volatile constituents for its hardening. It is comparatively free from the objection of being picked up and thrown by the wheels of vehicles, and although it has a decided odor which lasts for a short time after application, this is not particularly objectionable and to most people is much less offensive than that of crude oil. An objection is sometimes raised to the use of tar on account of a fine black dust which wears off of the tarred surface. It is true that such a dust is formed, but the amount is insignificant in comparison with the dust which would have formed if the road had been untreated.

It is claimed that coal tar has a decided antiseptic value, but how much importance can be attached to this feature is questionable. It is reported that an investigation was carried on in France to determine the number of germs present in the atmosphere over a tarred and an untarred road in the same neighborhood, and the number over the latter was found to be considerably in excess of those over the tar-treated section. Crude oil also possesses a similar antiseptic property, but to a very much less degree.

A properly tarred road is similar to an asphalt pavement, although of a more resilient character. The stone is all bonded together by the tar into a smooth, firm surface which can be swept and washed in much the same manner as an asphalt pavement.

The principal agencies which cause deterioration of tarred or oiled surfaces are heavy rain, frost, and the decaying organic matter which accumulates on the surface of the road. So far as can be determined, one kind of road withstands the action of these agencies as well as the other.

Water gas tar is used in connection with coal tar, but not to any great extent by itself. It has a greater power of penetration and less of it is required, but it is not so lasting in character. It is really in a class by itself and occupies an intermediate position between the temporary and the permanent binders. In some cases where a limited amount of money is available or where for climatic reasons it is advisable to treat the road with the idea of its lasting only through one season, water gas tar should prove a valuable dust layer, and any extension of its use will undoubtedly be in this direction.

The value of coal tar in the preservation of macadam roads and as a dust preventive is still unsettled. It is certain, however, that in the majority of cases the life of a treated road has been materially lengthened, and by applying tar the complete rebuilding of many roads at an enormous expense has been avoided.

One great drawback in the standardization of tar treatment is the impossibility of securing a uniform supply of coal tar. Coal tar is purely a by-product, and the processes by which it is derived are never run with reference to the quality of tar produced, but solely to obtain maximum yields of gas or coke, as the case may be.

The impossibility, therefore, of manufacturing tar to meet definite requirements makes it necessary to utilize the supply available, but in so doing a certain amount of selection can be exercised and changes made whereby some degree of uniformity is obtained. Some attempts have been made to control the quality of the tar, but with rather unsatisfactory results. The manufacture of special coal tar preparations was intended to provide a greater uniformity, but many of these are, in the opinion of those who have used them, very variable, and the success attending their use is not in proportion to the extra price paid for them.

Strictly surface treatment of an already existing road, even under the best conditions, can only be regarded as a temporary expedient, and its use will probably extend only in cases where for financial or other reasons the rebuilding of the road is not justified.

Partial reconstruction of the road whereby the sur-

face is loosened, reshaped and the tar applied before the rolling is done is undoubtedly a method of considerable value and one which will find more general application in the future. Many highway engineers

have predicted an entire change in the methods of road construction, but it is difficult to believe that the macadam method, which has been so universally and so successfully used for a long time, can be elimi-

nated. It is more probable that some modification of the macadam form of construction will be adopted, in which event the tar macadam method is sure to be one of the first to receive serious consideration.

CHARTING THE HEAVENS.

THE MEETING OF THE PERMANENT INTERNATIONAL COMMISSION.

BY JULES BAILLAND.

THE sixth meeting of the Permanent International Commission for Charting the Heavens has just been held at the observatory of Paris. The work of the commission is very important, and deserves detailed explanation.

In 1887 an International Congress decided to make a new photographic map of the heavens by the co-operation of seventeen observatories, situated in various countries and using instruments of the type of the astrophotographic equatorial telescope with which the brothers Henry had obtained some admirable photographs at the observatory of Paris. This immense work, which will give with precision the positions and magnitudes of more than 20,000,000 stars, will certainly furnish, when completed, an invaluable foundation for astronomical researches of all kinds. The accomplishment of the task appeared, at first, to require not more than fifteen years, but twenty years have passed and the end is not in sight. This delay was unavoidable and it has proved fertile, for the introduction of a new method brings to light new and unexpected problems and the work of the commission has influenced almost every branch of astronomy.

