

CHAPTER THREE

THE CONQUEST OF DISTANCE

- § 1. *The Increasing Range of Modern Life.*
- § 2. *Railway and Steamship.*
- § 3. *The New Road and the Airway.*
- § 4. *The Transmission of Fact. The Present Moment
Becomes World-Wide.*
- § 5. *Print and Film.*

CHAPTER THREE

THE CONQUEST OF DISTANCE

§ 1. *The Increasing Range of Modern Life*

THE preceding chapters have been, as it were, preparatory to the essential material facts we have to consider. We are now in a position to set about our summary of man's activities, our actual world in its present phase of evolution from local and transitional to world-wide and measured and planned economics.

In the next three or four chapters it will be convenient to use that non-existent *Science of Work and Wealth* to which we have already made reference, as though it were a work actually at hand, even more frequently than we have done already. And also these museums yet to come must be invoked again and again. We go through these chapters in great danger of technological avalanches. Whenever the detail becomes too abundant and threatens to encumber the development of the general argument, or where material has been altogether unattainable, we will wave a hand towards phantom galleries or carry over by a reference to the encyclopædic contents of that imaginary work.

When some years ago I made the first rough notes for this work, I planned to begin with food. I thought we could open our survey with the present food supply of mankind and tell how man eats - and how he gets his food. That had an attractively fundamental air about it. One must eat to live. And the rest follows. But so soon as I came to the detailed planning of this part it became evident that we must first deal with the transport systems of the world. The world a century or so ago was living upon food that grew at its door. The modern eater in the great modernized communities stretches his hand half-way round the world for every other mouthful. This increase of range is a prior consideration to any treatment even of the eating, much more of the clothing or housing of mankind.

THE WORK, WEALTH & HAPPINESS OF MANKIND

Extended range of action is indeed the key idea to almost all the great problems with which mankind is at present confronted. In the *Outline of History* it is shown how this has acted as an expansive force politically and how the salvation of man from the ever more destructive and disorganizing activities of war is now only possible through the establishment of a World Pax. The revolution in transport has made all existing governments provisional. It has "abolished distance" and jumbled them up together. In this work we must extend these political conclusions to the whole of the economic life. It has become infinitely easier to-day for a New Yorker to trade with a man in Pekin than it was for him to trade with a man in Maryland a hundred years ago. It is necessary to say something of the processes by which things have come to this pass before we can study the developing consequences.

§ 2. *Railway and Steamship*

A full and exhaustive account of world transport would have to begin with a brief review of transport in the past and the progressive escape of mankind from geographical limitation. Here we can but glance back for a moment to our historical opening and say something about the more or less concurrent invention of wheel and road. The Hittites had roads. The great Persian roads that figure so importantly in classical history were but an extension of that more ancient system.

What seem to have been the primary civilizations had, however, little need of road or road transport, and in Mesopotamia and Egypt road systems remained undeveloped. These first states grew up upon the courses of great rivers, and the river was the connecting link that bound the village to the city and the cities into a state. Man learnt to navigate on these rivers before he put out to sea.

For a long time sea communications were too precarious for essential economic interchanges. There was overseas trade in ornaments and luxuries generally, in rare metals and substances and the like. Probably kidnapping and slave-trading played a large part in the early stages of overseas merchandising. The seaman could lapse very easily into piracy; the shore trader become a wrecker. And early navigation was a very marginal and subsidiary thing to the general economic processes of that time. The general life would

THE CONQUEST OF DISTANCE

have lost only a gleam of colour and a touch of variety if there had been no sea trade at all. There was one exception in the case of Rome during its period of maximum expansion, but otherwise overseas shipping was not a vital organ in economic processes.

Coming on from the older phases of human prosperity to the modern renewal of progress it is interesting to note the development of the canal system in the opening phase of the new industrial age. It will serve to remind us of an important fact already noted in the *Outline of History*, that the industrial revolution preceded the mechanical and scientific one. They were two separate processes which became confluent. One had a precedent and the other was new. There had been an industrial revolution and a factory system (book-copying, e.g.) in Rome. And these eighteenth-century canals also were the revival of a very old idea which had been worked out in China ages before.

But a new intellectual activity was afoot. A certain William Smith, an engineer engaged in canal-making in England, noticed the relations of strata and fossils in the earth in which he worked, and evoked stratigraphic geology as a by-product. He gave body and reality to the speculations of the scholars and philosophers. The traditional cosmogony, the literal authority of the Bible and much else, was drowned by accident in the waterways of the English Midlands. Research and innovation were thereby disencumbered from a very heavy obstruction.

The Marquis of Worcester's *Century of Inventions* (1663) was an early indication of the essentially practical stir that distinguished the intellectual revival of post-mediaeval Europe from the phase of Hellenic vigour. That book described a vague, unrealized steam engine, the intimation of what was at hand.

The steam engine arose as a pumping engine, a clumsy mechanical Dinotherium. The first one in use was Savery's, in 1698. For a whole century the steam engine did little more than pump. It came out of the mines at last (1803) to meet with the old obvious idea of rails and give us the railway. A road steam carriage had already been made in France in 1769 by Cugnot. The steam railway had become possible because iron rails had become possible. But it was still extraordinarily clumsy by present-day standards, because the conquest of the necessary substances was only beginning. Stephenson's *Rocket* was made of "cast and wrought iron and a small

THE WORK, WEALTH & HAPPINESS OF MANKIND

amount of brass, while, as Sir Henry Fowler has pointed out, specifications for fifty-five separate metals are now required for a modern locomotive."* An encyclopædic *Science of Work and Wealth* with unlimited illustrations would have space to tell the subsequent history of the railway in full and "feature" its more vivid episodes. It would show by period maps how the railways, once they were begun, spread through the world like nerves in a developing embryo. Let us give, at any rate, a few salient facts from this mechanical drama and leave such filling in as the reader who is specially interested in this field needs, to his further reading.

September, 1930, witnessed the centenary of the opening of the first railway, in the modern sense of a public steam railway, between Liverpool and Manchester. There had been tentative railways or tramways with steam locomotives in colliery districts and on the north-east coast nearly twenty years before this event. But though George Stephenson was an ardent advocate of steam traction, the use of that method on the first railway was decided only at the last moment, after competitive trials. The result was so convincing that a number of lines were constructed during the next few years. At first it seems to have been the capacity, and the speed over short distances, rather than the increased range that attracted attention. The new lines were short. They had a strictly local value, and some of the large systems—the Midland more especially—were created by the amalgamation of small and relatively local concerns.

Passenger traffic, also, was underestimated. The advantage of carrying heavy stuff in big loads loomed so large in men's minds that no one seems to have realized the importance the new methods of transport would assume for travel and journeying. And so, too, no one visualized the social and political influence of the new means of communication. These unforeseen consequences as they were revealed stimulated the expansion of railways enormously, and railway development became a mania in the thirties. In 1825 Great Britain had only 26 miles of line; in 1850 there were more than 6,600 miles; in 1870, more than 15,000 miles; in 1890, more than 20,000; and to-day, 24,000. France and the United States began to experiment with steam locomotives in the year that the Liverpool and Manchester railway was opened. Germany and Belgium were five years later.

* Sir Richard Gregory in a lecture on "Science and Labour."

THE CONQUEST OF DISTANCE

From these beginnings the railway spread rapidly over the world. Content at first to join up neighbouring centres, engineers soon began to visualize lines which would cross continents and bring distant peoples into direct and easy communication. The first trans-continental line spanned the United States in 1869, rising 7,000 feet above sea level in the Sierras, crossing 700 miles of desert and hundreds of miles of country inhabited by tribes of hostile red men. The last spike of the Canadian Pacific was driven in November 7, 1885. By the end of the century the Trans-Siberian Railway was in operation, and the duration of a journey round the world had been reduced to thirty-three days. The Australian can now travel by train from Perth to Adelaide, and Africa is the only continent still incompletely spanned by the iron road.

By 1924 there were nearly 238,000 miles of line in Europe, 316,000 miles in North America, 55,000 miles in South America, 81,000 miles in Asia, 37,000 miles in Africa, and 30,000 in Australasia. North America and Australasia now have more than 22 miles for every 10,000 of the population, Europe 5.28 miles, and Asia only 0.8 mile. The ratio of mileage to population is naturally highest in a large country with a thinly scattered population. In Africa it is low because there are so few lines. Gold, diamonds and wild forest products make small demands upon transport. Cultivation of the soil and manufactures are necessary for abundant railway expansion.

The story of these engineering achievements, of the knowledge and skill which have been employed, of the hardships and dangers from rigours of climate and pestilence which have been incurred, would fill many volumes. The way has been blasted along the face of vertical cliffs and through the hearts of mountains. Stephenson had to pump water out of the Kilsby tunnel on the London-Birmingham line for eight months. The first of the great Alpine tunnels, under Mont Cenis, seven and a half miles long, occupied fifteen years in construction. The St. Gothard Tunnel, twelve and a half miles long, took ten years. The temperature at the working face arose to 100° F., and water entered at the rate of 3,000 gallons an hour. The Simplon, of the same length, but begun a quarter of a century later, required only eight years—the result of improved appliances. The Gravelhals tunnel on the Bergen-Oslo Railway is only three miles long, but involved thirteen years of labour. Steep

THE WORK, WEALTH & HAPPINESS OF MANKIND

gradients on the Jungfrau Railway and on the Canadian Pacific between Hector and Field have been overcome by spiral tunnels inside the mountain.

Rivers have been crossed by tunnels and bridges. The boring of the Severn Tunnel occupied thirteen years. Four times water flooded the workings and brought progress to a standstill. In some subaqueous tunnels the excavation has been only a few feet below the bed of the river. The men have a "shield" behind them and the water is kept back by compressed air. In 1880, when the Hudson River Tunnel was under construction, the air blew out through the river bed, water rushed in, and twenty men lost their lives. A "shield" is used in driving through soft ground whether water is present or not. And so accurately are the surveys made that the deviation from the true direction is trivial. In the $12\frac{1}{2}$ miles of the Simplon Tunnel the error in direction was $8\frac{1}{2}$ inches, and in level only $3\frac{1}{2}$ inches. The Hampstead Tube had an error in direction of $\frac{1}{4}$ inch and in level of $\frac{1}{8}$ inch. The amazing "truth" of the base of the Great Pyramid, the sides of which, over 750 feet in length, have only a mean error of $\frac{3}{5}$ of an inch from those of a perfect square, has long been a marvel to posterity. But this is better.

