trimeric SI locates itself on top of the trimeric S2 stalk (45). Recently, structural analyses of the S proteins of COVID-19 have revealed 27 amino acid substitutions within a 1,273-amino-acid stretch (16). Six substitutions are located in the RBD (amino acids 357 to 528), while four substitutions are in the RBM at the CTD of the S1 domain (16). Of note, no amino acid change is seen in the RBM, which binds directly to the angiotensin-converting enzyme-2 (ACE2) receptor in SARS-CoV (16, 46). At present, the main emphasis is to knowing how many differences would be required to change the host tropism. Sequence comparison revealed 17 non-synonymous changes between the early sequences of SARS-CoV-2 and the later isolates of SARS-CoV. The changes were found scattered over the genome of the virus, with nine substitutions in ORF1ab, ORF8 (4 substitutions), the spike gene (3 substitutions), and ORF7a (single substitution) (4). Notably, the same non-synonymous changes were found in a familial cluster, indicating that the viral evolution happened during person-to-person transmission (4, 47). Such adaptive evolution events are frequent and constitute a constantly ongoing process once the virus spreads among new hosts (47). Even though no functional changes occur in the virus associated with this adaptive evolution, close monitoring of the viral cat and camels, respectively, act as amplifier hosts (40, 41).

Corona-virus genomes and sub-genomes encode six ORFs (31). The majority of the 5´end is occupied by ORF la/b, which produces 16 nsps. The two polyproteins, pp la and pp l ab, are initially produced from ORF la/b by a -1 frame-shift between ORF la and ORF 1b (32). The virus-encoded proteases cleave polyproteins into individual nsps (main protease [Mpro], chymotrypsin-like protease [3CLpro], and papain-like proteases [PLPs)) (42). SARS-CoV-2 also encodes these nsps, and their functions have been elucidated recently (31). Remarkably, a difference between SARS-CoV-2 and other CoVs is the identification of a novel short putative protein within the ORF3 band, a secreted protein with an alpha helix and beta-sheet with six strands encoded by ORF8 (31).

Corona-viruses encode four major structural proteins, namely, spike (S), membrane (M), envelope (E), and nucleocapsid (N), which are described in detail below.

S Glycoprotein

Corona-virus S protein is a large, multifunctional class I viral transmembrane protein. The size of this absence of this protein is related to the altered virulence of corona-viruses due to changes in morphology and tropism (54). The E protein consists of three domains, namely, a short hydrophilic amino terminal, a large hydrophobic transmembrane domain, and an efficient C-terminal domain (51). The SARS-CoV-2 E protein reveals a similar amino acid constitution without any substitution (16).

N Protein

The N protein of corona-virus is multipurpose. Among several functions, it plays a role in complex formation with the viral genome, facilitates M protein interaction needed during virion assembly, and enhances the transcription efficiency of the virus (55, 56). It contains three highly conserved and distinct domains, namely, an NTD, an RNA-binding domain or a linker region (LKR), and a CTD (57). The NTD binds with the 3´ end of the viral genome, perhaps via electrostatic interactions, and is highly diverged both in length and sequence (58). The charged LKR is serine and arginine rich and is also known as the SR (serine and arginine) domain (59). The LKR is capable of direct interaction with in vitro RNA interaction and is responsible for cell signaling (60, 61). It also modulates the antiviral response of the host by working as an antagonist for interferon new targeted drugs, and prevention of further epidemics (13). The most common symptoms associated with COVID-19 are fever, cough, dyspnea, expectoration, headache, and myalgia or fatigue.

In contrast, less common signs at the time of hospital admission include diarrhea, hemoptysis, and shortness of breath (14). Recently, individuals with asymptomatic infections were also suspected of transmitting infections, which further adds to the complexity of disease transmission dynamics in COVID-19 infections (1). Such efficient responses require in-depth knowledge regarding the virus, which currently is a novel agent; consequently, further studies are required.

