EASY LESSONS IN SANITARY SCIENCE

WILSON.

Return

DRAINAGE FOR HEALTH.

Electrotypes of any of the Illustrations used in this book can be had at a moderate price upon application to the publisher.

A GENTLEMAN OF THE MALARIOUS COUNTRY VISITS THE CITY; AND AT THE SAME TIME GIVES HIS FAMILY A NICE CARRIAGE RIDE.—(*From a Photograph.*) See page 33.

DRAINAGE FOR HEALTH,

OR,

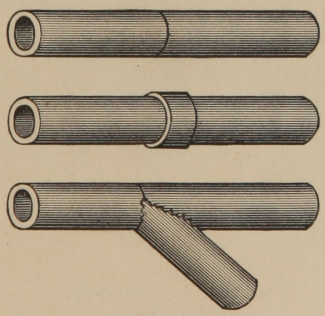
EASY LESSONS

IN

SANITARY SCIENCE.

BY

JOSEPH WILSON, M.D.,
Medical Director, U. S. Navy.



PHILADELPHIA:
PRESLEY BLAKISTON,
1012 WALNUT STREET.
1881.

SHERMAN & CO., PRINTERS,
PHILADELPHIA.

PREFACE.

THE present general interest in the subject of public health seems to call for such a work as is here attempted, simple in style and language, brief but correct as far as it goes, with sufficient variety to make easy reading. It is supposed that any gentleman may conveniently read it in leisure moments.

To the medical profession this summary may be found useful. Prepared with a view of meeting the wants of sanitary engineers and members of boards of health, farmers and legislators; if it should enable these to discuss its subjects intelligently, the object in preparing it will be satisfactorily accomplished.

HOLMESBURG, PHILADELPHIA, 1881.

CONTENTS.

ILLUSTRATIONS.

ON DRAINAGE.

CHAPTER I.

THE DRAINAGE OF LAND.

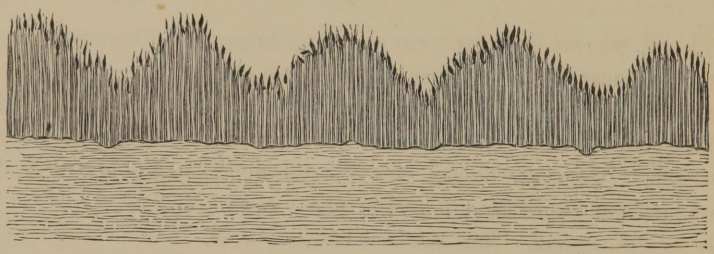
(1) A YOUNG lady informs me that, being ambitious to possess a very elegant flower for her window, she planted a geranium in a small keg, an old paint keg, for want of a flower-pot large enough. This vessel neatly painted in white and brown stripes was gay enough. When the flower was first planted it looked pretty well, and she had hopes that it would excel everything of the kind in the neighborhood. But she was disappointed. Pretty soon there was a yellow leaf, next a dead leaf. The new growth was but a few very small leaves, while the old leaves wilted and died. Her plant was growing smaller every day, and it was made up principally of dead leaves and half-dead twigs.

The plant did not reach this condition without a few suggestions from friends. One thought that it was not watered enough, and this unlucky hint caused it to decline the faster. One was sure that it was not watered often enough; a little and often became the maxim, and still it declined. One imagined that it was watered too much, but this suggestion did not help the matter. The poor thing was nearly dead, just ready to be thrown on the dirt heap, when a more fortunate suggestion was made. A friend had a flower-pot with a hole in it, and when she was going to put a cork in the hole to prevent it from soiling the window, a gardener told her not to do so or she would kill the plant. After a long consultation a gimlet was borrowed, three holes were bored in the keg, and after this experiment, with so little of hope or apparent reason about it, the plant began to grow. There were new leaves, handsome flowers, larger branches. The paint keg

with its load of flowers became the admiration of the neighborhood.

(2) The clay soil of a meadow, like the bottom of the paint keg, does not allow the water to penetrate or filter through. Partly the rainfall flows over the surface, washing it into gullies, and partly it evaporates; but the crops never flourish on this clay soil. The farmer, when he prepares his field for wheat, tries to remedy this by ploughing his land into ridges and hollows, thus making surface drains. The earth to the depth stirred by the plough is permeable to water, which thus finds its way to the drains without washing the surface so much into gullies. The wheat grows best on the middle of the ridge, the highest part, and scarcely any grows in the hollows. This peculiarity of the growing crop is

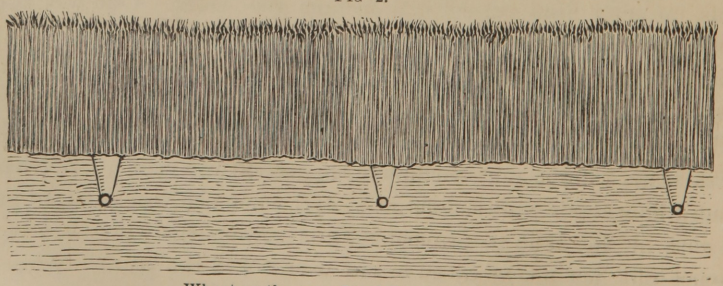
FIG. 1.