The original project called for the construction of an atlas showing all stars down to the 14th magnitude; that is to say, all the stars that can be seen with a telescope of 24 inches aperture. But, while existing atlases merely enable the astronomer to find his position among the stars, the new atlas will be a document of extreme accuracy, as the purely photographic method of reproduction necessarily records with precision, not only the positions, but also the relative sizes of the stellar images, although these are only a few thousandths of an inch in diameter.

At the 1896 meeting of the commission it was decided to adopt the heliogravure process, which has the very great advantage of preserving for the future, in the copper plate from which the maps are printed, an almost indestructible document, but which has the inconvenience of introducing a large number of false images. In order to distinguish the true images from the false it is necessary to expose each negative three times, thus producing for each star three images, arranged to form an equilateral triangle. In this way the true images can be easily recognized, but the time of exposure is tripled. Consequently, the photographic work of the commission is still far from completion. The French observatories have accomplished about one-third of the task assigned to them, and so have the observatories of San Fernando in Spain, and Tacubaya in Mexico. The heliogravure plates of their work are being made in France. The English observatories and the observatory of Helsingfors in Finland made their negatives by single exposures, and have finished their work. The plates made at Greenwich have already been printed, but these gelatino-bromide prints on paper, although very beautiful, are assuredly far less permanent, and consequently less valuable than the copper heliogravure plates. Some of the observatories have scarcely commenced their task, and a few have given up the work.

To the construction of this atlas was added in 1899

the work of establishing a catalogue of the exact positions of all stars down to the 11th magnitude. The short exposure negatives necessary for this purpose could be obtained rapidly in most observatories, and the practical difficulty, which is due wholly to the enormous number of measurements and calculations, becomes reduced to a question of money. There are, however, some theoretical difficulties. A star map represents a central projection of the celestial sphere upon a tangent plane. The rectangular measurements made in this plane are not directly expressed in the spherical co-ordinates, right ascension and declination. It was necessary, therefore, to establish formulas of reduction, as simple as possible. This auxiliary work necessitates a preliminary knowledge of the spherical co-ordinates, obtained by meridian instruments, of a number of stars, called stars of reference.

Unfortunately, good meridian positions are not known for all the stars which it was desired to use, and one of the first tasks of several of the observatories was the establishment of supplementary meridian catalogues, a task which certainly did not enter into the original project. The plan of work which has been adopted, however, allows the number of reference stars to be diminished. The parts of the sky photographed on the different plates overlap, so that the same co-ordinates ought to be obtained for any star found on two plates, no matter which plate is used. This fact makes it possible to use, in the determination of the elements of a plate, the reference stars of adjoining plates. This work of adjustment has not been begun, nor is the best method of accomplishing it yet decided upon.

In addition to the positions of stars, the catalogue gives their magnitudes. Here the problem to be solved is three-fold. It is required first to classify the stars of each plate according to magnitude; then to make a photometric adjustment of the different plates, so that their data shall be comparable to each other, notwithstanding the apparent differences caused by differences in the sensitiveness of the plates and the transparency of the air; and, finally, to fix the units in which the results shall be expressed. It is not difficult to classify the star images of a plate, for their diameters increase in proportion to the magnitudes of the stars, but in regard to securing uniformity among the plates and selecting the unit of magnitude there was no agreement until the last meeting of the commission. Many observers had partly solved the problem by comparing the magnitudes of certain stars, determined by visual photometric processes, with their magnitudes as estimated from the plates. But as these two results are furnished by different rays of the spectrum, they are not strictly comparable.

The advantages which observations of the planet Eros, made during the winter of 1900, offered for the determination of the solar parallax, and the great precision attributed to the photographic method, caused a large proportion of the observatories, at the suggestion of Loewy, to interrupt their work on the chart of the heavens for a time in order to make and reduce observations of Eros. The discussion of the

enormous mass of data thus accumulated has been concluded by Hinks of the observatory of Cambridge. This discussion, independently of its intrinsic importance, has been of great benefit in the work of the photographic star catalogue, by exposing numerous sources of error arising from defects of lenses and methods of reduction, and errors in the positions of reference stars.

In the meeting just held, the commission discussed all the questions at issue and prepared for observations of Eros during its opposition in 1931. Of particular interest was the announcement of the value found by Hinks for the solar parallax, 8.806 sec., with a probable error of two or three millionths of a second. The value previously accepted was 8.80 sec.