Comparing the genome of SARS-CoV-2 with that of the closely related SARS/SARS-like CoV revealed that the sequence coding for the spike protein, with a total length of 1,273 amino acids, showed 27 amino acid substitutions. Six of these substitutions are in the region of the receptor-binding domain (RBD), and another six substitutions are in the underpinning sub-domain (SD) (16). Phylogenetie analyses have revealed that SARS-CoV-2 is closely related (88% similarity) to two SARS-like CoVs from bat SARS-like CoVs (bat-SL-CoVZC45 and bat-SL-CoVZXC21) (Fig. 1)

Initially, the epicenter of the SARS-CoV-2 pandemic was China, which reported a significant number of deaths associated with COVID-19, with 84,458 laboratory-confirmed cases and 4,644 deaths as of 13 May 2020 (Fig. 4). As of 13 May 2020, SARS-CoV-2 confirmed cases have been reported in more than 210 countries apart from China (Fig. 3 and 4) (WHO Situation Report 114) (25, 64). COVID-19 has been reported on all continents except Antarctica. For many weeks, Italy was the focus of concerns regarding the large number off cases, with 221,216 cases and 30,911 deaths, but now, the United States is the country with the largest number of cases, 1,322,054, and 79,634 deaths. Now, the United Kingdom has even more cases (226,467 1) and deaths (32,692) than Italy. A John Hopkins University web platform has provided daily updates on the basic epidemiology of the COVID-19 outbreak encircled With an envelope containing Viral nucleocapsid. The nucleocapsids in CoVs are arranged in helical symmetry, which reflects an atypical attribute in positive-sense RNA viruses (30). The electron micrographs of SARS-CoV-2 revealed a diverging spherical outline with some degree of pleomorphism, virion diameters varying from 60 to 140 nm, and distinct spikes of 9 to 12 nm, giving the virus the appearance of a solar corona (3). The CoV genome is arranged linearly as 5´-leader-UTR-replicase-structural genes (S-E-M-N)-3´ UTR-poly (A) (32). Accessory genes, such as 3a/b, 4a/b, and the hemagglutinin-esterase gene (HE), are also seen intermingled with the structural genes (30). SARS-CoV-2 has also been found to be arranged similarly and encodes several accessory proteins, although it lacks the HE, which is characteristic of some betacorona-viruses (31). The positive-sense genome of CoVs serves as the mRNA and is translated to polyprotein la/lab (ppla/lab) (33). A replication-transcription complex (RTC) is formed in double-membrane vesicles (DMVs) by nonstructural proteins (nsps), encoded by the polyprotein gene (34). Subsequently, the RTC synthesizes a nested set of subgenomic RNAs (sgRNAs) via discontinuous transcription (35).

range of hosts, producing symptoms and diseases ranging from the common cold to severe and ultimately fatal illnesses, such as SARS, MERS, and, presently, COVID-19. SARS-CoV-2 is considered one of the seven members of the CoV family that infect humans (3), and it belongs to the same lineage of CoVs that causes SARS; however, this novel virus is genetically distinct. Until 2020, six CoVs were known to infect humans, including human CoV 229E (HCoV-229E), HCoV-NL63, HCoV-OC43, HCoV HKUI, SARS-CoV, and MERS-CoV. Although SARS-CoV and MERS-CoV have resulted in outbreaks with high mortality, others remain associated with mild upper-respiratory-tract illnesses (4).

Newly evolved CoVs pose a high threat to global public health. The current emergence of COVID-19 is the third CoV outbreak in humans over the past 2 decades (5). It is no coincidence that Fan et al. predicted potential SARS- or MERS-like CoV outbreaks in China following pathogen transmission from bats (6). COVID-19 emerged in China and spread rapidly throughout the country and, subsequently, to other countries. Due to the severity of this outbreak and the potential of spreading on an international scale, the WHO declared a global health emergency on 31 January 2020 subsequently and deaths. The COVID-19 outbreak has also been associated with severe economic impacts globally due to the sudden interruption of global trade and supply chains that forced multinational companies to make decisions that led to significant economic losses (66). The recent increase in the number of confirmed critically ill patients with COVID-19 has already surpassed the intensive care supplies, limiting intensive care services to only a small portion of critically ill patients (67). This might also have contributed to the increased case fatality rate observed in the COVID-19 outbreak.

