patient commenced treatment is in itself probably of little importance when allowance is made for the age at first onset of the disease and for the length of time it has been in existence.

Relation to Etiological Factors.

Heredity.—The occurrence of asthma in one or more of the near relatives of the patients has been taken for our purpose as evidence of a positive inheritance. Such an association has been found in 37.3 per cent. of all the cases in the present series. It should be noted that although a definite inheritance is more common in those patients who begin to have symptoms in the first ten years of life (about 1 in every 2 patients), there is a fairly uniform proportion of positives in each succeeding period (1 in 3 patients). From the table it will be seen that the figures for the cured and for the dead are distinctly lower than those for the other groups. If the occurrence of skin lesions among relatives is also included as evidence of an "exudative" heredity, the figures become even more definite. The percentage of positives for the whole series now becomes 41.0 and for the various groups: "cured" 31.7, "improved" 42.2, "unchanged" 48.4, dead 31.5. An attempt has been made to gauge the constitutional element by grouping the patients according to the number of the following factors which they show: asthma heredity, the occurrence of skin lesions among relatives, and the presence of hay fever, skin rashes, or protein sensitiveness in the patient. It is found that those subjects with the greater evidence of allergy begin to have symptoms earlier in life. From this it would appear that asthmatics having a positive heredity are somewhat less amenable to treatment, and that the less favourable results for the first five years of life might be explained by the greater proportion of hereditary cases commencing at this period.

Protein Sensitivity.—From a statistical point of view it is unfortunate that all the subjects have not been exposed to the same set of proteins. Owing to the large number of individual test substances available, it was not at first found possible to employ them all on each patient, and the choice was mainly guided by the history of the case. Later, the plan of testing every subject with a comprehensive series of "grouped" proteins has been adopted. The figures obtained, therefore, do not necessarily represent the true extent of sensitization, but merely the positive reactions found. The "positives" recorded include multiple sensitivity as well as single specific responses. The groups give a similar proportion of positive results, except that the figure for fatal cases is a little low. It should be observed, however, that in the case of the "cured" patients about half of the positives reacted to a single protein.

Respiratory Catarrhs and Infections.—These appear to be of great importance in the development of the asthmatic condition at all ages. It is sometimes said that in early life the exudative diathesis manifests itself by respiratory symptoms indistinguishable from bronchitis. After middle life a history of prolonged or severe bronchitis is more commonly found as a forerunner of the asthma. The patients, when examined, were merely asked whether such conditions were present at the time of, or immediately before, the first attack of asthma, and no account has been taken of previous health in regard to respiratory disorders. The proportion of individuals who give this history is high, and is much the same in each group. There is really no significant difference between the groups in this respect, and this factor does not appear to influence the result of treatment.

The Fatal Cases.

This group stands out from the others in various respects. Inheritance and protein sensitization are rather lower in this class, while respiratory infections are much the same as in the others. The average age of onset in the group is considerably higher—namely, 34.4 years, as contrasted with 21.5, 17.5, and 20.4 for the others. While 7 cases began before the age of 20, a large percentage of this group developed symptoms after middle life. A number of deaths is to be expected in such a group, but the proportion actually recorded is very much greater than would occur in a similar age sample of the community during the same length of time. Of the 36 deaths, 28 occurred in subjects

over the age of 40, 3 were under 20 years of age, and 5 between 20 and 40. Acute illnesses accounted for at least 8 of the deaths; these were influenza (patients aged 7, 14, 48, 55); pneumonia (aged 17); cholecystitis (54); meningitis (40); gastric haemorrhage (39). There were two suicides (50 and 61). Two fatalities were due to phthisis (26 and 32), both patients having previously had undoubted asthmatic symptoms. Syphilis accounted for 4 deaths (36, 60, 60, and 70) and cerebral haemorrhage for one (51). Five were attributed to heart failure (36, 43, 58, 63, and 70). In the case of the remaining 14 the exact cause of death has not been ascertained. These include some of the most severe cases, in which the patients are known to have been almost constantly dyspnoeic and in a condition of status asthmaticus with advanced emphysema and cardiac embarrassment. Additional information shows that before death 2 of the patients had been "cured" of their asthma, 7 were considerably improved, 2 slightly benefited, and 15 were unchanged. These figures have not been incorporated in the other sections.

Summary.

