Mathematicians have postulated that three kinds of space may be possible—*viz.*, Euclidean, hyperbolic and spherical (Riemann). Propositions in hyperbolic geometry or Riemannian geometry can be translated into analogous propositions in Euclidean space. So if there be no inconsistency in Euclidean geometry, there will not be any inconsistency in the other geometries. This is what is called by Poincaré as "the dictionary method of proof". A simple analogy between French and English may make the point clear. Any idea capable of being expressed in English can equally be well expressed in French—we cannot say one language is more perfect than the other. Similarly, we cannot say that Euclidean geometry is more perfect than the Riemannian geometry. Each is self-consistent and is found to be within limits of our empirical observations, but when we have to explain astronomical phenomena we find that Riemannian geometry suits us better. In accordance with Einstein's theory of Relativity, matter is responsible for curvature of space dimensions. Space if there be matter inside it bends round until it closes up.

Initially gravitation balanced repulsion, but it was an unstable condition. A slight disturbance must have caused the original space (containing matter) or the universe to contract or expand. Eddington and Lemaitre maintain that the universe is expanding. The spectrum of a star or a nebula has got a number of dark lines which are found to be shifted from their proper positions when compared with light from terrestrial sources. In most of the nebulæ the shift is towards the red end of the spectrum and the light emitted by a nebula when it reaches the earth has larger wavelength and smaller pitch than the normal. It is a matter of common observation that the sound emitted by a motor car horn becomes lower in pitch when it is receding from us than when it is coming towards us. So it is a possible explanation that the nebulæ are receding from us. It is also found that the velocity of recession of a nebula is proportional to its distance from us. So we may have been originally bounded in a nutshell, but as the universe is steadily increasing we may rightly think that we are gradually conquering infinite space.

Other explanations may be possible for the shift of spectral lines, some of these theories are more novel and more grotesque than the theory of expanding universe. We are not really in a position as yet to know the exact truth.

An astrophysicist can verily be compared to a blind man seeking for a black cat in a dark room that is not there. The present position of a scientist may be summed up as follows:—

"Nature and Nature's laws lay hid in night
God said, 'Let Newton be' and all was light
But not for long. The devil howling 'Ho'!
Let Einstein be, restored the *status quo*,
For how long? the sceptic smiling ask
No answer comes, Nature puts on her mask."

Chemistry in Modern Warfare.*

By Sir Martin Forster, F.R.S.

THERE are so few fundamental phases of twentieth century war into which chemistry does not enter, that it is unhappily permissible to define modern warfare as chemistry applied to the destruction of life and property. The principal factors in such warfare, other than the human beings who use them and are destroyed by them, are propellents, high explosives, detonators, poison gases, screening smokes, toxic smokes, incendiaries and gas masks.

A successful propellent must produce a relatively large volume of gas in an orderly and progressive manner, this purpose being best fulfilled by cordite which began to supersede gun-powder nearly fifty years ago. Cordite is a tough, amorphous, waxy solid produced by compounding the trinitrates of cellulose and glycerol (better known as gun-cotton and nitro-glycerine respectively) with vaseline, acetone also being used to facilitate incorporation. Gun-cotton being a trinitric ester of cellulose is a chemical step-sister of artificial silk in one of its forms, namely, acetylcellulose.

The most commonly used high explosives are picric acid (formerly called lyddite) and trinitrotoluene, familiarly known as T.N.T., the former is obtained from phenol (carbolic acid) by nitration, and as the quantity of carbolic acid obtainable from the purification of illuminating gas was inadequate when the Great War began, phenol came to be manufactured in large amounts from benzene. T.N.T. is obtained by the same process (nitration) applied to toluene, a new source of which was found in Borneo petroleum. Both picric acid and T.N.T. are yellow solids; they are melted and poured into the shells where they are detonated by mercury fulminate.

The sudden demand for cordite, picric acid and T.N.T. caused by the outbreak of the Great War led to a corresponding demand for nitric acid, and a far-reaching consequence, immeasurably important because it unhappily lengthened hostilities by two or three years, was the manufacture of nitric acid from air nitrogen by the German chemists. Before the War, the principal source of nitric acid was Chile saltpetre, and when the naval blockade deprived Germany of this material it was found that the accumulated stock in that country would be consumed before the close of 1915. Further attack on the allies must then have ceased. Confronted by this quandary, German chemical resource displayed itself in dauntless measure. Already there were known several ways by which inert atmospheric nitrogen could be fixed, the principal ones being the arc process of Birkeland and Eyde, and the catalytic process of Haber. The former required unlimited electric power in which Germany was deficient, so the Haber process by which nitrogen is combined with hydrogen to

* Summary of a lecture delivered on 10th January 1936 in Bangalore (University Extension Lecture, University of Mysore).

form ammonia, came to be adopted. Ostwald had shown how ammonia may be catalytically oxidised to nitric acid, so by linking the Haber and Ostwald processes Germany provided herself with the vast quantities of nitric acid required for continuing the war.