The railway evoked the great bridge. Before 1850 the longest iron span was that over the Wear at Sunderland—234 feet. The Britannia Tubular Bridge over the Menai Strait (1846-50) has two spans of 460 feet. The Brooklyn Suspension Bridge (1870-83) has a span of 1,596 feet, and the Williamsburg Bridge (1895), a mile away from the Brooklyn, a span of 1,600 feet. That towering mass of steel, the Forth Bridge, was opened in 1890. It has two spans of 1,710 feet, and for twenty-seven years this was the greatest distance which engineers had attempted to cross in one leap. But in 1917 the Quebec Bridge, which crosses the St. Lawrence in one span of 1,800 feet, was opened for traffic, after a disastrous failure ten years earlier. The present stage in bridge-building is illustrated by the magnificent arch across Sydney Harbour, and the still more magnificent structure spanning the Hudson River.

Throughout the growth of this network—more than three quarters of a million miles in a century—steam traction retained its supremacy and is only now being seriously challenged by electricity and the Diesel engine. In the little *Rocket* were embodied all the principles of the modern locomotive, though not its size and

THE CONQUEST OF DISTANCE

form. It had coupled driving wheels, a tubular boiler, and the exhaust steam was discharged up the chimney to increase the draught.

As the volume of traffic increased, locomotives have become larger and more powerful. Size in Great Britain is limited by the distance apart of the rails and the height of tunnels and bridges. The pioneers who determined these conditions did not imagine the future boldly enough. Brunel alone, whose mind ran to big things (he was the designer of the *Great Eastern*), adopted a 7-foot gauge for the Great Western Railway, but Stephenson's curious choice of 4 feet 8½ inches had secured too strong a hold for this to become general.

Though the locomotive, on this account, could not be made much larger, it could be made more efficient. Various improvements were made in the valve gear which controls the admission of steam to the cylinders. Then the boiler, and especially the firebox, was improved. Compounding, by which the steam was expanded successively through the cylinders, was introduced, chiefly in countries where the cost of coal justified the additional expense of construction and maintenance. With the higher pressures rendered possible by boiler plate of higher quality, compounding became more common. Then the steam was superheated on its passage from the boiler and more power obtained from the same quantity of fuel. The increased pressures now being used for stationary engines (there is a power plant in America using steam at 1,200 pounds the square inch) are spreading to the locomotive. Until 1895 the pressure did not exceed 160 pounds on the square inch. Then 200 pounds was tried. While a common pressure to-day is 250 pounds per square inch, there are several using steam at 350 to 400 pounds. Experimental engines using steam at 850 to 900 pounds are under trial, and at the time of writing one is under construction which will use steam at 1,700 pounds—more than three-quarters of a ton on every square inch of internal surface.

These improvements have been made possible by metallurgical advance, and they have been stimulated during the last twenty years by the increasing cost of fuel, the competition of electricity and the influence of the Diesel engine. Steam-turbine locomotives and Diesel locomotives are already the subject of experiment. Apart from main principles, the modern steam locomotive is an amazing

THE WORK, WEALTH & HAPPINESS OF MANKIND

contrast, not only in size but also in performance and complexity, to the simple little engine that satisfied the Manchester to Liverpool trials, 100 years ago.

The development of railways depended upon their capacity and speed as compared with other forms of transport, and speed with safety depended not merely on power, but also on effective control of train movements. Traffic was at first regulated by "policemen" with flags and lamps, and later by the familiar semaphore. When these signals were worked mechanically they were "interlocked" so that a wrong signal could not be given.

The invention of telegraphy by Wheatstone and Morse permitted the movement of trains to be flashed almost instantaneously along the line, and enabled the approach of a train to be anticipated with a far greater margin of time. This stage was reached in 1850.

The range of signalling was again increased when signals were operated by compressed air or by electricity or the two in combination, and to-day the elimination of human error is being achieved by the use of automatic methods by which the train gives its own signal of approach, or picks up the signal and stops of its own accord. Eleven thousand miles of road and 8,500 locomotives in the United States were provided with automatic train-control apparatus by 1928.

Meanwhile the amenities of railway travelling have been enormously improved. The open trucks for third-class passengers had a very brief existence. Seats have been upholstered, carriages warmed, and facilities for eating and sleeping provided. In spite of isolated instances to the contrary, the punctuality of trains is extraordinary. The cheapness and range of railway travel have enormously enriched life for millions who, in an earlier age, would have been doomed to a narrow and monotonous existence.

On the other hand, railway transport is inelastic in many respects. The units are large, the demand cannot always be foreseen, and the fixed track limits the area from which passengers can be drawn. For this reason road transport has become a serious competitor, and it is perhaps unfortunate that the motor bus developed so much later than the steam locomotive. Instead of co-operating in the provision of a close network of economical and efficient transportation, the railways may buy up the bus services as they did the canals, solely for the sake of maintaining the returns upon lines which are, or

THE CONQUEST OF DISTANCE

threaten to become, unremunerative.

But it is in goods traffic that railways stand in greatest need of improvement. There is, perhaps, no more uneconomical appliance than a railway truck. It has been estimated that one per cent of a truck's life is spent in running full, three per cent in running empty, and ninety-six per cent in standing in sidings. Before the war British railways were laying down sidings at a far greater rate than running tracks. They were becoming warehousemen—of empty trucks. On the Continent and in America nearly all wagons belong to the railways. In Great Britain about half of the 1,280,000 belong to private owners. Railway company trucks stand empty, heavy capital expenditure is involved in sidings, and time is lost in sorting out trucks when required. In common with many other aspects of industrial activity, transportation has grown upon altogether too narrow lines. It has neither been planned with vision nor administered with enterprise. It is burdened and cramped by tradition and routine, and each form of enterprise tends to treat an alternative form, not as a collaborator to be encouraged, but as a competitor to be crushed.

Why, people are asking, should the railways be cluttered up with coal trucks for the home trade in districts where canals are lying idle? Why invest capital twice for the same purpose? The annual fuel requirements of any particular area can be forecast with tolerable accuracy. Coal could be stored. A steady stream of barges would convey the requisite quantity to many districts, and enable a seasonal demand to be met by uniform production at the coal face.

Transport by canal, railway and road has developed independently, and it needs now to be organized as a whole, as co-ordinated and co-operating rather than as competing units. And road or cross-country motor transport needs to be used to provide existing networks with a finer mesh, and to extend the systems into areas, rich in natural resources, which have not yet been able to bear the capital cost of a permanent way.

The first electric railway was exhibited by Siemens at Berlin in 1879. But electric generators and motors were then in their infancy. Ten years were to elapse before big machines were available, and another ten before many of the details of transmission were worked out. The Liverpool Overhead Railway and the City and South London Railway were opened about 1890. Then several short lines

THE WORK, WEALTH & HAPPINESS OF MANKIND

were converted from steam to electricity. Meanwhile the New York, New Haven & Hartford and other American electric lines were opened, and electrical working adopted for the tunnel sections of the Swiss railways.

The advantages of electricity were more obvious, and the difficulties of introduction and operation less in the case of short suburban and interurban lines with a heavy passenger traffic. By distributing motors along the train, the grip on the rails was increased. Electricity secures quicker acceleration than steam, and less time is lost in increasing or decreasing speed when leaving or approaching a station. It had obvious advantages, too, on underground lines and in long tunnels which are difficult to ventilate. As the power from a large central station is more flexible than that of a steam locomotive, there were also advantages in the use of electricity on main lines with steep gradients. And so the new method of traction has gradually invaded the domain of the steam engine.

That, however, could not be done in a day. It required cheap power such as can be obtained most economically from falling water. Hydro-electric development was a powerful stimulus. Then there was an enormous field to be explored. The most economical pressure for the transmission of electrical energy; whether it should be direct or alternating current, and, in the latter case, whether it should be single-phase or three-phase; the most satisfactory method of communicating energy to the train; the best type of motor: these were only a few of the questions which had to be investigated. Each one of them carried a mass of detail in the design of auxiliary devices. Throughout the nineties and beyond, the patent offices were busy in registering new ideas.

The most wonderful achievement during the last ten years is the equipment of automatic sub-stations. The line is divided into sections of a dozen miles or more in length, and each section is supplied independently with energy from the central power station through a sub-station. The sub-station contains machinery or apparatus for transforming the high-tension current into one of low enough tension to be communicated to, and used with safety on, the train. The overhead lines are liable to have produced in them surges of electrical energy from lightning flashes; the sub-station machinery may be overloaded by too many trains on the section, and a number of irregularities may occur which formerly required an

THE CONQUEST OF DISTANCE

operator to observe them and make the necessary adjustments. This is now unnecessary. The sub-station can be, and often is, entirely automatic. When an irregularity occurs the machines correct themselves or stop. And the man in charge of the control station can see, by glancing at coloured lamps on a board, whether each control device is doing the work for which it was designed.

As yet we are only on the threshold of this phase of transportation. Omitting urban and interurban lines, there are only 6,500 miles of electrified track out of 563,000 miles. The United States has less than 1,500 miles out of more than 236,000 miles of line. Great Britain has 400 miles out of 20,000. Italy has made use of her immense hydro-electric resources in the streams which flow down the southern slopes of the Alps. She has 670 miles of electric railway out of 12,500 miles. But the greatest development has been in Switzerland. The figures—595 miles out of 1,852—hardly reveal the truth. No less than 67 per cent of the track is electrified and 85 per cent of the trailing-ton miles is accomplished by electrical power. Man has been observing, experimenting, discovering, for scores of generations. Within the last three he has achieved the railway, and within the last one the electric train.