The results of treatment in 291 cases of asthma are reported. Of these, 66 per cent. have been benefited and 12.4 per cent. have died. No single scheme of treatment can be laid down for all cases; each patient must be treated individually. The most successful forms of therapy appear to be elimination when applicable, and vaccine treatment where respiratory infections complicate the asthma. Cases which react to a single protein are usually favourable, but the occurrence of multiple sensitivity is of little importance in relation to treatment. Among many factors less easy to assess, change of residence and general hygienic measures have contributed to the patients' improvement. The results of operations on the nose or throat are disappointing, and such treatment should only be recommended to relieve definite local symptoms. Cases arising in the first five years of life are less successful than those beginning later. This may depend on the unfavourable factor of a positive heredity. Asthmatic symptoms commencing after middle life are also apt to be less amenable to treatment. The duration of the disease before effective treatment is undertaken is of the greatest importance; the longer the delay the less satisfactory the result, although certain cases of long standing have benefited considerably under adequate treatment.

REFERENCE.

Lancet, March 9th, 1929, p. 517.

A GOITRE SURVEY IN ALBINO RATS.

BY

ROBERT McCARRISON, C.I.E., K.H.P.,
M.D., F.R.C.P.,

COLONEL, INDIAN MEDICAL SERVICE; DIRECTOR, NUTRITIONAL RESEARCH,
I.R.F.A., PASTEUR INSTITUTE, COONOR, S. INDIA.

DURING the past three years the practice has been followed of recording, at post-mortem examination, the state of the thyroid gland in all animals used in the laboratories of the Pasteur Institute, Coonoor, for experimental work on diseases of faulty nutrition. Post-mortem records of 2,561 albino rats have accumulated during this period. It is with these that the present survey deals.

Of the 2,561 animals 393 were "controls" fed throughout life on complete diets, and 2,168 were rats fed from an early age (approximately 40 days) until the time of their death on various deficient diets. Goitre did not occur in the former group; 148 cases of the disease occurred in the latter. The goitres were classified as follows: (a) Small enlargements amounting to less than twice the size of the normal organ, 84; these were called "slight goitres." (b) Moderate enlargements amounting to more than twice but less than four times the size of the normal organ, 41; these were called "small goitres." (c) Marked enlargements amounting to four or more times the size of the normal organ, 23; these were called "large goitres."

The relation of these goitres to endemic and hereditary influences, to hygienic conditions of life, to age, sex, and atmospheric temperature, to food, and to iodine, has now to be considered.

Endemic Influences.

Goitre is not endemic in Coonoor, nor in its neighbourhood. The indigenous inhabitants are entirely free from it. European and Anglo-Indian settlers do not acquire it, though their children may occasionally exhibit slight swellings of the gland, especially girls about the age of puberty. The iodine content of the soil is relatively high—118 to 400 parts per 10 millions (Newcomb). The urinary excretion of iodine by young adult males ranges from 60 to 400* per litre. The water supply is piped; it is bacteriologically pure and exceptionally soft. There is a poverty of lime in the soil. Endemic influences played no part in the causation of the goitres with which this survey deals.

Hereditary Influences.

Although many post-mortem examinations have been made in our well-cared-for and well-fed rats, no case of goitre has so far been found among them. This stock has been bred through many generations during the past eight years and has become acclimatized to the altitude (6,000 feet above sea-level). New blood is introduced from time to time to prevent in-breeding. The rats are small-sized and their thyroids are, at all ages and body weights, about half the size of those of albino rats used for experimental work in the United States of America (Fig. 1). Hereditary predisposition—a potent influence in the genesis of goitre—played no part in the causation of the goitres with which this survey deals.

Hygienic Conditions.

These are as nearly perfect as is possible in animals kept in captivity. A stock of between 500 and 800 animals is maintained throughout the year for breeding purposes. They live in straw-filled, screened cages; a pair with their young to each cage. The cages are kept scrupulously clean, and the straw is constantly renewed. The animals are exposed to sunlight when weather conditions permit; these conditions are favourable for the greater part of the year. The stock diet consists of unleavened bread (chapattis) made from whole wheat flour (atta) and lightly smeared with butter, the hard crusts of white loaves, diluted milk, sprouted "gram" (legume), green vegetables, and carrots *ad libitum*, an occasional small ration of raw meat, and fresh water in abundance. Under these conditions the stock animals remain in perfect health, are very fertile, and invariably rear the whole of their young, no matter how large the litters may be. There is practically no infantile mortality. During the past fifteen months there has been no death from natural causes among this stock. Reduction of their numbers is effected by killing off the older animals when they are 20 to 24 months old; in such of these as have been examined goitre has not been found. The young are removed for experimental purposes when they are about 40 to 50 days old; a sufficient number being retained for replenishment of the breeding stock. From time to time numbers of these young rats have been killed and their thyroids examined; no enlargement of the gland has ever been found. It may therefore be assumed that no young rats come to the experimentation rooms with enlarged thyroids. Any enlargement of the gland occurs subsequent to their transfer from stock.