Some important resolutions were passed. The zones of the southern celestial hemisphere, work on which has not yet been commenced, were distributed among three observatories. Heliogravure plates have been made hitherto only for the French observatories and those of San Fernando and Tacubaya. The royal observatory of Belgium will follow their example in making the map of a region, of which the catalogue will be made by the observatory of Potsdam. There remain many regions which have been abandoned by the observatories to which they were assigned, because of lack of time, money, or facilities for heliogravure work. The French astronomers have had the great satisfaction of seeing confided to France the reproduction of the negatives of all the hitherto uncompleted zones traversed by the ecliptic; thus they will bequeath to future astronomers the image, engraved on copper, of a full half of the sky, constituting its most interesting portion, a monument worthy of their compatriots, by whose labors the visual map of the zodiac was made in the nineteenth century.

The attempt to make the magnitudes of stars in the new catalogue agree with the magnitudes in the visual catalogues has been abandoned, and as types of magnitude a number of circumpolar stars which have been photographed by the observatory of Harvard College have been chosen. Finally, in order to improve the positions of the stars of reference, it has been decided to make a new and complete system of fundamental meridian catalogues. This is an enterprise of the greatest importance and difficulty, which is made possible only by the progress accomplished in the last twenty years in the construction of meridian instruments. The task should be completed within a comparatively short period, owing to the collaboration and agreement of a large number of observatories and astronomers skilled in this special work. The permanent commission of the chart of the heavens, which had already extended its function to include the observations of Eros, has now extended them much further. In fact there is hardly a branch of astronomy, with the exception of spectroscopy, which will not be affected by the change in the positions and magnitudes of fundamental stars. Hence the commission, as one of its eminent members remarked, is reorganizing astronomy.—Jules Bailland, adjunct astronomer at the observatory of Paris, in *Revue des Sciences*.

ANTS AND THEIR SLAVE GUESTS.

ON some of the fine warm days that burst upon us in the early autumn, large swarms of winged ants issue forth and fill the air in certain localities, swarming over the bushes and trees, and even the grass in prodigious numbers.

These extraordinary excursions are expensive to life, for it would not be an exaggeration to say that the majority of these hordes perish, many from their enemies the insect-eating birds, and many more from cold and exposure during the damp autumnal evenings. These winged ants that swarm thus are composed of the two higher grades of caste in the communities, the males and females, some of whom are destined to be queens; the workers, which are the mainstay of the community, are modified females, and are wingless, and consequently take no part in these flittings. The main purpose of this autumnal migration from the nest appears to be for mating, and the females that survive become the founders of fresh colonies, or find their way into existing nests, which they strengthen the ensuing season by introducing fresh stock.

There are some species of ants that keep their colonies going by kidnapping at this time of the year the workers from other nests, and compelling them to work for the benefit of their community. These slave raids are made chiefly by the large Amazon ant, and the nests raided are generally those of the familiar brown garden ant. They time their raids to a nicety, for they make their attack just about the time the males and females are emerging from the pupa stage, but they do not want these; their object is to carry off the pupa of a worker, the others being left to perpetuate the species. These red marauders carry out their attacks in a very workmanlike manner, for an advance of scouts, who hurry back to report, always precedes the storming of the castle. A small vanguard, consisting of a few individuals, makes the preliminary assault; its object seems to be to engage the guardians of the castle, who quickly raise the alarm, and the garden ants pour out from the labyrinths of their nest in thousands. This is the signal for the main attack, and the red ants rush in in a body, and, overpowering the defenders, make their way into the

inner recesses, to emerge again, each one with a worker pupa in its jaws, and an orderly retreat is made back to their own quarters, where the pupæ are deposited, and tended with the greatest care. These kidnapped workers finally emerge into a state of utter slavery, for they have to perform the whole work of the red ants' nest; they build the passages, do the repairs, undertake the care of the pupæ, and work apparently just as hard and just as willingly for this more aggressive species as if they had been working for their own.

This employment of other species to serve their own ends is quite common among all ants, for it is a well-known fact that they keep cattle, in the shape of the aphides, which they tend very carefully, drawing a supply of milky fluid from them. The working ants, whether of their own or of another species, are always in a condition of slavery; guests are frequently entertained, certain beetles being always found in their nests, where, apparently, they serve no useful purpose, but are fed by their hosts with a liberal hospitality. The large horse ant always allows a smaller species