We turn now to the modernization of shipping and the struggle of the sailing ship against extinction. The story of shipping is a continuing story of growth in size, power, and speed. We will not dwell here upon the safety and comfort of modern ocean travel, and we can speak only in general terms of the main economic and political effects of ocean transport. As the *Outline of History* insists, the second British Empire, that is to say, the present British Empire which arose after the separation of the United States, is essentially a steamship empire. It came with the steamship, and with the appearance of air transport and the diminishing importance of the steamship in world communication it is bound to undergo great changes either of adaptation or dissolution.

The steamship phase has so far lasted little more than a century. In 1777 a Frenchman bought one of Watt's engines and used it to propel a boat along the river at Lyons. Symington exhibited a steamboat on Dalswinton Loch in 1798. The *Charlotte Dundas* clove the waters of the Clyde in 1802. Fulton's *Clermont* navigated the Hudson in 1807. By 1823 more than 300 steamboats had been built in America for use on rivers and lakes while in Great Britain

THE WORK, WEALTH & HAPPINESS OF MANKIND

steamers came into use in a tentative way for coasting and cross-channel trade. The first vessel using steam crossed the Atlantic from America in 1818. But in this and later ships steam was used only as an auxiliary to sails. Steam, as the chief agent of propulsion, dates from 1838.

While all steamships have increased from these beginnings in size, power and speed, those built for the Atlantic passenger service have undergone the most uniform and extensive development. The Cunarders of 1840 were 207 feet long, with engines of 740 horse-power. From this length and power they increased slowly to 500 feet, and 5,300 horse-power in 1880. In the same interval the average speed increased from 8.5 to 15.5 knots. The greater length and speed were facilitated by the use of steel in construction. Composite ships, with wooden frames and iron plating, were built from 1840, but it was the invention of Bessemer steel (1856-60) which led to the great increase in size. Brunel anticipated events by building the *Great Eastern* of iron, 680 feet long, in 1859; but she never fulfilled expectations, and it was forty years before another ship of her size was attempted.

In the opening of the twentieth century, came a vigorous competition between the German, British and American ship-builders for the trans-Atlantic trade, and great floating palaces of 700, 800 and 900 feet appeared. Ships are now on the stocks which will be 1,000 feet—333 yards—in length. The *Leviathan* (U.S.A.) weighs just upon 60,000 tons and is 907 feet long; the *Majestic* (British) is equally huge and is eight feet longer. The *Bremen* (German) is just under 900 feet, but she is narrower and about 8,000 tons lighter.

The earlier vessels were driven by paddles, which take up a great deal of space amidships and are in the way when entering and leaving dock. The screw propeller was patented in 1836 and first used in 1839. The first large vessel to be provided with this means of propulsion was the *Great Britain*, designed by Brunel. She was 320 feet long and was launched in 1844. But the paddle was not displaced for large steamers until the sixties, and it is still used for boats which ply on rivers and lakes. Paddle vessels of nearly 8,000 tons are used on the Great Lakes to-day. Twin screws were tried from 1862, but only obtained popularity on the fastest boats. The maximum growth, however, in size and speed, could only be attained by the use of three and four screws.

THE CONQUEST OF DISTANCE

Meanwhile, an ever-increasing economy was sought in the engine-room. The compound engine was introduced in 1854, the triple-expansion engine in 1873, and the quadruple-expansion engine in the last decade of the century. Further economy was secured by the steam turbine first tried for ship propulsion in 1894. The first merchant ship was provided with turbines in 1901. There were, at first, many difficulties and disappointments. There were difficulties arising from construction which were overcome by improved materials and design. The high speed of the turbine and the low speed at which a screw propeller, working in water, is efficient, were conciliated by improved gearing. Alternatives to toothed wheels which have been tried are the Foettinger hydraulic and the electric systems. In the former the turbine drives a centrifugal pump, which forces water through a water turbine on the propeller shaft. In the latter the turbine drives electric generators, and the propeller shaft is driven by an electric motor.

Again, in contrast to the steam turbine, operating with or without a reciprocating engine, and acting through gearing, water power or electricity, is the Diesel engine. Until after the war the Diesel engine had only been tried on cargo boats of relatively low tonnage. But it has been applied far more widely than steam for cargo vessels, and has invaded the field of the turbine on passenger ships. The *Britannic* has Diesel engines of 20,000 horse-power, and an Italian vessel, similar engines of 27,000 horse-power. During 1930 the increase in the world's steam tonnage was 148,176, and of motor tonnage, 1,468,235—an amazing development in less than fifteen years. The advantages are simplicity, compared with the turbine and its auxiliaries; smaller storage space for oil than for coal, and fewer men required to run the machinery. So far as shipping is concerned, an oil age has already begun.

During the last year nearly 70,000,000 tons of shipping have been available for the world's needs. They have enabled human beings of different races and tongues to meet and mingle. Raw materials have been carried nearly round the world and exchanged for other raw materials and goods. But until fifty years ago most articles of food were perishable. Apart from a somewhat limited trade in live cattle, meat, fish, fruit and vegetables had to be consumed within a few hundred miles of their source. Only salted food could be kept for any length of time. The preservation of food by cooling it

THE WORK, WEALTH & HAPPINESS OF MANKIND

below the temperature at which the bacteria of putrefaction were active began in the middle of last century. The first cargo of beef was sent from America to England in 1877; the first cargo of mutton came from Australia in 1880. Scientific investigation has fixed the most suitable temperature for preserving every article of food for which there is a distant market. Many foods have ceased within the last thirty years to be "seasonable." The world dines at one table, and the fare is vastly richer and more varied than it ever was before. Could anything illustrate more simply or more forcibly the difference created by the railway and the steamship? Mining and manufacture lead to great concentrations of population which far exceed the food-producing capacity of the immediate neighbourhood. Yet they labour for the rest of the world, and the rest of the world supplies them in greater abundance and variety than they could produce directly for themselves. But this is anticipating our next chapter.

We may glance here at the question of freight charges, and particularly at the ideas of David Lubin and the more experienced work of Sir Arthur Salter. Lubin dealt with the question of freights before the war; he wanted to fix them instead of leaving them to a complex process of haggling; he wanted an international transport at fixed rates on the model of international postage. His suggestions are full of mental invigoration.

Salter's work, *Allied Shipping Control*, arose out of his experiences with transport problems during the war. Enormous economies were effected by putting all the allied shipping under a common direction. At one time American wheat was going to Italy, while Indian wheat was passing it *en route* for England. The wartime pooling of shipping put a stop to such absurdities—"for the duration." The American wheat was turned aside to London, and the Indian to Italy, and thousands of miles of transport were economized. "For the duration." Thereafter everything was allowed to lapse back into the hands of the private profit-seekers.

A complete survey of transport by rail and sea would give typical pictures and descriptions of modern docks and transshipment methods. It would involve a great history and description of harbours. At first these were the natural mouths of rivers or sheltered bays, with staging of timber or stone to facilitate loading and unloading; then, in the order of elaboration, a bay sheltered

THE CONQUEST OF DISTANCE

from the waves by an artificial embankment or sea wall. The sides of the river or the shores of the bay would next be excavated to provide a number of huge tanks, separated or confined by massive concrete walls. On these walls appear cart tracks and then railway sidings, and at length miles of railway, bigger and bigger open sheds, tall warehouses, machinery for pumping and for loading vessels with astonishing speed and economy of human effort, great chutes for loading a ship with ore or corn carried in bulk. (On the Great Lakes 12,508 tons of ore have been loaded in $16\frac{1}{2}$ minutes, and unloaded in 3 hours and 5 minutes.) Corn is poured into a ship down a chute and sucked out of it through great tubes from which the air is continuously withdrawn by a fan—waterfalls of grain, and reversed waterfalls with the grain pouring upward.

Provision has to be made not merely for cargo but for the repair of ships. Where it is not considered desirable on the ground of expense or urgency to construct a permanent dry dock, a floating dock is used. There is one at Southampton, and another at Singapore, either of which will accommodate the largest ships. A floating dock is like an immense box, open at the top and ends. Or it may be likened to a steel trough. The sides and bottom are hollow and are divided into compartments into which water may be admitted or from which it may be pumped. The dock is sunk by admitting water, the vessel is moored over it, the water pumped out, and as the dock rises the vessel is lifted out of the water. The Southampton dock is 860 feet long and will lift 60,000 tons; that at Singapore has a lifting capacity of 50,000 tons. They are floating factories, portable shipyards, equipped with workshops and machinery to enable any kind of repairs to be carried out. That at Singapore was towed all the way from the Tyne. There or elsewhere you could, if necessary, build a ship.

Another great item in the spectacle of modern transport is the development of ship canals and particularly the development of Suez, Panama, the Manchester Ship Canal, the St. Lawrence chain and the Kiel Canal. To the present generation all these great waterways are accepted with little emotion or understanding; to our parents and grandparents they were objects of awe and admiration. Conceived in earlier times merely as substitutes for roads or rivers, canals in the latter half of the nineteenth century became also links in oceanic communication and terminal extensions which enabled

THE WORK, WEALTH & HAPPINESS OF MANKIND

oceanic transport to penetrate deeply into land areas. A few canals by-pass tempestuous or dangerously crowded seas. To the first class belong Suez and Panama; to the second the Manchester Ship Canal and the St. Lawrence chain, the Amsterdam Canal, and the New Orleans Industrial Canal; instances of the third type are the Corinth and Cape Cod canals. In a number of cases the canal route is not only safer but shorter.

The Suez Canal, opened in 1869, occupied ten years in its construction. It was merely the last of many efforts, none completely successful or permanent, to connect the Red Sea with the Mediterranean. The history and legend of these efforts cover more than three thousand years. Before work upon the existing canal was commenced the proposal was debated for more than half a century. It was accomplished by the labour of a quarter of a million men and the expenditure of twenty million pounds. Half as much again has been expended in widening, deepening and otherwise improving it. In 1870 only 451 ships made the passage. By 1927 the number of ships had increased to 5,545, and the tonnage was 28,962,048. How would trade have developed in the Mediterranean and the Far East, and what would have been the political history of Europe had it never been undertaken?