Viewpoint on SARS-CoV-2 Transmission, Spread, and Emergence

The novel corona-virus was identified within 1 month (28 days) of the outbreak. This is impressively fast compared to the time taken to identify SARS- CoV reported in Foshan, Guangdong Province, China (125 days) (68). Immediately after the confirmation of viral etiology, the Chinese virologists rapidly released the genomic sequence of SARS-CoV-2, which played a crucial role in controlling the spread of this newly emerged novel corona-virus to other parts of the world (69). The possible origin of SARS-CoV-2 and the first mode of

Some therapeutic options for treating COVID-19showed eflicacy in *in vitro* studies; however, to date, these treatments have not undergone any randomized animal or human clinical trials, which limit their practical applicability in the current pandemic (7, 9, 19-21).

The present comprehensive review describes the various features of SARS-CoV-2/COVID-19 causing the current disease outbreaks and advances in diagnosis and developing vaccines and therapeutics. It also provides a brief comparison with the earlier SARS and MERS CoVs, the veterinary perspective of CoVs and this emerging novel pathogen, and an evaluation of the zoonotic potential of similar CoVs to provide feasible One Health strategies for the management of this fatal virus (22-367).

THE VIRUS (SARS-CoV-2)

Corona-viruses are positive-sense RNA viruses having an extensive and promiscuous range of natural hosts and affect multiple systems (23, 24). Corona-viruses can cause clinical diseases in humans that may extend from the common cold to more severe respiratory diseases like SARS and MERS (17, 279). The recently emerging SARS-CoV-2 has wrought havoc in China and caused a pandemic situation in the worldwide population leading to fever, cough, and sputum (83). Hence, the clinicians must be on the look-out for the possible occurrence of atypical clinical manifestations to avoid the possibility of missed transmission ability of SARS-CoV-2 was found to be diagnosis. The early similar to or slightly higher than that of SARS-CoV, reflecting that it could be controlled despite moderate to high transmissibility (84).

Increasing reports of SARS-CoV-2 in sewage and wastewater warrants the need for further investigation due to the possibility of fecal-oral transmission. SARS-CoV-2 present in environmental compartments such as soil and water will finally end up in the wastewater and sewage sludge of treatment plants (328). Therefore, we have to reevaluate the current wastewater and sewage sludge treatment procedures and introduce advanced techniques that are specific and effective against SARS-CoV-2. Since there is active shedding of SARS-CoV-2 in the stool, the prevalence of infections in a large population can be studied using wastewater-based transcription-epidemiology. Recently, reverse transcription-quantitative PCR (RT-qPCR) was used to enumerate the copies of SARS-CoV-2 RNA concentrated from wastewater collected from a wastewater treatment plant (327). The calculated viral RNA copy numbers determine the number of infected individuals. The

the initial stages of the outbreak, only mild symptoms were noticed in those patients that are infected by human-to-human transmission (14). The initial trends suggested that the mortality associated with COVID-19 was less than that of previous outbreaks of SARS (101). The updates obtained from countries like China, Japan, Thailand, and South Korea indicated that the COVID-19 patients had relatively mild manifestations compared to those with SARS and MERS (4). Regardless of the corona-virus type, immune cells, like mast cells, that are present in the sub-mucosa of the respiratory tract and nasal cavity are considered the primary barrier against this virus (92). Advanced in-depth analysis of the genome has identified 380 amino acid substitutions between the amino acid sequences of SARS-CoV-2 and the SARS/SARS-like corona-viruses. These differences in the amino acid sequences might have contributed to the difference in the pathogenic divergence of SARS-CoV-2 (16). Further research is required to evaluate the possible tropism, transmission of this novel agent associated with these differences in pathogenesis, and change in the amino acid sequence. With the current outbreak of COVID-19, there is an expectancy of a significant increase in the number of published studies about this emerging corona-virus, as occurred visible signs of infection, making it challenging to identify animals actively excreting MERS-CoV that has the potential to infect humans. However, they may shed MERS-CoV through milk, urine, feces, and nasal and eye discharge and can also be found in the raw organs (108). In a study conducted to evaluate the susceptibility of animal species to MERS-CoV infection, llamas and pigs were found to be susceptible, indicating the possibility of MERS-CoV circulation in animal species other than dromedary camels (109).