The young rats used for the experimental production of diseases of faulty nutrition live under similar conditions of perfect cleanliness. Their screened cages are frequently sterilized; droppings adhering to the screens are removed by hand. A large staff of animal attendants is employed to maintain the high standard of cleanliness demanded. The animals are usually confined in separate cages; but sometimes they are paired for special purposes, as when it is desired to note the effects of certain diets on fertility. Their conditions of life differ from those of the stock animals in the following particulars: the majority are isolated from companionship with their kind; they are not provided with straw for bedding; and their food, except in well-fed controls, is invariably faulty in some respect. Both in the stock rats and in those used for experimental

purposes the goitrogenous influence of "dirt"—a potent one in ill-fed animals—is thus rigidly excluded. This factor was not, therefore, concerned in the causation of the goitres with which this survey deals.

Influence of Sex.

Among the 148 goitres there were 56 in males and 92 in females—an incidence of 4.5 per cent. in the former and of 7.8 per cent. in the latter. This difference in sex incidence is in conformity with the well-known fact that females are more subject to goitre than males.

Influence of Age.

One fact of probable significance emerged from a statistical analysis of the data relating to the age of the animals and the incidence of goitre. The incidence of the disease was highest (12.4 per cent.) in rats whose age—100 to 120 days—corresponded to the period of attainment to sexual maturity. A second rise, to 11 per cent., occurred in rats aged 220 to 240 days; but the number of animals of this age was small (76). No goitre occurred in rats aged 60 to 80 days. At age periods other than the three mentioned, the incidence of the disease was between 5 and 7 per cent.

Influence of Atmospheric Temperature.

The maximum shade temperature in Coonoor rarely rises above 76° F.; the minimum rarely falls below 50° F. From the middle of March to the beginning of October the maximum temperature in my animal houses is round about 75° F., the minimum round about 65° F. From October to March the maximum is 60° to 65° F.; and the minimum 55° to 60° F., falling occasionally to 50° F., and very occasionally to below 50° F. The temperature conditions prevailing between March and October appeared to be more favourable to the development of these goitres than those prevailing between November and the end of February.

Influence of Associated Diseases.

Associated diseases do not appear to have exercised any influence on the incidence of goitre in these rats; for whatever these diseases may have been—and they covered a wide range of morbidity—they were found as frequently in non-goitrous as in goitrous animals. In 51 of the 148 cases of goitre there was no associated disease.

Influence of Food.

As previously stated, no case of goitre occurred among 393 well-fed rats, while 148 cases occurred among 2,168 deficiently fed rats. This difference is statistically significant. It indicates that faulty food, deficient in certain elements and complexes necessary for normal nutrition, was the direct, or the indirect, cause of the goitres from which the rats suffered.

FIG. 1.—Showing the weight of the thyroid gland of Coonoor albino rats according to body weight (regression line $y = 0.080x + 1.24$; standard deviation of thyroid weights about the regression line: 1.35; correlation between thyroid weight and body weight: +0.95. For these calculations I am indebted to Lieut.-Colonel C. Newcomb, I.M.S.). The curve of thyroid weights for U.S.A. albino rats (Donaldson's *The Rat*, 1924, p. 218) is included for purpose of comparison.

1. The Well-fed Group.

Of the 393 animals in the well-fed group 121 were controls, fed on stock diet. They were killed by drowning. Their thyroids were removed and weighed, and the weights charted against the body weights of the animals (Fig. 1).

* γ represents 1/1,000 of a milligram.

So far from any of these thyroids being enlarged they were all found to be small relative to those of albino rats in the United States of America.

Forty animals in the well-fed group were fed, from the age of 40 days to the end of their lives, on certain national diets of India. These were of good biological value and of similar composition to that on which the stock rats were fed. The animals were killed by drowning on the 198th day of life; none were goitrous. A third group of 144 were fed on certain complete natural diets into which whole milk entered largely; these also were killed by drowning, at ages ranging from 200 to 220 days; no case of goitre occurred among them. The remaining 88 animals received complete synthetic diets containing iodine in the form of potassium iodide, this salt comprising 0.45 per cent. of the "salt mixture" (McCullum's) used in the preparation of the diets. These were killed by drowning at ages varying from 143 to 254 days; none were goitrous. It is to be noted that in the presence of a complete diet the continued ingestion of iodine in relatively large amounts did not cause thyroid enlargement in any of the 88 animals.