The history of the Panama Canal would afford material for a modern epic. The earlier years were grim with tragedy. De Lesseps, elated with his conquest of the sands of Suez, utterly underestimated the magnitude and difficulty of the task in Central America. In spite of heroic efforts, he failed. Between 1879 and 1887, no less than £66,000,000 was sunk in the enterprise, and 16,000 men died from disease. The United States government took over responsibility in 1904. By 1914 it had completed the work at a cost of £75,000,000. Two factors contributed to the American success. One was modern medical and sanitary service--particularly the steps taken to prevent mosquito-borne disease; the other, military discipline. There was a tendency among the civilian engineers at first employed to quarrel with one another or to leave for more remunerative posts. To secure loyalty and continuity President Roosevelt replaced them by military officers. Military officers could neither disobey orders nor seek other employment. In 1927, 5,475 ships with a tonnage of more than 27,000,000 used the passage. There is thus a peculiar symmetry in the flow of

THE CONQUEST OF DISTANCE

traffic through the Suez and Panama canals, the easterly and westerly exits from the North Atlantic system.

The Manchester Ship Canal has enabled that city, situated 45 miles from the sea, to become the third port in Great Britain. A similar but far deeper penetration is effected by the chain of canals along the St. Lawrence, and the Welland Canal between Lake Erie and Lake Ontario, still under construction. A small ship can now be loaded at Manchester and discharge its cargo at Chicago. A limit to the size of vessel is imposed at present by the St. Lawrence canals, which permit only a 14-foot draught. It is proposed to deepen the channels throughout the whole length, and the next generation may see the largest cargo vessels moving athwart the south Lancashire landscape and so out to sea, and ending their journey by passing through cultivated fields for hundreds of miles to a port a thousand miles from the ocean.

The traffic on these inland waterways is amazing. The Sault Sainte Marie, between Lake Superior and Lake Huron, carries more than \$5,000,000 tons a year—more than Suez or Panama.

On these narrow ribbons of water traffic is concentrated. Dispersed on the wide oceans is a mass, stupendous by comparison, whose total bulk defies the imagination. Millions of horse-power and hundreds of thousands of men are moving thousands of millions of tons from those who have to those who need, with ever-increasing speed and no regard for distance. No central mind directs this world circulation; and yet a routine is perceptible which suggests conscious co-operation and a purpose clearly seen, an order, as it were, crystallizing out of chaos. Can the inorganic world with its atoms and molecules, its crystalloids and colloids, show anything more wonderful or inexplicable than human transport at its present stage of development?

There is another aspect of the development of great ships and controlled shipping and water transport at which we can glance here only for a moment. That is the elimination of human suffering that has gone on at the same time. We do not mean simply the heroic sufferings of shipwreck and famine and natural disaster; those we can in a sense tolerate. But it is certain that in the past the small sailing ship far from land, remote from the influence of women and children and all social restraints, was all too often a pit not simply of deprivation but of cruelty. The galley slave was a slave,

THE WORK, WEALTH & HAPPINESS OF MANKIND

but throughout the eighteenth and early nineteenth centuries the sailors, often beguiled aboard, were among the poorest and most evilly entreated of labourers. Almost inadvertently science and invention have lit and cleansed those miserable caskets of oppression beneath the tall masts and the bellying sails of the old order of things at sea.

§ 3. *The New Road and the Airway*

A new chapter of the history of communications is opened when we consider the modern revival of the road. The macadamized road was the high-water mark of roadmaking in the pre-railway era. With the coming of the automobile a new phase in the history of roads opened, roads of a harder, firmer type appeared, more or less freed from the filth of horses and the disintegrative beating of their hoofs. The internal combustion engine, rubber tyres and new road surfaces have interacted in the evolution of our modern road traffic, a multitude of illuminating problems of traffic control and of road-and town-planning have arisen and are arising out of this evolution. But of town-planning we will write later. A full encyclopædia of *Work and Wealth* would have to expand copiously upon such problems as the possibility of a closer co-operation of road and railway through the transfer of large package units from chassis to truck.

And then we turn our attention to the air. The very recent but very complex story of the achievement of mechanical flight has still to be written. At present the organization of air services in a practicable form is enormously hampered by the jealousies and frontier impediments of the seventy-odd petty sovereign divisions with which our developing world is still entangled. *The Science of Work and Wealth* would have, of course, a full and fully illustrated review of the latest development of aircraft and it could weigh the merits of the airship against the aeroplane. Here, we must say to the reader, is a way of going wherever you like about the world, very swiftly and agreeably, so soon as you are sufficiently tired of the traditions of nationalist and imperial conflict, to turn to these new powers and conveniences.

The internal combustion engine lies at the root of both these developments, the automobile and aviation. They came in a

THE CONQUEST OF DISTANCE

necessary sequence. The automobile was the inevitable predecessor of the airship and aeroplane. Until a fairly reliable light engine had been worked out upon the ground, where sudden stoppages did not involve disaster, sustained flying was no more than a dream. The early "gliders" in the gliding machines, Lilienthal, Pilcher and Chanute, were plainly and consciously preparing for the advent of an efficient engine. So soon as sure and sufficient power was available, both flying and the navigable balloon became inevitable.

The automobile story is still a confusion of claims and disputations. Gottlieb Daimler (1885-86) was early in the field, but it is alleged that Siegfried Rarkus in Austria had made and driven a four-wheeled car with an internal combustion engine as early as 1875 (*Encyclopædia Britannica*). By 1897 a lot of people were busy making experimental cars of various types, in France, Germany, England and America. To show the manner of the growth and do justice to these experimenters would require furlongs of museum gallery. It took a dozen years and the toil of many thousands of inventors before a really trustworthy car, that would not only take its driver out but bring him home again, had become a marketable commodity. In 1897 there were ninety cars upon the roads of the United States; in 1906 the hundred thousand mark was passed, in 1913 the million and in 1928 twenty-one million. There is now (1931) a car to every seven people in the United States and to every sixty people in Great Britain and France.

The aeroplane followed fast on the car. The world of inventors was in labour, so to speak, with the automobile in 1896-97. That was the great time of road trials and freaks. The corresponding years for the aeroplane were 1909-11. By 1903 Wilbur and Orville Wright had already added a petrol motor to the gliders with which they had been experimenting since 1900 at Dayton in Ohio. They were certainly flying in 1905. Santos Dumont flew in 1906, and Farman, at the Voisin works at Issy near Paris, in 1908. In July, 1909, Blériot flew across the English Channel, and from that date onward the record is crowded with flights of increasing length and height. The Atlantic was first crossed in 1919 by Alcock and Brown.

The very earliest speculations on the possibility of mechanical flight were based upon flapping wings. The significance of soaring, with wings placidly outspread, was not at first apparent. And

THE WORK, WEALTH & HAPPINESS OF MANKIND

though Sir George Cayley in 1809 stated the principles upon which a heavier-than-air machine could be employed, a hundred years elapsed before this became an accomplished fact. The balloon, invented by the Montgolfier brothers at the end of the eighteenth century (1783)—lifted by hot air, hydrogen or, after 1821, coal gas—had buoyancy, it was capable of lifting a load up into the air, but its direction was that of the wind. In 1852 Gifford fitted a steam engine to a balloon and propelled it at five or six miles an hour. But a larger machine, built three years later, came to grief. During the Franco-German War a balloon which had a propeller worked by eight men was used. In 1885 Renard and Krebs constructed an airship, *La France*, propelled by a nine horse-power electric motor. This machine flew over Paris and attained a speed of fourteen miles an hour. But that was about as far as the lighter-than-air machine could go until the internal combustion engine came to its assistance. This association became possible at the dawn of the twentieth century. In 1901 Santos Dumont flew a navigable balloon, like a fat flabby fish, for seven miles out and home, round the Eiffel Tower.

The earlier French airships were "non-rigid." They consisted of a lozenge or fish-shaped envelope containing the gas, and the car for pilot, passengers and machinery was suspended from a net, embracing the fragile gas container. The "rigid" type, in which the fabric is stretched over a sausage-shaped metal framework, and the gas is contained in "ballonnets" in separate compartments of the larger vessel, was developed in Germany by that great experimentalist, Count Zeppelin. He was at work before the end of the nineteenth century. He was the first to make a rigid airship (of aluminium covered with silk and linen and containing hydrogen). It made successful flights before the end of 1900. But his Zeppelins remained very tender and fragile for ten years. It was only with the invention of duralumin (an alloy of aluminium) in 1909 that a really adequate, strong and light frame for a rigid airship became possible. Duralumin has five times the strength of aluminium and is nearly as light. During the war France and Great Britain developed non-rigid types of airship, and by 1918 the latter country had several hundred of them for scouting and coastal patrol. Italy showed a preference for semi-rigid ships—non-rigid envelopes stiffened by a metal keel. Germany, keeping the lead Count Zeppelin had given her, went on building rigid airships of the largest size and using them

THE CONQUEST OF DISTANCE

very effectively, and until 1916 when the L 33 was brought down near London, there was no information available outside Germany as to their design and construction.

Experimental work with large airships is less easy than with aeroplanes; airships are infinitely more costly to build. They are relatively fragile, and when a disaster occurs they are more expensive in human life. Until hydrogen can be replaced by the non-inflammable gas helium, the menace of fire will always be associated with them. Helium is the next lightest element to hydrogen, and although abundant in the sun's atmosphere, it is on earth a gas of rare occurrence. It is found in various natural gases and in the water of some mineral springs. It is widely distributed, but only in very small amounts; it is obtainable in considerable quantities in America alone. The supplies are manifestly limited, and this puts yet another obstacle in the way of general airship development.

The armament competitions of the opening decade of the twentieth century, and then the war, were tremendously stimulating to both airship and aeroplane construction. At the outset of the conflict aeroplanes were used only for reconnaissance and to mark for gunfire. By the end of the war an elaborate system of air fighting existed, and night after night great air raids—in which the big aeroplane of the Handley Page-Gotha type presently ousted the more vulnerable Zeppelin—bombed the belligerent populations behind the fighting lines.