Following the outbreak of SARS in China, SARS-CoV-like viruses were isolated from Himalayan palm civets (*Paguma larvata*) and raccoon dogs (*Nyctereutes procyonoides*) found in a live-animal market in Guangdong, China. The animal isolates obtained from the live-animal market retained a 29-nucleotide sequence that was not present in most of the human isolates (78). These findings were critical in identifying the possibility of interspecies transmission in SARS-CoV. The higher diversity and prevalence of bat corona-viruses in this region compared to those in previous reports indicate host/pathogen corona-viruses also have been found circulating in the Chinese horseshoe bat (Rhinolophus sinicus) populations. The in vitro and in vivo studies carried understanding of the lung inflammation associated with this infection (24).

SARS is a viral respiratory disease caused by a formerly unrecognized animal CoV that originated from the wet markets in southern China after adapting to the human host, thereby enabling transmission between humans (90). The SARS outbreak reported in 2002 to 2003 had 8,098 confirmed cases with 774 total deaths (9.6%) (93). The outbreak severely affected the Asia Pacific region, especially mainland China (94). Even though the case fatality rate (CFR) of SARS-CoV-2 (COVID-19) is lower than that of SARS-CoV, there exists a severe concern linked to this outbreak due to its epidemiological similarity to influenza viruses (95, 279). This can fail the public health system, resulting in a pandemic (96).

MERS is another respiratory disease that was first reported in Saudi Arabia during the year 2012. The disease was found to have a CFR of around 35% (97). The analysis of available data sets suggests that the incubation period of SARS-CoV-2, SARS-CoV, and MERS-CoV is in almost the same range. The longest predicted incubation time of SARS-CoV-2 is 14 days. Hence, suspected individuals are isolated for 14 days to avoid the risk of further spread (98). Even though a high similarity has been reported

Splits Tree phylogeny analysis.

In the unrooted phylogenetic tree of different betacorona-viruses based on the S protein, virus sequences from different subgenera grouped into separate clusters. SARS-CoV-2 sequences from Wuhan and other countries exhibited a close relationship and appeared in a single cluster (Fig. 1). The CoVs from the subgenus *Sarbecovirus* appeared jointly in Splits Tree and divided into three sub-clusters, namely, SARS-CoV-2, bat-SARS-like-CoV (bat-SL-CoV), and SARS-CoV (Fig. 1). In the case of other subgenera, like *Merbecovirus*, all of the sequences grouped in a single cluster, whereas in *Embecovirus*, different species, comprised of canine respiratory CoVs, bovine CoVs, equine CoVs, and human CoV strain (OC43), grouped in a common cluster. Isolates in the subgenera *Nobecovirus* and *Hibecovirus* were found to be placed separately away from other reported SARS-CoVs but shared a bat origin.

CURRENT WORLDWIDE SCENARIO OF SARS-CoV-2

This novel virus, SARS-CoV-2, comes under the subgenus *Sarbecovirus* of the *Orthocoronavirinae* subfamily and is entirely different from the viruses

From experience with several outbreaks associated with known emerging viruses, higher pathogenicity of a virus is often associated with lower transmissibility. Compared to emerging viruses like Ebola virus, avian H7N9, SARS-CoV, and MERS-CoV, SARS-CoV-2 has relatively lower pathogenicity and moderate transmissibility (15). The risk of death among individuals infected with COVID-19 was calculated using the infection fatality risk (IFR). The IFR was found to be in the range of 0.3% to 0.6%, which is comparable to that of a previous Asian influenza pandemic (1957 to 1958) (73, 277).

Notably, the reanalysis of the COVID-19 pandemic curve from the initial cluster of cases pointed to considerable human-to-human transmission. It is opined that the exposure history of SARS-CoV-2 at the Wuhan seafood market originated from human-to-human transmission rather than animal-to-human transmission (74); however, in light of the zoonotic spillover in COVID-19, is too early to fully endorse this idea (1). Following the initial infection, human-to-human transmission has been observed with a preliminary reproduction number (R_0) estimate of 1.4 to 2.5 (70, 75), and recently it is estimated to be 2.24 to 3.58 (76). In another study, the average reproductive number of

The results of the studies related to SARS-CoV-2 viral loads reflect active replication of this virus in the upper respiratory tract and prolonged viral shedding after symptoms disappear, including via stool. Thus, the current case definition needs to be updated along with a reassessment of the strategies to be adopted for restraining the SARS-CoV-2 outbreak spread (248). In some cases, the viral load studies of SARS-CoV-2 have also been useful to recommend precautionary measures when handling specific samples, e.g., feces. In a recent survey from 17 confirmed cases of SARS-CoV-2 infection with available data (representing days 0 to 13 after onset), stool samples from nine cases (53 %; days 0 to 11 after onset) were positive on RT-PCR analysis. Although the viral loads were lower than those of respiratory samples (range, 550 copies per ml to 1.21x 10^5 copies per ml), this has essential bio-safety implications (151).