The average urinary excretion of iodine by the animals comprising the well-fed group was as follows: (a) stock diet, 56 γ per litre; (b) national diets, 85 γ per litre; (c) milk diets, 70 γ per litre; (d) synthetic diets, 200,000 γ per litre.

2. The Deficiently Fed Group.

A large number of faulty diets were used in the feeding of the 2,168 animals comprising this group. It is unnecessary for my present purpose to describe each of these in detail. Some were synthetic diets made up of refined materials; but the majority were defective diets composed of foodstuffs in common use by man. All had one or other or several of the following faults: deficiency of vitamin A, deficiency of vitamin B (fractions not differentiated), deficiency of vitamin C, deficiency of mineral salts, and deficiency of animal protein. No diets were used in which "vitamin B" (or either of its fractions), "vitamin D," "mineral salts," or "protein" was the sole deficiency. The various diets were grouped, according to the nature of their defects, into twelve categories. These, together with the number of animals used and the number of goitres occurring among them, are shown in Table I.

TABLE I.—Showing Deficiencies of Diets, Number of Animals Fed on the Deficient Diets, and Number of Goitres.

Category.	Deficiency or Deficiencies of the Diets.	No. of Animals Used.	No. of Goitres.	Percentage Incidence of Goitre.
I.	Vitamin A	79	2	2.5
II.	Vitamin C	110	0	0
III.	Vitamins A and C	376	17	5.5
IV.	Vitamins B and C	54	1	1.8
V.	Vitamins A, B, and C	357	42	11.4
VI.	Vitamin A and animal protein	20	1	5.0
VII.	Vitamins A and B and animal protein	36	4	11.1
VIII.	Vitamins A and C and animal protein	354	11	3.1
IX.	Vitamins A, B, and C and animal protein	30	6	20.0
X.	Vitamins A and C, mineral salts, and animal protein	628	55	8.7
XI.	Vitamins A, B, and C, mineral salts, and animal protein	120	7	5.8
XII.	Vitamin C, mineral salts, and animal protein	64	2	3.1
	Total	2,168	143	6.8
	Nil: Complete diets	393	0	0

These results appear to justify the general conclusion that vitamin deficiency was the main dietetic factor concerned in the occurrence of goitre in the rats under survey. While not desiring to assign to any single vitamin deficiency a

paramount place in favouring the development of these goitres, it would seem from the foregoing data that deficiency of vitamin A was of great importance, that a combination of vitamin deficiencies was more potent in favouring the development of goitre than the deficiency of a single vitamin, and that default of other food essentials, such as suitable protein and mineral salts, was not without some contributory influence. Whatever may have been the paramount dietetic factor concerned in the production of these goitres the broad general fact remains: rats living under sanitary conditions and fed on perfectly constituted diets did not develop goitre, whereas rats fed on imperfectly constituted diets did.

Some of the deficient diets were of a composition admitting of little or no growth, as, for instance, when their content of certain vitamins was very low; the period of survival of these rats was relatively short. Other diets, though lacking optimum amounts of one or more vitamins, contained enough to allow of considerable growth, and of longer periods of survival. An analysis of the rates of growth and of the periods of survival of the 2,168 ill-fed rats with respect to size of the goitres showed that the greater the daily average gain in body weight and the longer the period of survival, the larger, as a rule, were the goitres. Thus, a diet composed of white flour, meat residue, olive oil, salt mixture (containing potassium iodide), and water permitted of little or no growth in young rats, though a few survived for periods as prolonged as 165 days and were then killed. The incidence of goitre (which was of the lymphadenoid type) in rats fed on this diet was 25 per cent.; but all the goitres were "slight" or "small." On the other hand, a diet composed of white bread, dried yeast, lime, and feebly iodized water admitted of considerable growth and of the survival of some animals for periods as prolonged as 191 days. The incidence of goitre among young rats fed on this diet, during the spring and summer months, was 41.7 per cent., the majority being "large goitres." Both the rate of growth and the period of survival of the animals were dependent in great measure on the character of the food and the degree of its defects. The dietetic conditions most favourable to the production of considerable goitres were provided by diets composed of foodstuffs which, while deficient in certain essentials (chiefly vitamins), were not wholly devoid of them.