The Peace of Versailles released the accumulated possibilities of the civil transport aeroplane. The first regular air services had already been established before the war in Germany in 1912, when rigid airships were used. By 1920 there were three British and two French companies providing cross-channel services by means of aeroplanes. The British interests were, subsequently (in 1926) concentrated in Imperial Air Services, Ltd., which operates between England and France, Switzerland, Germany, and Belgium. British Empire routes were also established in Africa, the Near East, India and Australia. But the British Empire is not very happily planned for air transport. Britain has a very central maritime position, but the main air services of the future are more likely to radiate from the centres of the great land masses of our planet. By 1926 the route mileage of the world's air transport had reached 50,000, and the number of miles flown in that year along these routes was nearly

THE WORK, WEALTH & HAPPINESS OF MANKIND

17,000,000. This progress testifies not only to great improvements in the design and construction of the machines, but also to the increase in efficiency of the internal combustion engine. In 1915 the lightest water-cooled motor weighed four pounds per horse-power, and the lightest air-cooled engine three pounds. To-day the weights of these engines are more than halved.

Apart from transport, the aeroplane is being used for many economic and administrative purposes. Vast areas where the population is sparse and means of communication poor are being surveyed from the air. In 1925 and 1926, 120,000 square miles were mapped by aerial photography in Canada. Rivers and coast lines and routes for new roads and railways have been surveyed in the United States, and in Australia the extent and form of the Great Barrier Reef have been recorded. The forest areas of Germany, Canada and other countries are being determined in this way. Mineral resources in Africa and the United States are being investigated. Town surveys have been made in the United States and Germany. The Canadian Salmon Fisheries are being policed by aeroplanes, and cotton and other crops are being sprayed or dusted with insecticides or fungicides by low-flying machines.

Few people before 1918 could have believed that archæological work would ever be undertaken in an aeroplane. But thanks mainly to the energy of one man, Mr. O. G. S. Crawford—who learnt the business as an aerial photographer at Arras during the war—the aeroplane has become now a most important instrument in reconstructing the life of the past. An aerial photograph reveals details in the texture and quality of the ground which are totally invisible to a man on the surface, and the long unsuspected vestiges of ancient settlements and the prehistoric layout of the land have been elucidated to a very remarkable extent in this way.

From its very beginnings civil air transport has found itself entangled amidst the narrow political boundaries of the past. An International Convention for the Regulation of Aerial Navigation was ratified by many countries in 1922. This was followed by an International Commission for Air Navigation on which twenty-five states were represented. The Commission acts as an advisory body to the governments which send representatives on such questions as customs, licences and certificates of airworthiness, and the establishment of lighting systems and the provision and dis-

THE CONQUEST OF DISTANCE

semination of meteorological information—a strange complex of fiscal, legal and scientific services.

It is plain that we are still only in the beginnings of this new age of road and air transport which the internal combustion engine has made possible. The new highroad and the airway are at about the stage the railway had reached a century ago. The actual mechanism, the automobile or the aeroplane, that is to say is in existence in a working state. It is the development of the network that has now to be undertaken. Over great parts of the world the normal automobile cannot yet be used because of the want of modern roads. Either it must be replaced by automobiles of a special type and toughness—like the Citroën cars used in the North African desert and the crossing of Central Asia—or it cannot be used at all.

Still more is regular and trustworthy air travel restricted by ground conditions. Night flying and long distance cannot be considered safe until invention and organization have collaborated to anticipate and deal with the at present very heavy risks of fog. But, as we shall see in the next section, conquest of fog by the development of beam wireless and particularly of the new micro-rays, to which fog and rain are transparent, is close at hand. There is also needed a great effort in the development and application of meteorological science, so that the aviator may plan his route with assurance, free from the dread of adverse surprises by rain, snow, fog and tempest. Only by evolving a cosmopolitan organization can meteorology achieve that manifest task before it.

Week by week, year by year, at this point, at that, the road map and air route map of the world are being elaborated and redrawn, and every change in these maps involves political, social, and economic consequences of the most fundamental order. The transport framework of a new world system is being pieced together in spite of a thousand traditional antagonisms and impediments.

§ 4. *The Transmission of Fact. The Present Moment Becomes World-Wide*

But this chapter is concerned not simply with Transport, but with all methods of communication. We are considering not only how men and things can be moved about the modern world, but also the movement of information and ideas. Mankind seems to be approach-

THE WORK, WEALTH & HAPPINESS OF MANKIND

ing a phase when we shall realize and think almost as if we had one mind in common. Political disorder and various sorts of uproar delay the attainment of that phase, but there is an element of inevitableness in its advance. We move towards a time when any event of importance will be known of almost simultaneously throughout the planet. Everywhere it will presently be the same "*now*."

The story of communications, written regardless of any limitations of space or time would deal with signalling, with semaphores, smoke signals, practised by every savage people from the Picts to the Polynesians, and the like, and then go on to the story of electrical communication, with the electric needle, the telephone, the dawn of radio communication and the possibilities of the wireless transmission of visual impressions, as its chief episodes.

We may perhaps glance at a few facts in this latter story. It all falls within the compass of a century and a half. Until the end of the eighteenth century few of the phenomena of electricity were recognized; its nature was a subject of speculation rather than organized experiment. Volta had shown how to produce a continuous current of electrical energy in 1793. In 1819-20 Oersted discovered that a wire conveying a current would deflect a magnetic needle; in 1825 Ampère studied the forces exerted between a current and a magnet and between two currents of electricity; and in 1832 Faraday showed that when a current was started or stopped in one wire, another current in the opposite direction was "induced" in a neighbouring wire. At the time these things, the germs of all the telegraphic and telephonic developments of to-day, seemed curious minor facts.

Soon after Oersted's discovery, attempts were made to transmit messages by the deflection of a magnetic needle. In 1820 Ampère constructed a telegraph which had twenty-six wires and twenty-six needles—a wire and a needle for each letter of the alphabet. It was not until 1836 that a measure of success was achieved by Gauss and Weber in Germany, and Cooke and Wheatstone in England. Wheatstone's first instrument had five needles, but these were reduced to two, and in 1845 to one. The letters were arranged on a dial, and the needle pointed to a particular letter, according to the signal received. The instrument had the merit that no special knowledge or skill was required to operate it.

THE CONQUEST OF DISTANCE

Meanwhile Morse, in America, adopted a different plan. He devised a code of "dots and dashes" by sending a current along the line for a shorter or longer period and recording them by a pointer, or "pencil," which pressed against a moving strip of paper while the current flowed. His first patent was taken out in 1835. By 1851 there were fifty companies using the Morse code in America. In Europe the needle instrument prevailed, and the Morse code and system did not come into use until 1861. In 1853 duplex telegraphy was invented. By this method two messages could be sent simultaneously over the same line. Edison invented quadruplex telegraphy, by which two messages can be sent in each direction simultaneously, in 1874. These are two out of scores of refinements which increased the speed and range of electric communication. The needle instrument and the dot and dash apparatus were supplemented, and to some extent superseded, by printing telegraphs, in which each letter is produced in type on a moving strip of paper. During the last twenty years it has become possible to transmit facsimiles of letters and photographs.

Transmission under water demanded elaborately constructed and insulated cables, and created many unexpected problems. England and the Continent were joined in 1851. A cable was laid between Ireland and Newfoundland in 1858, but it broke three years later. The first permanent Atlantic cable was laid in 1866. More sensitive recording instruments than those which sufficed for land lines were required. These were found, first, in the mirror galvanometer, and secondly, in the siphon recorder, both invented by William Thomson, afterwards Lord Kelvin. The siphon recorder has a siphon dipping into a vessel of ink. The long limb of the siphon, drawn out to a fine point, rests upon a moving strip of paper. The signals are received by a sensitive galvanometer with a suspended coil of wire instead of a needle, and the deflections for dots and dashes are in opposite directions. These deflections are communicated to the siphon, which traces a straight line so long as no message is coming through, and a wavy one when signals are being received. The dots were indicated by waves on one side, and the dashes by waves on the other side of the line.

By the aid of a number of subsidiary devices, the speed of cable transmission has been increased from 15 letters a minute in 1858 to 2,500 letters a minute at the present day. There are now more than

THE WORK, WEALTH & HAPPINESS OF MANKIND

3,000 submarine cables in the world, with a total length of about 300,000 miles, and twenty-one of these lie between Europe and North America. The whole of that network of intercommunication has been established within eighty years—the lifetime of a single individual. It has effected a revolution in method of government and in the conduct of business. It tends to make the world one unit to a greater extent even than the railway or the steamship. It permits of instantaneous decisions in places remote from one another. It annihilates time—in some cases it antedates events. An incident in the Far East may be known in England before the hour by Greenwich time at which it occurred.

The transmission of human speech, with its vowels and their consonantal modifications, was a more delicate matter than the transmission of dots and dashes. From 1854 onward inventors were busy on this problem. Some means had to be devised to cause an electric current to vary with the vibrations of the human voice, and then to reproduce these vibrations at the receiving end. The problem was solved in 1876 by Graham Bell. Briefly, his apparatus consisted of a transmitter and a receiver with a connecting wire. The transmitter was composed of a flexible ferrotype disc, a disc that is of very thin sheet iron, gripped by its edges and fixed opposite the end of a magnet. Round the magnet was a coil of wire through which a weak current of electricity flowed. When a person spoke to the ferrotype plate it was set in vibration. Its approach to and recession from the magnet altered the magnetic field and caused corresponding alterations in the strength of the current which set up similar vibrations in a disc in a similar instrument at the receiving end. The chief modification since then is in the transmitter. This consists of a box with a flexible disc on one side. It is filled with granules of carbon, through which passes an electric current. A person speaking to the disc causes it to vibrate, and the vibrations are communicated to the carbon granules. This causes variations in resistance and consequent variations in the strength of the current.

So it became possible for one person to speak to another at a distance, and the next step was obviously to devise methods of getting into communication with the person with whom speech was desired. Here again was a new field for invention and enterprise. Switchboards through which a number of subscribers could be put into intercommunication were devised. The first was set up at New

THE CONQUEST OF DISTANCE

Haven, Connecticut, in 1878, with several thousand subscribers. In London in the same year the subscribers were less than a dozen. To-day there are about 20,000,000 telephones in the United States, or nearly 16 for every hundred of the population, and there are more than 30,000,000 telephones in the world.