The samples from 18 SARS-CoV-2-positive patients in Singapore who had traveled from Wuhan to Singapore showed the presence of viral RNA in stool and whole blood but not in urine by real-time RT-PCR (288). Further, novel SARS-CoV-2 infections have been detected in a variety of clinical specimens, like bronchoalveolar lavage fluid, appeared asymptomatic[45]. Another serological study detected SARS-CoV-2 neutralizing antibodies in cat serum samples collected in Wuhan after the COVID-19 outbreak, providing evidence for SARS-CoV-2 infection in cat populations in Wuhan, although the potential of SARS-CoV-2 transmission from cats to humans is currently uncertain[46].

Receptor use and pathogenesis

SARS-CoV-2 uses the same receptor as SARS-CoV, angiotensin-converting enzyme 2 (ACE2)[11,47]. Besides human ACE2 (hACE2), SARS-CoV-2 also recognizes ACE2 from pig, ferret, rhesus monkey, civet, cat, pangolin, rabbit and dog[11,43,48,49]. The broad receptor usage of SARS-CoV-2 implies that it may have a wide host range, and the varied efficiency ofACE2 usage in different animals may indicate their different susceptibilities to SARS-CoV-2 infection. The S1 subunit of a corona-virus is further divided into two functional domains, an N-terminal domain and a C-terminal domain. Structural and biochemical analyses identified a 211 amino acid region (amino acids 319-529) at the S1 C-terminal domain of SARS-CoV-2 as the RBD, which has a key role in virus entry and is the target of neutralizing antibodiess05 (FIG. 3a). The RBM mediates con- tact with the ACE2 receptor (amino acids 437-507 of SARS-COV-2S protein), and this region in SARS-CoV-2 differs from that in SARS-CoV in the five residues critsignificance of frequent and good hand hygiene and sanitation practices needs to be given due emphasis (249-252). Future explorative research needs to be conducted with regard to the fecal-oral transmission of SARS-CoV-2, along with focusing on environmental investigations to find out if this virus could stay viable in situations and atmospheres facilitating such potent routes of transmission. The correlation of fecal concentrations of viral RNA with disease severity needs to be determined, along with assessing the gastrointestinal symptoms and the possibility of fecal SARS-CoV-2 RNA detection during the COVID-19 incubation period or convalescence phases of the disease (249-252).

The lower respiratory tract sampling techniques, like bronchoalveolar lavage fluid aspirate, are considered the ideal clinical materials, rather than the throat swab, due to their higher positive rate on the nucleic acid test (148). The diagnosis of COVID-19 can be made by using upper-respiratory-tract specimens collected using nasopharyngeal and oropharyngeal swabs. However, these techniques are associated with unnecessary risks to health care workers due to close contact with patients (152). Similarly, a single patient with a high viral load was reported to contaminate an entire endoscopy room by shedding the virus, which may remain viable for at turtles, ducks, fish, Siamese crocodiles, and other animal meats without any fear of COVID-19. The Chinese government is encouraging people to feel they can return to normalcy. However, this could be a risk, as it has been mentioned in advisories that people should avoid contact with live-dead animals as much as possible, as SARS-CoV-2 has shown zoonotic spillover. Additionally, we cannot rule out the possibility of new mutations in the same virus being closely related to contact with both animals and humans at the market (284). In January 2020, China imposed a temporary ban on the sale of live- dead animals in wet markets. However, now hundreds of such wet markets have been reopened without optimizing standard food safety and sanitation practices (286).