The urinary excretion of iodine by animals fed on the deficient diets ranged between 33 and 158 γ per litre; except in animals fed on synthetic diets containing potassium iodide, when it averaged 200,000 γ per litre.

Influence of Iodine.

Iodine, either in the form of iodized drinking water or of potassium iodide, was added to the diets of 630 of the 2,168 ill-fed rats; it was not added to the diets of the remaining 1,538. Seventy-three cases of goitre, or 11.5 per cent., occurred among those receiving iodine; 75 cases, or 4.8 per cent., occurred among those not receiving iodine.

Of the twelve categories into which the deficient diets fell (Table I) there were three which afforded definite information regarding the effect of adding or withholding iodine. These were: (III) a combination of vitamin A and vitamin C deficiencies, other essentials being adequate; (V) a combination of vitamin A, vitamin B, and vitamin C deficiencies, other essentials being adequate; and (X) a combination of vitamin A and vitamin C deficiencies with deficiency of mineral salts and of animal protein. Grouping the diets having these faults together, it was found that 576 animals fed upon them had iodine added to their food, while 725 had no iodine added to their food. In the former there were 66 goitres, or an incidence of 11.4 per cent.; in the latter there were 48 goitres, or an incidence of 6.6 per cent. Taking into consideration only those experiments in which goitre occurred it was found that there were 73 goitres among 378 animals to whose food iodine was added, and 75 among 1,236 animals to whose food iodine was not added; an incidence of 19.3 per cent. in the former, and of 6 per cent. in the latter.

Twelve of the 23 "large goitres" occurred in 72 animals to whose food iodine was added; an incidence of 16.6 per cent. Eleven of the 23 "large goitres" occurred in 280 animals to whose food iodine was not added; an incidence of 3.9 per cent.

Seventeen of the 41 "small goitres" occurred in 132 animals to whose food iodine was added; an incidence of 12.8 per cent. Twenty-four of the 41 "small goitres" occurred in 500 animals to whose food iodine was not added; an incidence of 4.8 per cent.

Forty-four of the 84 "slight goitres" occurred in 174 animals to whose food iodine was added; an incidence of 25.3 per cent. Forty of the 84 "slight goitres" occurred in 456 animals to whose food iodine was not added; an incidence of 8.7 per cent.

These differences are statistically significant; they indicate that the administration of iodine to the deficiently fed animals definitely favoured goitre-production.

The urinary excretion of iodine in the rats to whose deficient food iodine was added, and amongst whom goitre occurred, ranged between 85 and 158 γ per litre, except in animals fed on synthetic diets containing potassium iodide, when it averaged 200,000 γ per litre.

Histological Appearances of the Goitres.

Ninety-five of the 148 goitres were serially sectioned and examined microscopically. In 16 of these the post-mortem changes were so marked as to obscure the histological picture. The remaining 79 fell into the following groups, though it was not always easy to decide to which group certain specimens belonged.

(a) Nine were glands presenting no abnormality other than their "slight" increase in size.

(b) Seven were "slight" or "small" enlargements in which intense hyperaemia was the only obvious pathological change.

(c) Eight were colloid glands, all being "slight goitres." Some of them contained small keratinization cysts.

(d) Sixteen were simple hypertrophic enlargements, several appearing to merge into the lymphadenoid condition. Nine were "large" and seven were "small" goitres.

(e) Thirty-five were lymphadenoid goitres, 25 being "slight," 4 "small," and 6 "large." The characters of this type of goitre and the dietetic conditions under which it arises have previously been described in this *Journal*.

(f) Four were chronic hypertrophic goitres, presenting the features characteristic of this condition. All were of moderate size and all occurred in rats fed for long periods on natural diets consisting largely of whole wheat flour (atta) but poor in green vegetables and in vitamin A-bearing ingredients.

Summary.

1. A survey was made of 2,651 albino rats in a locality (Coonoor) where goitre is not endemic; 148 were found at post-mortem examination to have goitre. Of these goitres 84 were classified as "slight," 41 as "small," and 23 as "large."

2. The temperature conditions of the spring and summer months in Coonoor appeared to have been more favourable to the development of the goitres than those of the autumn and winter months.

3. The incidence of goitre was higher in females than in males.

4. Goitre was commonest in rats whose age corresponded to the period of attainment to sexual maturity.

5. Associated diseases did not appear to have exercised any appreciable influence on the incidence of goitre in these rats.