The distance over which messages could be sent increased. Many improvements had to be made in auxiliary apparatus before long-distance telephony was possible. For long-distance lines, the feeble currents which represent speech have to be reinforced by valves such as are used in wireless telephony. But with no unreasonable delay the chief towns of Europe and America were brought into communication, and the human voice was carried across the wide seas. In the towns the telephone operator is gradually being displaced for local calls by the automatic exchange, a wonderfully ingenious arrangement by which any subscriber can call up any other in the area by "spelling" the number on a dial.

But now a new phase in communication was to appear—the transmission of signals and speech without connecting wires. This development began in the mind of a mathematician and in the laboratory of a professor of physics. Like the preceding developments, it was a triumph of pure science. In 1865 Clerk Maxwell published his electro-magnetic theory of light in which he suggested that electricity was propagated through space by a wave motion similar to that of light. About 1887 Hertz detected these waves. It was known that when electricity jumped across the gap, a spark was produced. It was known, too, that when the discharge took place between large metal plates or coils of wire the spark was not a single flash, but a series of flashes caused by the electricity surging backwards and forwards millions of times a second. This surge in the circuit which contains the spark sends out waves. Fitzgerald had suggested in 1883 this method of producing electric waves, but there was no way of detecting them. Hertz formed a circuit composed of two conductors "connected" by a straight piece of wire with a gap in it. The conductors were charged with electricity by an induction coil—a coil similar to, but larger than, that which thousands of people have used for administering "shocks" to their friends. When the spark jumped across the gap, sparks also passed between pieces of metal placed very close together in other parts of the laboratory. The electric waves had reached them, a similar surge

THE WORK, WEALTH & HAPPINESS OF MANKIND

was set up, and with each oscillation a spark passed.

These pieces of metal served their purpose for confirming the existence of the electric waves and enabled their properties to be studied. But a more suitable form of detector was invented by Branly, and in 1896 Marconi took the step which rendered possible the wireless transmission of signals. He connected one of the terminals between which the spark passed to a long wire slung in the air, and the other terminal to a metal plate buried in the earth. The "earthed" aerial radiated waves far better than any other device, and has remained an essential element in wireless transmission ever since.

Marconi brought his apparatus to England and demonstrated its practicability over a distance of $1\frac{1}{4}$ miles on Salisbury Plain. Before the end of 1897 he sent signals 14 miles. In 1899, messages were sent 85 miles. In 1901, received by an improved detector, messages passed between Poldhu in Cornwall and St. John's, Newfoundland, a distance of 2,000 miles. In their course the waves kept to the curvature of the earth, surmounting a "hump" of the Atlantic 125 miles above the direct line joining the two stations. This result could not have been predicted by the scientific knowledge then available. The practical test revealed a new fact of enormous importance to future development. Electric waves would spread over the surface of the earth and be within range of millions who had the means of detecting them.

Further advances were rendered possible by new devices, more especially by the thermionic valve which could be used not only to detect signals but to amplify them. We have no space here to describe these devices, nor the hundreds of others which played their part in the development of wireless telegraphy.

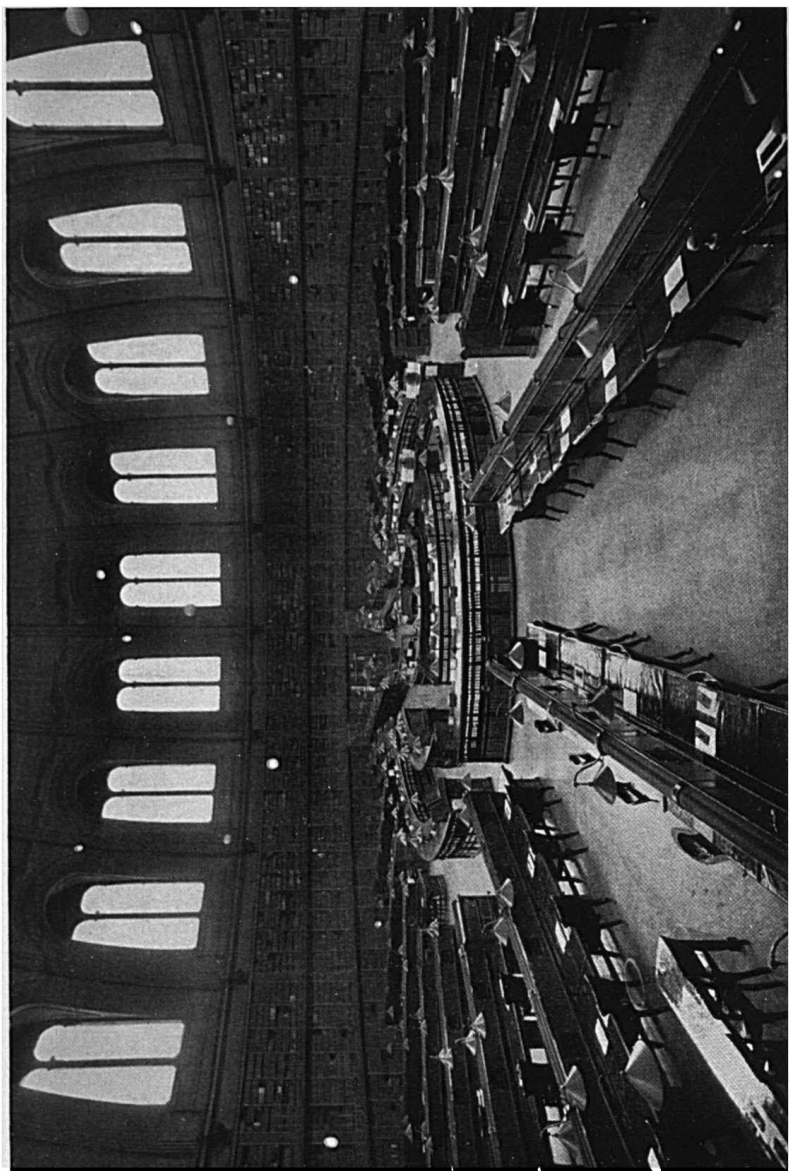
We pass on to the next stage in this amazing story of achievement—the transmission of speech. For this purpose the original Marconi system of producing waves was unsuitable. The sparks were violent intermittent disturbances which produced short trains of waves, each of which rapidly died away. If you throw a stone into a pond it sets up a train of ripples on the surface. If you then throw another stone in the same place, another train of ripples is set up. If, instead of throwing a stone, you dip your hand into the water and move it rapidly and regularly up and down, you will send a continuous stream of waves over the water as long as you keep up the



(By courtesy of Sport and General)

LINERS IN SOUTHAMPTON DOCKS

In one dock on the left are the *Majestic*, *Berengaria*, *Aquitania*, *Homerick* and *Mauretania*; on the right is the *Empress of Britain*



(By courtesy of the Trustees)

A CELL OF THE WORLD'S BRAIN: THE CENTRAL READING ROOM OF THE BRITISH MUSEUM LIBRARY

THE CONQUEST OF DISTANCE

motion. If the movement upwards and downwards of the hand is slow, the distance from crest to crest of the waves—the wave length—is longer than if the movement of the hand is quick. It was the persistent hand and not the occasional stone, that voice transmission, as distinguished from signal transmission, required.

An alternating electric current flowing with extraordinary rapidity and regularity up and down the aerial was necessary to produce the continuous waves required for wireless telephony. Several rival systems of wireless transmission produced waves of this kind, and a new method was available after 1913, when it was discovered that the valve, hitherto used for detecting and amplifying the signals, was itself capable of acting as an oscillator and of radiating electric waves. The transmission of speech was then achieved by imposing on the continuous waves much coarser variations corresponding to the vibration of the human voice. The speaker's words are received by a microphone, which is really a sensitive telephone transmitter. The electric current flowing through the microphone is modified by his voice and conveys these modifications to the outgoing wave. This wave conveys the modifications to a distance, where they are rendered audible in a telephone receiver or a loud speaker. Such, in brief, is the general procedure by which wireless telephony has been accomplished.

By 1920 our world by land and sea was everywhere throbbing with dots and dashes and living words. For half a dozen years Europe and America had been in wireless telephonic communication. The British government had projected a chain of wireless stations. The most remote parts of the Empire were to be brought into communication. All over Europe and in North America there was intense activity, when suddenly the whole practice of long-distance transmission was changed by a most curious circumstance.

No branch of applied science has ever exercised such a fascination for the man in the street as radio transmission. Advance had been so rapid, the field was so new, that the physicist and the engineer had not swept it clean. They had left things to be discovered—mostly new arrangements of the parts, of which there is a bewildering variety. That was a great opportunity and stimulus for the gleaming amateur experimentalist. But while opportunities for private experiment in reception were unlimited, those for experiment in transmission were limited to wave lengths which did not

THE WORK, WEALTH & HAPPINESS OF MANKIND

interfere with public service. For public use, the relatively long waves were monopolized, for the earlier investigators had found these to be the most effective for their immediate purposes.

Consequently the amateur was forced to use short waves. But he was not necessarily limited to short distances. In 1921-22, American, British, French, and German amateurs were communicating with one another across the Atlantic with far less power than that required by the big stations. Through their efforts it was realized that for the longest distances the short wave is the more effective, and the cost of equipment less. This was especially the case when it was further discovered that with a special form of aerial the short waves could be radiated even more effectively in the form of a beam with very little spreading. This beam aerial consists of a number of parallel wires hanging vertically and in a straight line. If the row of wires is north and south the waves are radiated east and west. If the row is east and west the waves proceed north and south. They form a beam with a very slight divergence, whereas long waves spread fanwise over a wide area. If similar, but more numerous, wires are hung behind the others, they form a screen, and the waves are radiated only from the front. This beam wireless has the same relation to the long wave wireless, that a focussed searchlight has to an unshaded arc light. By beam wireless England is now in regular communication with South Africa, India, Australia, Canada, the United States and other countries. Long-distance lines in America also employ this method.