With China being the most populated country in the world and due to its domestic and international food exportation policies, the whole world is now facing the menace of COVID-19, including China itself. Wet markets of live-dead animals do not maintain strict food hygienic practices. Fresh blood splashes are present everywhere, on the floor and tabletops, and such food customs could encourage many pathogens to adapt, mutate, and jump the species barrier. As a result, the whole world is suffering from novel SARS-CoV-2, with more than as an enry receptor while exhibiting an RBD similar to that of SARS-CoV (17, 87, 254, 255). Several countries have provided recommendations to their people traveling to China (88, 89). Compared to the previous corona-virus outbreaks caused by SARS-CoV and MERS-CoV, the efficiency of SARS-CoV-2 human-to-human transmission was thought to be less. This assumption was based on the finding that health workers were affected less than they were in previous outbreaks of fatal corona-viruses (2). Superspreading events are considered the main culprit for the extensive transmission of SARS and MERS (90, 91). Almost half of the MERS-CoV cases reported in Saudi Arabia are of secondary origin that occurred through contact with infected asymptomatic or symptomatic individuals through human-to-human transmission (92). The occurrence of superspreading events in the COVID-19 outbreak cannot be ruled out until its possibility is evaluated. Like SARS and MERS, COVID-19 can also infect the lower respiratory tract, with milder symptoms (27). The basic reproduction number of COVID-19 has been found to be in the range of 2.8 to 3.3 based on real-time reports and 3.2 to 3.9 based on predicted infected cases (84).

power. The work started in my shop on the farm. Then I was offered a job with the Detroit Electric Company as an engineer and machinist at forty-five dollars a month. I took it because that was more money than the farm was bringing me and I had decided to get away from farm life anyway. The timber had all been cut. We rented a house on Bagley Avenue, Detroit. The workshop came along and I set it up in a brick shed at the back of the house. During the first several months I was in the night shift at the electric-light plant - which gave me very little time for experimenting after that I was in the day shift and every night and all of every Saturday night worked on the new motor. I cannot say but that it was hard work. No work with interest is ever hard. I always am certain of results. They always come if you work hard enough. But it was a very great thing to have my wife even more confident than I was. She has always been that way.

I had to work from the ground up that is, although I knew that a number of that the internal combustion engine could ever have more than a limited use. All the wise people demonstrated conclusively that the engine could not compete with steam. They never thought that it might carve out a career for itself. That is the way with wise people are so wise and practical that they always know to a dot just why something cannot be done; they always know the limitations. That is why I never employ they an expert in full bloom. If ever I wanted to kill opposition by unfair means I would endow the opposition with experts. They would have so much good advice that I could be sure they would do little work.

The gas engine interested me and I followed its progress, but only from curiosity, until about 1885 or 1886 when, the steam engine being discarded as the motive power for the carriage that I intended some day to build, I had to look around for another sort of motive power. In 1885 I repaired an Otto engine at the Eagle Iron Works in Detroit. No one in town knew anything about them.

There was a rumour that I did and, although I had never before been in contact with one, I undertook and carried through the job. That gave me a chance to study the new engine at first hand and in 1887 I built one on the Otto four-cycle model just to see if I understood the principles. “Four cycle” means that the piston traverses the cylinder four times to get one power impulse. The first stroke draws in the gas, the second compresses it, the third is the explosion or power stroke, while the fourth stroke exhausts the waste gas. The little model worked well enough; it had a one-inch bore and a three-inch stroke, operated with gasoline, and while it did not develop much power, it was slightly lighter in proportion than the engines being offered commercially. I gave it away later to a young man who wanted it for something or other and whose name I have forgotten; it was eventually destroyed. That was the beginning of the work with the internal combustion engine.

I was then on the farm to which I had

It was in 1890 that I began on a double-cylinder engine. It was quite impractical to consider the single cylinder for transportation purposes the fly-wheel had to be entirely too heavy. Between making the first four-cycle engine of the Otto type and the start on a double cylinder I had made a great many experimental engines out of tubing. I fairly knew my way about. The double cylinder I thought could be applied to a road vehicle and my original idea was to put it on a bicycle with a direct connection to the crankshaft and allowing for the rear wheel of the bicycle to act as the balance wheel. The speed was going to be varied only by the throttle. I never carried out this plan because it soon became apparent that the engine, gasoline tank, and the various necessary controls would be entirely too heavy for a bicycle. The plan of the two opposed cylinders was that, while one would be delivering power the other would be exhausting. This naturally would not require so heavy a fly-wheel to even the application of problems were simple enough - and then I definitely abandoned the whole idea of running a road vehicle by steam. I knew that in England they had what amounted to locomotives running on the roads hauling lines of trailers and also there was no difficulty in designing a big steam tractor for use on a large farm. But ours were not then English roads; they would have stalled or racked to pieces the strongest and heaviest road tractor. And anyway the manufacturing of a big tractor which only a few wealthy farmers could buy did not seem to me worthwhile