6. The goitres are not due to endemic influences.

7. The rats had no hereditary predisposition to goitre, nor were they subjected to insanitary conditions of life; both of these influences are favourable to the genesis of goitre.

8. Well-fed rats (393), living under sanitary conditions, did not develop goitre; ill-fed rats (2,168), living under sanitary conditions, did. The incidence of goitre in the latter was 6.8 per cent.

9. Faulty food deficient in vitamins was the direct, or the indirect, cause of the goitres.

10. The dietetic conditions most favourable to the production of considerable goitres were provided by diets deficient in, but not wholly devoid of, certain food essentials (chiefly vitamins).

11. The administration of iodine to deficiently fed rats was definitely favourable to goitre production; its administration to rats fed on physiologically complete diets did not favour the occurrence of goitre.

12. All grades of goitre ("slight," "small," and "large") were more common in deficiently fed rats to whose food iodine was added than in those to whose food iodine was not added.

13. The urinary excretion of iodine by rats fed on deficient diets having a composition favourable to goitre production was in some experiments as low as 33 γ per litre and in others as high as 200,000 γ per litre.

14. The histological appearances of 79 of the 148 goitres are briefly described; 44.3 per cent. were lymphadenoid goitres; 25.3 per cent. were hypertrophic goitres, some merging into the lymphadenoid condition.

15. The normal thyroid glands of Coonoor stock albino rats are, at all ages and body weights, approximately half the size of the normal thyroid glands of albino rats in the United States of America. Standards of normal thyroid weights for albino rats in one part of the world may not be applicable to albino rats in another part of the world.

COKE-MEN AND BY-PRODUCTS WORKERS: THEIR COMPLAINTS AND MALADIES.

BY

SIR THOMAS OLIVER, M.D., F.R.C.P.,

EMERITUS PROFESSOR OF MEDICINE, UNIVERSITY OF DURHAM COLLEGE
OF MEDICINE, NEWCASTLE-UPON-TYNE.

COKE, so essential for the smelting of iron, and also useful for domestic heating, is the residue left when coal has been subjected to a high temperature, away from contact with air, and which during the process of carbonization has lost several of its volatile constituents. It is a British product. Coking of coal goes back as far as 1580, when a patent was granted to John Thornberough, a Dean of York. Until recently, the carbonization was mainly effected in what are known as "bee-hive" coke ovens, rows of which can be seen from almost any railway train passing through a mining area. When these ovens are properly filled with coal, closed up, and heated by flues, the gas given off ignites within the ovens and fills the dome with flame. When all the gas has burned off the upper part of the dome is opened, the red-hot material inside is cooled by water spray, and is subsequently removed. As this is a wasteful method, "bee-hive" ovens have been replaced by "retort" and by "by-product" ovens. In the latter the gases are not burned off at their point of origin inside the oven, but pass by an up-take pipe to the roof into a water-sealed trough or collecting main, whence, to quote from the *Encyclopædia Britannica*, "they are drawn by exhausters through a series of air and water-cooled condensers and scrubbers." In the first condenser, tar is deposited by the fumes passing from the ovens, and in the second the ammoniacal liquor is caught. This liquor, after a process of scrubbing, and with its ammonia content increased, passes on to the ammonia stills. During scrubbing with creosote or heavy tar oil, benzene is removed. When the remaining material is distilled, the tar, having yielded up burning oil, becomes pitch, and the benzene is removed from the creosote oil by steam in heated stills. To the ammoniacal liquor lime is added, and on heating this the ammonia is vaporized. The ammonia is collected, and is subsequently condensed in metallic tanks containing sulphuric acid. Ammonium sulphate—a highly valued product for manurial purposes—is thus formed. Further by-products can still be obtained, such as toluol, naphthalene, pyridine, and motor spirit—the last, also known as benzol, being a mixture of benzene, toluene, and xylene.

The by-products obtained from coal vary with the coal-fields which furnish the raw material. South Wales coal gives the largest amount of coke—80 per cent., compared with 75 per cent. from that of county Durham; but Durham coal furnishes a larger amount of tar—3.85 per cent., compared with 2.6 per cent. from Welsh coal. The coal of South Yorkshire contains the largest amount of crude benzol—namely, 1.37 per cent.—while the coal of Durham contains 0.93 per cent., and that of South Wales 0.60 per cent. These figures are interesting, not on account of their varying commercial and economic values, but because they