In April, 1931 (says *Discovery*, May, 1931), a new "ultra short wave" radio equipment was demonstrated. Conversations were exchanged between Dover and Calais on a wave length of only eighteen centimetres, using aerials of less than an inch in length, with a power of half a watt—which is just sufficient to light an ordinary flash-lamp bulb. In this new apparatus, the sound of the speaker's voice at the transmitting station is carried to a "micro-radion" tube where waves called "micro-rays" are generated; the waves oscillate at a rate of sixteen hundred million times a second. After concentration by an ingenious combination of two reflectors into a fine pencil of rays, somewhat similar to the rays sent out by a searchlight, the waves are transmitted into space. An important feature of the micro-rays is that they are not subject to the "fading" effects encountered in ordinary wireless transmission, and

THE CONQUEST OF DISTANCE

they are not absorbed by rain or fog, as is the case with light rays. The demonstration has shown that wave lengths of between ten and a hundred centimetres can be used for commercial transmission. This gives a great range of difference in transmission and nearly a quarter of a million micro-ray instruments will be workable without any one of them interfering with another.

Wireless communication was rapidly adopted for use at sea. All ships making long voyages are equipped for it, and by the direction finder they are able to ascertain the point of the compass from which signals come. It is also destined to facilitate aerial navigation very greatly. An airman can already find his way to the aerodrome through darkness or fog by noting the direction and strength of signals which are continually emitted for his guidance. And these new micro-rays will manifestly play a large part in the complete development of such vitally necessary facilities. The aeroplane of the future will have micro-ray eyes, and it is within the limits of scientific possibility that that which these radio eyes will see may be translated again into direct vision for the pilot.

The broadcasting of entertainments began in Canada in 1920. In 1922 the British Broadcasting Company was formed. In America, many broadcasting services were established by private enterprise. The isolated farmer, the aged and infirm, the sick are brought into touch with the world. The colonial settler, a hundred miles from a railway, can hear during his dinner hour the weather forecast, the crop reports, market prices, as well as many things remote from "the daily round, the common task." In Europe a man may, by merely turning a knob, hear music in variety, or speech in one of half a dozen tongues. What is distance? Where are political boundaries when man can speak to many men across a thousand miles of space?

The possibilities are boundless. And yet as we go to press official announcement has just been made of a difficulty which may, for a time, block progress and largely frustrate the efforts of all these scientists and inventors. The ether is becoming over-crowded. Powerful stations, broadcasting variety entertainment, are so increasing their range as to interfere with reception thousands of miles away. Even signals of distress from ships at sea are said to have been drowned. There is a destructive competition going on in the ether which in the end will benefit nobody and lead to nothing

THE WORK, WEALTH & HAPPINESS OF MANKIND

but a deadlock unless it can be solved by international agreement.

Yet manifestly more is still to come. Television is already possible on a small scale. The unsurmounted difficulties here are still immense. To appreciate these, consider the simpler case of transmitting a photograph by electricity. The original picture is divided into a number of minute squares. Each of these squares is illuminated in turn by a spot of light until the whole photograph has been explored. The light reflected from the surface will vary in intensity according to the light or shadow of the part illuminated. This reflected light falls upon a cell sensitive to light—a vacuum tube having the inner surface coated with a metal that changes in resistance as light falls upon it. So, as the spot of light runs over the picture and explores it, the current through the cell varies with the light and shade and conveys these differences to the outgoing waves. At the receiving end these waves act on a mirror galvanometer which regulates a minute beam of light in an otherwise darkened chamber, falling successively on a series of small areas of a piece of sensitized paper. This paper, on development, yields a copy of the original photograph. This process of transmission may take ten or fifteen minutes.

In television a distant person or object has to be explored in the same way by a spot of light. That is not difficult. No photography is involved. At the receiving end corresponding spots of light, of greater or less intensity, according to the light and shade of the original, have to be thrown on a screen with such rapidity that the last has appeared before the first has faded from view. When anyone looks at an object, an image is formed on a sort of screen—the retina, at the back of the eye. This image persists, after the object has been removed from sight, for one tenth of a second! On this elementary fact of the persistence of vision the cinema rests. But see the limiting time conditions imposed on television! The distant person or object must be explored ten times a second, and the transmitted image formed on the screen with the same rapidity. The apparatus must be capable therefore of working at least three thousand times faster than that used for transmitting a photograph. The difficulties in achieving this rapidity are partly mechanical, and partly they lie in securing a sufficient intensity of light to illuminate a large area. At present the transmitted picture could be contained on a postcard.

THE CONQUEST OF DISTANCE

But who dares say that these difficulties will not be overcome? The time may yet be when a man will talk to another a thousand miles or more away, and each may be able to see, life size, every movement of the lips and every changing expression that indicate the other's mood. Everyone in that concentrated and intensified world will be living, so to speak, in the next room from everybody else and able with little effort to step into that next room to speak to a friend or make an explanation to remove a misunderstanding. The whole world will be a meeting place.

§ 5. *Print and Film*

This recent and dazzling development of electrical communications which has made the present moment world-wide must not blind us to the major importance of that larger organization of human communications which is concerned with the establishment of ideas, the supply of ordered knowledge, the maintenance and development of common understandings—namely, the printed word. Electrical communication is a matter of the past century; the book has been developing for more than two thousand years; the newspaper, in its modern form, as an addition to the world's mental power, is a thing scarcely two centuries old.

We live in the light of a hard, crude alertness to events. It is a glaring and unshaded light, which casts strange shadows, but it is light. Few of us realize the darkness and the remoteness from current reality which characterized the minds of our great-grandparents. They had a few well printed books, bound in leather and handsomely out of date, a small news-sheet, and a monthly magazine as their chief sources of information. That was all.

The *Outline of History* tells in brief the main factors in the story of the book, because an outline of human history is necessarily a record of continually growing communities, and necessarily it deals with communications as matters of primary importance. Such figures as Alexander, Cæsar and Napoleon are mere passengers carried about by the real moving forces of life; the use of cavalry on the Persian roads, a new system of monetary trading, the sailing ship and the highroad. The entire contents of the *Outline of History* might easily be rearranged under five successive headings: (1) Before Speech, (2) Speech, (3) Writing, (4) the Printed Book, (5)

THE WORK, WEALTH & HAPPINESS OF MANKIND

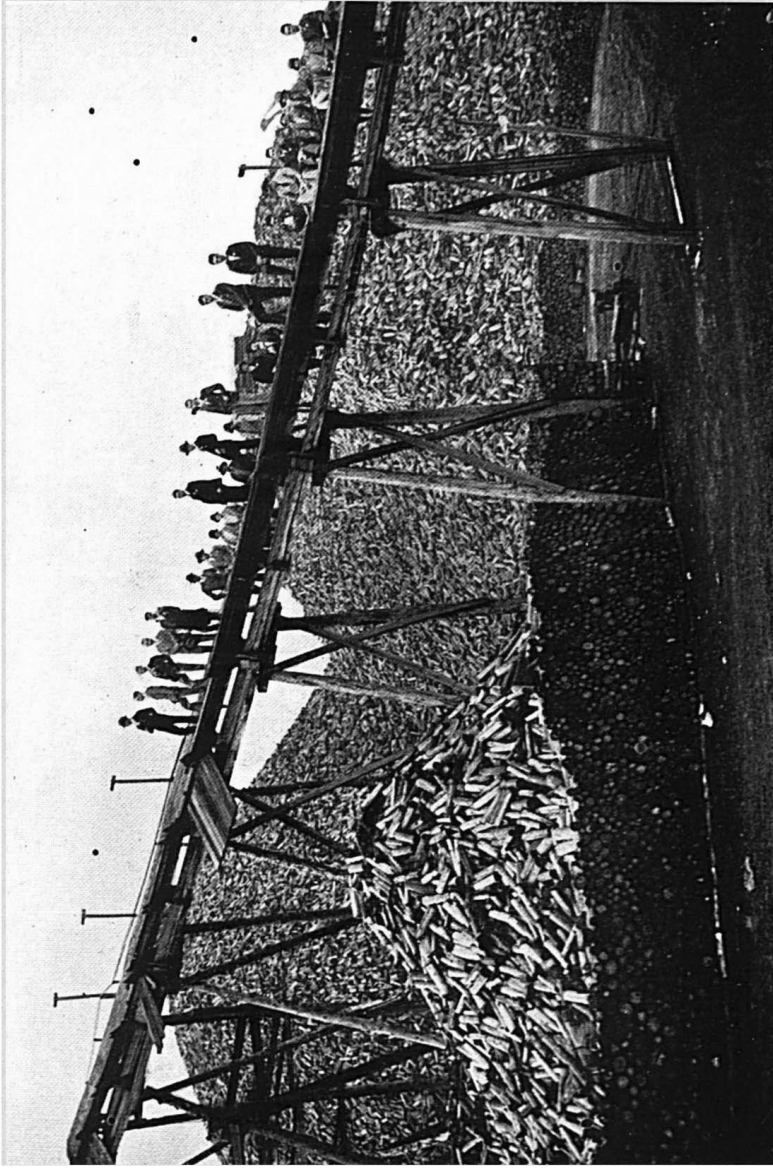
Mechanical Transport and Electric Communication, each indicating a revolution in communication and involving a new, larger, and more complex social organization. The printed book and map revolutionized the world at the Renaissance; the newspaper followed hard upon manageable paper and printing.

And here again our museums come to our aid. This time we can refer to actual museums. There are already many miles of galleries treating of the making and use of books. There are also vast collections of filed newspapers, and now such of the primitive machines as survive are being taken care of and found floor room. In these museum galleries it is possible to trace the first origins of the press in the classical white notice board, the "album," in the news-letter and news-sheet, and go on from that, step by step, until the throbbing great printing machinery and the stir and rush of a well equipped newspaper office are brought before our reader.

We dare not embark upon the story of newspaper work and the adventures of newspaper men. Interesting it would be to trace the thrill of excitement from the moment of a crime to the arrival of the reporter and the headline proclamation to the world. How is reporting done? That would be a queer chapter in the detailed story of human activities. Our picture, in its fullness, would include the government representative making his communication to the gentlemen of the press and the interesting, tactful and precarious work of a foreign correspondent. The editing and make-up of a paper would be shown.

The rôle of the newspaper in modern life is profoundly important. On the one hand it touches the book, on the other the pulpit, the lecture-theatre and now the radio talk. It is the modern man's daily reminder of things greater than himself, of a life of the race exceeding and comprehending his own. Every day that reminder comes to him. Few of us realize how the intensity of the individual life is diminished and the individual life *generalized* by the newspaper. To that we must return later when we come to review the education, formal and informal, of the modern citizen.