But I did not give up the idea of a horseless carriage. The work with the Westinghouse representative only served to confirm the opinion I had formed that steam was not suitable for light vehicles. That is why I stayed only a year with that company. There was nothing more that the big steam tractors and engines could teach me and I did not want to waste time on something that would lead nowhere. A few years before- it was while I was an apprentice returned, more because I wanted to experiment than because I wanted to farm, and, now being an all-around machinist, I had a first-class workshop to replace the toy shop of earlier days. My father offered me forty acres of timber land, provided 1 gave up being a machinist. I agreed in a provisional way, for cutting the timber gave me a chance to get married. I fitted out a sawmill and a portable engine and started to cut out and saw up the timber on the tract. Some of the first of that lumber went into a cottage on my new farm and in it we began our married life. It was not a big house thirty-one feet square and only a story and a half high - but it was a comfortable place. I added to it my workshop, and when I was not cutting timber I was working on the gas engines - learning what they were and how they acted. I read everything I could find, but the greatest knowledge came from the work. A gas engine is a mysterious sort of thing - it will not always go the way it should. You can imagine how those first engines acted!

people were working on horseless carriages, I could not know what they were doing. The hardest problems to overcome were in the making and breaking of the spark and in the avoidance of excess weight. For the transmission, the steering gear, and the general construction, I could draw on my experience with the steam tractors. In 1892 I completed my first motor car, but it was not until the spring of the following year that it ran to my satisfaction. This first car had something of the appearance of a buggy. There were two cylinders with a two-and-a-half-inch bore and a six-inch stroke set sides by side and over the rear axle. I made them out of the exhaust pipe of a steam engine that I had bought. They developed about four horsepower. The power was transmitted from the motor to the countershaft by a belt and from the countershaft to the rear wheel by a chain. The car would hold two people, the seat being suspended on posts and the body on elliptical springs. There were two speeds – one of ten and the

- I read in the World of Science, an English publication, of the “silent gas engine” which was then coming out in England. I think it was the Otto engine. It ran with illuminating gas, had a single large cylinder and the power impulses being thus intermittent required an extremely heavy fly-wheel. As far as weight was concerned it gave nothing like the power per pound of metal that a steam engine gave, and the use of illuminating gas seemed to dismiss it as even a possibility for road use. It was interesting to me only as all machinery was interesting. I followed in the English and American magazines which we got in the shop the development of the engine and most particularly the hints of the possible replacement of the illuminating gas fuel by a gas formed by the vaporization of gasoline. The idea of gas engines was by no means new, but this was the first time that a really serious effort had been made to put them on the market. They were received with interest rather than enthusiasm and I do not recall any one who thought actual manufacture of road cars. I found eventually that people were more interested in something that would travel on the road than in something that would do the work on the farms. In fact, I doubt that the light farm tractor could have been introduced on the farm had not the farmer had his eyes opened slowly but surely by the automobile. But that is getting ahead of the story. I thought the farmer would be more interested in the tractor.

I built a steam car that ran. It had a kerosene-heated boiler and it developed plenty of power and a neat control - which is so easy with a steam throttle. But the boiler was dangerous. To get the requisite power without too big and heavy a power plant required that the engine work under high pressure; sitting on a high-pressure steam boiler is not altogether pleasant. To make it even

reasonably safe required an excess of weight that nullified the economy of the high pressure. For two years I kept experimenting with various sorts of boilers the engine and control habit of getting around. One of the most remarkable features of the automobile on the farm is the way that it has broadened the farmer's life. We simply took for granted that unless the errand were urgent we would not go to town, and I think we rarely made more than a trip a week. In bad weather we did not go even that often.