Coming now to the so-called poison gases, it will be appropriate briefly to comment on the history and ethics of gas-warfare. In the first place it will have been observed that it is erroneous to imagine that the term chemical warfare applies only to gas-warfare. All modern warfare is chemical warfare and gas-warfare is only one aspect of it. Moreover, the idea at least and to some extent the practice of gas-warfare is by no means new. The Spartans, earlier than 400 B.C., used sulphur dioxide, and similar use of poisonous gases was made in the Middle Ages. During the Crimean War (1853-56) it was proposed to use sulphur dioxide against the Russians, but the British Government of the period rejected that plan on the ground of humanity. At the Hague Congress of 1907 it was expressly forbidden to use poisons or poisonous weapons in war.

It was therefore a complete and overwhelming surprise when, on April 22nd, 1915, the Germans launched their first gas attacks using chlorine projected from pressure-cylinders containing the liquefied gas. It occurred on the north-west part of the Ypres salient, and the effect was disastrous. A breach, both deep and wide, was made in the Allied line, and had the Germans been ready to follow up their advantage the result might have had a rapid and permanent effect on the course of the War: but happily they surprised themselves as well as the Allies, and the only permanent effect was adoption of reprisals. In May 1915, it was decided to organise a gas service which became effective in September and until the Armistice in November 1918 gas-warfare became an increasingly important branch of the conflict.

Chlorine was the most readily available of the poison gases, the pre-War manufacture being enormous owing to its use in the manufacture of bleaching powder. Moreover, it is the foundation material of other poison gases, of lachrymators and sternutators, while conversely it was used for sterilising the drinking-water required by the armies. Following chlorine there came in December 1915, phosgene, a compound of chlorine with carbon monoxide. Phosgene is much more toxic than chlorine, and being chemically less reactive, protection from it is more difficult. Fortunately the British were informed beforehand of its intended use, and were therefore ready with hexamethylenetetramine in the masks.

Mustard gas (dichloroethyl sulphide) was first used in the War by the Germans at Ypres in July 1917. By this time wave-attacks had been largely superseded by shells containing the noxious materials, this being widely distributed when the shells burst. Consequently and in view of its low vapour pressure mustard gas-attacks were always made by shell. The first was another surprise, causing twenty thousand casualties in six weeks, the physiological action being disastrous and peculiar. As in the case of poisoning by phosgene, there is a latent period before any effects are noticed, the most characteristic of these being the vesicant, or skin-blistering action, which occurs from four to twelve hours after exposure to the vapour or splashes. This action is much more intense when the skin is wet than on dry skin; consequently the effects on the eyes and lungs are frightful, besides being toxic. It lingers for two or three days in the warmest weather; while in cold, damp weather it is dangerous for a week or ten days. It is only slowly destroyed in the earth, so that digging round shell-holes remains dangerous for months.

Besides the foregoing, there were used as poison-gases chloropicrin and diphenylchloroarsine (sneezing-gas), but the deadly Lewisite was elaborated only as the War closed, and was never used on the battle-front. Lachrymators, that cause involuntary weeping which leads to temporary disablement, were usually bromine compounds, *e.g.*, bromoacetone, benzyl bromide and bromobenzyl cyanide. With improved efficiency of gas-masks these diminished in importance being useful chiefly against unprotected troops.

Screening-smokes have great practical value and are produced by burning phosphorus or by launching into moist air the vapours of tetrachlorides of tin, silicon, or titanium, all of which are thus converted into the hydrated metallic oxides. Latterly came Berger Mixture (containing zinc, carbon tetrachloride, sodium chlorate, ammonium chloride and magnesium carbonate), used in the smoke box and smoke candles. Toxic smokes are screening-smokes which carry a poison-gas, diphenylchloroarsine for instance. Another type of smoke is used for signalling, and depends on volatilisation of organic dyestuffs, *e.g.*, chrysoidine, auramine and indigo. Incendiary bombs depend principally on thermite (aluminium and oxide of iron), but as its action is confined to a small area and being rapid, quickly disperses the heat-energy, thermite is used in conjunction with so-called solidified oil, *i.e.*, petroleum absorbed by soap.

Measures taken for defence against gas revealed ingenuity and resource corresponding to the demands made by complications in gas-warfare, and led finally to the box-respirator, whose essential mechanical features are: (1) an enclosed face-piece protecting the eyes and skin, (2) a flexible hose connecting this with a canister of absorbents, (3) an exhalation valve, and (4) an efficient packing of chemical absorbents in the canister. The requirements of an efficient absorbent are: (1) Absorptive activity, *i.e.*, a very high rate of absorption, (2) Absorptive capacity, *i.e.*, the material must hold large gas-volumes per unit weight, (3) Versatility, *i.e.*, protection against any kind of toxic gas, (4) Mechanical strength to resist conditions of transport and field-use, (5) Chemical stability, *i.e.*, escape from deterioration with time, and (6) Low breathing-resistance, importance of which may be realised from the fact that a normal man when exercising violently, inhales about 60 litres of air per minute. The absorbents best qualified to meet these requirements are activated charcoal made from cocoanut-shells, and soda-lime with a small proportion of sodium permanganate.