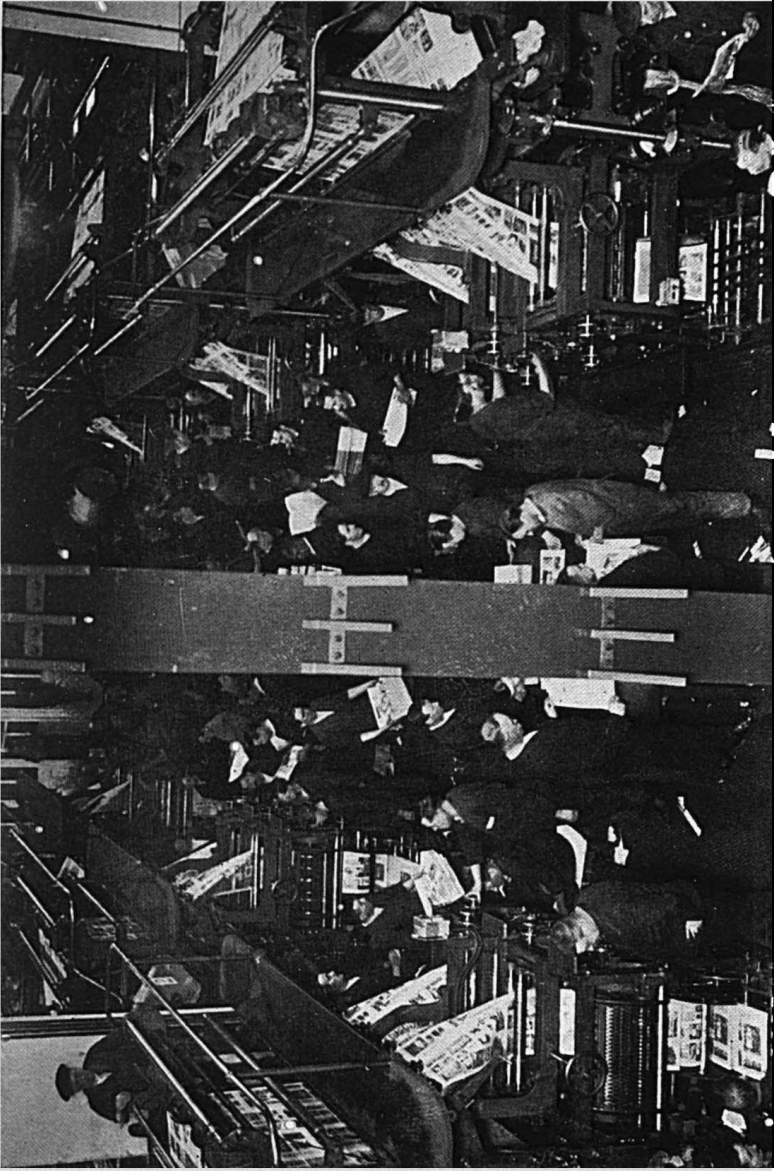
The newspaper is so much with us now that it is already difficult to imagine a world without it. Still more difficult is it to realize what an extraordinary and possibly transitory thing it is in social life—in the form in which we know it now. It does work now vitally necessary to a modern community, and it does it very



(By courtesy of Allied Newspapers)

**“THE VAST DEMANDS OF THE DAILY PRESS ARE BEING MET BY A RUTHLESS DESTRUCTION
OF FORESTS” (p. 155)**

Wood to be used in the manufacture of newsprint paper



(By courtesy of the Graphic Photo Union)

"THE NEWSPAPER IS A NECESSARY PART OF MODERN SOCIAL ORGANIZATION" (p. 156)

A scene in the machine room of a London newspaper

THE CONQUEST OF DISTANCE

crudely. It began simply and frankly enough as a purely informative news-sheet. It was produced as that and bought and paid for as that. But from the very earliest stages it became evident that it had other uses. It was extraordinarily convenient for all sorts of announcements, which had previously been made chiefly by criers, by notices on church doors and suchlike frequented places, and its use for advertisement became rapidly profitable. It could, in addition to the news it supplied, supplement its interest by the discussion of public affairs.

Its rapid expansion in the nineteenth century was associated not merely with the spread of elementary education but with a revolution in paper making. The rag-made paper of the past could never have been produced in sufficient quantity for the modern press. Wood pulp, wrote Lord Northcliffe in the eleventh *Encyclopædia Britannica*, is at the roots of the expansion of the modern newspaper. The machinery to produce it in great quantities became available in the last quarter of the nineteenth century, and with that came huge printing machines, folding machines and the like, making the printing and distribution of a couple of millions of copies in a few hours easily possible.

The vast demands of the daily press are being met by a ruthless destruction of forests and have encouraged the planting of quick-growing soft timber at the expense of hard constructional varieties, which are also being exhausted to serve other human needs. It has been estimated that the present European demand for soft woods exceeds the annual growth of existing forests by three thousand million cubic feet.

From the first the newspaper was developed on commercial lines. It betrayed little ambition beyond profits and little consciousness of the rôle it was playing in the expansion of our new and larger world with which it was being evolved. Its successful proprietors, with a few distinguished and redeeming exceptions, have sought to give such news only as appealed to the commoner sorts of mind, to provide excitement and entertainment even at the cost of veracity, and to gather "publics" which would present an attractive field for well paid advertisements. Their temptations have been immense. They have been naturally and necessarily on the side of private adventure against comprehensive control. They have a bias against an orderly commonweal. Our press is an

THE WORK, WEALTH & HAPPINESS OF MANKIND

adventurer's press. Few newspapers have any interest in supporting or defending a soundly organized public service, nagging attacks on public services are a world-wide newspaper feature, but every newspaper has an interest in a shabbily conducted, privately owned transport system which is advertising to keep its passengers in a good temper, or in a purveyor of quack medicines or trashy foodstuffs sustaining a legend of merit by a lavish expenditure in display. No newspaper again has any interest in the exposure of fraudulent or adulterated commodities, unless such an exposure will frighten or flatter the owners of competing articles, to its profit. It has no organic links with political issues. Serious discussion may easily bore its readers; ridicule and caricature of men in difficult positions are not only easier to do but more acceptable to the ordinary man. It can offer or refuse, it can in fact sell, "publicity," that most precious commodity, exactly as it is disposed. The marvel is not that the ordinary modern newspaper succumbs too often to these manifest temptations, but that it has not been altogether overwhelmed and degraded by them, that it still, in its way, performs something of its necessary function in the new community. It does, as we have said, generalize its habitual reader and open his mind, however crudely, to a wider, more various life beyond his own.

But what needs to be made clear and is by no means clear to a generation born amidst newspapers and brought up on them is the extremely recent and the extremely provisional nature of the press as a social and political organ. Nobody seems to have foreseen how the community would be generalized by letterpress and by a universal habit of reading, and still less did anyone scheme or contemplate such a task of sustained information and direction as a better form of newspaper might undertake. The newspaper, a mere petty excrescence upon life in the early seventeenth century, is discovered to be a necessary part of our modern social organization. Now that we have it and observe it we realize that it is not only a vitally important organ, but also one still in the process of development and social adjustment.

The cinema, with its recent development, the talking cinema, destined it would seem at a not very distant date to be modified and mitigated into the artistic "sound film" in which talk will play a minor rôle, is a more modern and even more startling case of a

THE CONQUEST OF DISTANCE

new, important method of intercommunication gone very seriously astray. So far it has been developed chiefly on its "amusements" side. The story of the cinema is a worse record than that of the newspaper so far as the waste of serviceable opportunity through triviality of conception goes. Its obvious uses for educational purposes have still to be developed. The universities and schools of the existing régime lack the vigour and enterprise to control this new and powerful instrument for the distribution of mental impressions.

To that we must return later. A broad treatment of modern education will be the culmination of our enterprise, and in this chapter it will suffice to mention only the development, manufacture and distribution of the "movies."

Our imaginary economic museum, in its immense and spacious fashion, will have room to give an account of the making and display of a typical talkie-movie from the moment of its invention to its final disuse as a superannuated film. (I grow more and more pleased with the storage accommodation of these museums of ours.) And here again we shall be forced to note the inconvenience of outworn political traditions that now hamper, and may continue to hamper indefinitely, the world-wide spread of ideas by the cinema, in the interest of national antagonisms and national profiteers, the quotas, the customs dues and all the "blackmail of frontiers."

Another system of world communications, the international post, shows a better spirit at work. The creation of the Postal Union marks a phase of sanity breaking through the chronic spites of nationalism. The growing facilities of letter transport over great distances were first realized in America, and in 1862 the United States suggested a conference which was held in Paris in 1863. Wars interrupted the movement for some years, but in 1875 the first International Postal Convention was signed at Berne and the Postal Union brought into being. It has survived all the stresses of conflict that have since torn the world, and to-day, so far as letters go, our planet is practically one. Forty billion letters pass through the organized postal services of the world, besides newspapers, books, and parcels in great quantities. One scribbles a letter in a room in Manchester or Chicago and with a minimum of delay it starts on its journey, to a solitary Pacific island, to a factory in Soviet Siberia, to a boy on a battleship, to a prisoner in a gaol. More

THE WORK, WEALTH & HAPPINESS OF MANKIND

than a hundred million letters a day are rustling about the world.

This Book on Communication again, like the Book of Substances and the Conquest of Power, is given here in the briefest outline. But the *Science of Work and Wealth*, rest assured, if and when it comes into existence, will give by its unrestrained pictures and descriptions an illimitable store of interesting and curious detail, helpful but inessential and quite impossible to summarize. And when the *Science of Work and Wealth* has laid down the world's roads and railways, launched its fleets and traced its multiplying airways through the blue, it will turn round and tell the reader just how he can travel to the ends of the earth, how he may talk to and see his friend wherever he is upon the planet, and what are the facilities and conditions for sending a ton of goods from anywhere to anywhere.

And so the scale and tempo of the modern process will be set for the survey of feeding, clothing, housing, protecting and keeping in health and order, that will follow.