Being a full-fledged machinist and with a very fair workshop on the farm it was not difficult for me to build a steam wagon or tractor. In the building of it came the idea that perhaps it might be made for road use. I felt perfectly certain that horses, considering all the bother of attending them and the expense of feeding, did not earn their keep. The obvious thing to do was to design and build a steam engine that would be light enough to run an ordinary wagon or to pull a plough. I thought it more important first to develop the tractor. To lift farm drudgery off flesh and blood and lay it on steel and motors has been my most constant ambition. It was circumstances that took me first into the was the weight and the cost. They weighed a couple of tons and were far too expensive to be owned by other than a farmer with a great deal of land. They were mostly employed by people who went into threshing as a business or who had sawmills or some other line that required portable power.

Even before that time I had the idea of making some kind of a light steam car that would take the place of horses more especially, however, as a tractor to attend to the excessively hard labour of ploughing It occurred to me, as I remember somewhat vaguely, that precisely the same idea might be applied to a carriage or a wagon on the road. A horseless carriage was a common idea. People had been talking about carriages without horses for many years back – in fact, ever since the steam engine was invented - but the idea of the carriage at first did not seem so practical to me as the idea of an engine to do the harder farm work, and of all the work on the farm ploughing was the hardest. Our roads were poor and we had not the lost. I passed my apprenticeship without trouble - that is, I was qualified to be a machinist long before my three-year term had expired and having a liking for fine work and a leaning toward watches I worked nights at repairing in a jewelry shop. At one period of those early days I think that I must have had fully three hundred watches. I thought that I could build a serviceable watch for around thirty cents and nearly started in the business. But I did not because I figured out that watches were not universal necessities, and therefore people generally would not buy them. Just how I reached that surprising conclusion I am unable to state. I did not like the ordinary jewelry and watch making work excepting where the job was hard to do. Even then I wanted to make something in quantity. It was just about the time when the standard railroad time was being arranged. We had formerly been on sun time and for quite a while, just as in our present daylight-saving days, the railroad time differed from the local time. That bothered me a good deal and so succeeded in making a watch that kept both times. It had two dials and it was quite a curiosity in the neighborhood.

In 1879 that is, about four years after I first saw that Nichols-Shepard machine - I managed to get a chance to run one and when my apprenticeship was over I worked with a local representative of the Westinghouse Company of Schenectady as an expert in the setting up and repair of their road engines. The engine they put out was much the same as the Nichols-Shepard engine excepting that the engine was up in front, the boiler in the rear, and the power was applied to the back wheels by a belt. They could make twelve miles an hour on the road even though the self-propelling feature was only an incident of the construction. They were sometimes used as tractors to pull heavy loads and, if the owner also happened to be in the threshing-machine business, he hitched his threshing machine and other paraphernalia to the engine in moving from farm to farm. What bothered me twelve years old. The second biggest event was getting a watch which happened in the same year. I remember that engine as though I had seen it only yesterday, for it was the first vehicle other than horse-drawn that I had ever seen. It was intended primarily for driving threshing machines and sawmills and was simply a portable engine and boiler mounted on wheels with a water tank and coal cart trailing behind. I had seen plenty of these engines hauled around by horses, but this one had a chain that made a connection between the engine and the rear wheels of the wagon-like frame on which the boiler was mounted. The engine was placed over the boiler and one man standing on the platform behind the boiler shoveled coal, managed the throttle, and did the steering. It had been made by Nichols, Shepard & Company of Battle Creek. I found that out at once. The engine had stopped to let us pass with our horses was off the wagon and talking to the engineer before my father, who was driving, knew what I was up to. The engineer was very glad to explain the whole affair. He was proud of it. He showed me how the chain was disconnected from the propelling wheel and a belt put on to drive other machinery. He told me that the engine made two hundred revolutions a minute and that the chain pinion could be shifted to let the wagon stop while the engine was still running. This last is a feature which, although in different fashion, is incorporated into modern automobiles. It was not important with steam engines, which are easily stopped and started, but it became very important with the gasoline engine. It was that engine which took me into automotive transportation. I tried to make models of it, and some years later I did make one that ran very well, but from the time I saw that road engine as a boy of twelve right forward to to-day, my great interest has been in making a machine that would travel the roads. Driving to town I always had a pocket full of trinkets nuts, washers, and odds