Having now surveyed some applications of chemistry to modern warfare, some remarks may be offered on the non-technical aspect of these applications. In the first place, you will have seen that the popular use of the term "chemical-warfare" in connection only with poison-gas is erroneous: all modern warfare is chemical warfare and superiority is determined by capacity to manufacture and skilfully to apply chemical materials. In the second place, it is erroneous to regard gas-attacks as more inhumane than destruction with explosives or bayonets; probably this misconception is owing to the frightful results of such attacks on unprepared troops. After the first surprise and consequent elaboration of protective measures gas-attacks were far less destructive than bullets and explosives. This appears very clearly from the official casualty-lists of the American troops, who, coming late into the War, were fully prepared against gas. In round figures, 25 per cent. of all casualties from bullets and explosives resulted in death, while of those wounded by gas only 2 per cent. died. It is thus fallacious to blame Science for having made War, more inhumane. War is the most brutally inhumane agency imaginable and introduction of scientific methods only implies that the power commanding superior inventiveness must ultimately prevail. The famous American naval expert, Admiral Mahan, who wrote a masterly and arresting book entitled "The Influence of Sea-Power upon History" was an American delegate at the Hague Conference of 1899, when several of the more prominent nations of Europe and Asia, including Germany, pledged themselves not to use projectile whose only object is to liberate suffocating or poisonous gases. The United States never signed the declaration, and Admiral Mahan stated his position in these words:

"The reproach of cruelty and perfidy addressed against these supposed shells was equally uttered previously against fire-arms and torpedoes, although both are now employed without scruple. It is illogical and not demonstrably humane to be tender about asphyxiating men with gas, when all are prepared to admit that it is allowable to blow the bottom out of an ironclad at midnight, throwing four or five hundred men into the sea to be choked by water, with scarcely the remotest chance to escape."

The subject needs clear thinking. To me, the criminal aspect of poison-gas lies in breaking the agreement not to use it.

The Place of India in Pre-History.*

THOUGH absolute dating in time is impossible in pre-history a geological chronology can be constructed, and at the time when man appeared glacial deposits were being formed in the north, while in the tropics corresponding climatological changes have resulted in deposits the relation of which to those further north is now being investigated.

The evolution of man's brain from lower to higher levels is reflected in the degree of perfection achieved in the tools he used and, as different types of tools form a sequence agreeing with the sequence of geological strata, they afford the best available evidence of the course of human evolution during the early Ice Age, human fossils being fragmentary and very rare.

In Europe the most primitive tools are called Eoliths or "dawn stones". From these tools, which are so crude as to be scarcely recognisable as such except to a trained eye, the sequence passes through successive stages of finer and finer workmanship in the process of flaking by which they were made, to more useful artifacts upto those of the Neolithic Age of polished stone which in its turn passed into the metal era. Each stage —Chellean, Acheulean, Mousterian, etc.—is named after a type station in Europe, and such cultural stages are well defined and easily recognisable. But the evolution was not smooth, for in Europe two civilisations are found to have alternated, fluctuated and finally merged as the peoples respectively advanced and dominated or fell behind, till at last they were assimilated the one into the other. The first of these groups is called the Core Tool People since they generally used as implements stone cores shaped by the striking off flakes. The second is called the Flake Tool People, since they used as implements flakes struck off from a core — a difference in method of manufacture involving a fundamental difference in psychology. It seems likely that the Flake peoples of Europe were invaders from Asia and the Core peoples from Africa. The Mousterians were probably a mixture of the two, though there were later invasions from Asia during Upper Palæolithic and Neolithic times.

A somewhat similar history can be traced in Africa. But there the core technique was definitely dominant while the flake technique did not gain much hold except in the north, where Asiatic influence would be more readily felt. In China, on the other hand, all cultures so far studied are flake cultures, the earliest being rather Mousteroid in form but of a coarser type, though lately a core-pebble culture similar to that found in North India has been reported.

The special importance of India for the proper interpretation of the facts of pre-history lies in her position in the geographical centre for Europe, Africa, China and Java, as well as in the many artifacts known to occur there and in the Primate remains of the Siwalik deposits which give grounds for hope that humanid remains may eventually be found there also, especially in view of the hypothesis put forward by physical anthropologists that the strenuous climatic conditions resulting from the uplift of the Himalayas were deciding factors in human evolution.

Research in India is also needed to throw light upon the origin of the Asiatic invasions of Europe in Aurignacian and Neolithic times, for it is in India that the earliest proto-Neolithic tools of Asia seem to occur; while the apparent absence of true Asiatic flake cultures from India also calls for further investigation. Though Asia may open the door to a true concept of the pre-history of man, India holds its key.

* A brief summary of the lecture delivered by Mr. T. T. Paterson of the Yale-Cambridge India Expedition, on Thursday, November 28, under the auspices of the Archæological Society of South India, Madras.