Wheat on Heavy Land, as Commonly Cultivated.

seen all over the field. It is seen not only on marshy land, but on any ordinary soil resting on tolerably pure clay. Some plants can hardly be made to grow at all on such land; but with such drainage as we have just described—the ridges and surface drains—

FIG 2.



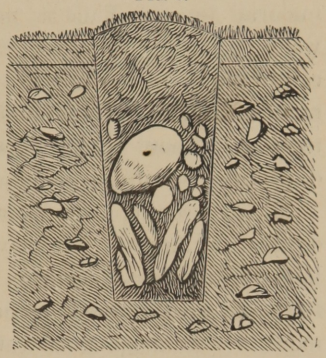
Wheat on the same Land Properly Drained.

wheat and grass crops, having their roots near the surface, do pretty well; but fruit trees and grapevines, having deeper roots, do not flourish without deeper and more effective drainage. Some-

times this is done by channels of earthen pipes, three or four feet beneath the surface.

(3) The physiologists have not told us why these holes in the flower-pot are so essential, or why this clay soil is so preventive of crops. It cannot be mere wetness or dryness, for that kind of difficulty would be obviated by a suitable supply of water. Virgil encourages us with the suggestion that it is a beneficent arrangement of Divine Providence to make us sharp, a sort of whetstone, *curis acuens mortalia corda.* Palladius and Columella, a century later, describe devices still in use for draining marshy fields. They had open ditches; they had covered drains made by filling the ditches half full of brush or stones, and covering them up with earth, as in what we call French drains. These devices must have been quite effective, for the Roman Campagna, where Cincinnatus followed his plough, is covered with the ruins of substantial houses, to say nothing of palaces. In modern times this Campagna is about the most pestilential spot on the face of the earth; the drains were neglected; the inhabitants died of *malaria;* the region is a desert, with a few huts among the ruined walls of ancient villas. Rasori studied the cause of this death and desolation; he called it *malaria.* Garibaldi engaged in the gigantic enterprise of restoring these ancient drains, of draining this marshy land, so as to render it healthy, fertile, habitable.

FIG. 3.



The French Drain of the Roman Plains.

(4) But we need not go so far as Italy to find land thus desolate for want of drainage, nor need we seek for flat and marshy land. *Any piece of land with its substratum of impermeable clay, no matter how manured or how watered, is unproductive of vegetation and unfavorable to health until it is provided with effective drainage.* The moisture, much or little, stagnating in the soil poisons vegetation. It has been suggested that the plants secrete poisons into the soil,—a poisonous excrement,—which, unless removed by percolating water, poisons the plants themselves; and this is, perhaps, the only explanation that has been offered.

There certainly is a very deadly poison about such land, very destructive of human life. This poison we know only by the

havoc it makes, the disease and death which it causes. It is called *malaria*—malarial miasm, malarial poison, marsh miasm, marsh fever, poison, etc. The diseases that it principally causes are various types of *periodic fever*,—intermittent, remittent, congestive, pernicious; and malarial anæmia and diarrhœa, ague-cakes and dropsy, jaundice and marasmus. Excepting the deaths of infancy and old age, probably one-third of all the deaths in the world are caused by malarial poisoning. During the first two years of our civil war 71,192 deaths were reported from all causes, and 20,675 of these deaths, more than two-sevenths ($\frac{2}{7}$) of them, were from malarial fevers. This is, perhaps, a fair average in a protracted war in a healthy country. Special service in less healthy countries causes much greater mortality. In 1809 a British army of 39,214 men embarked for Holland, and was nearly destroyed in four months. About nineteen-twentieths ($\frac{19}{20}$) of all the deaths and disabilities were from malarial disease.—BLANE.

(5) By keeping away from malarious places we may often avoid disease and death. We may sometimes do better by draining the land and making it healthy, thus increasing the crops two or three fold, and greatly lessening the labor of cultivation. The arrangements for drainage must vary according to the locality and character of the soil, thus:

Natural Subsoil Drainage.—In a hilly country with light soil not much need generally be done. When the forest is first cleared off and the soil turned up, the place is likely to be unhealthy; but after the land is fairly cleared and ploughed into ridges and surface drains in the direction of the slopes, as in ordinary wheat and grass farming, it immediately bears good crops and is quite healthy. There is no appearance of malarial poisoning. Such land, in the older settlements of the country, is instantly recognized by the elegant farmhouses and the big barns. The farmers occupying such land may be known by their florid complexions and fine forms. They are above the average size of men, bright and cheerful. They mostly have large families, many members of which live much beyond the average term of human life. The land undergoes subdivision from generation to generation till the farms become too small for further dividing, and then these healthy and fertile farms send off a constant stream of emigrants to the large cities, to the new countries. Nearly all the prosperous merchants, physicians and lawyers, clergymen and philosophers, philanthro-

pists and sages, refer to these healthy farms as the homesteads of their fathers and grandfathers.

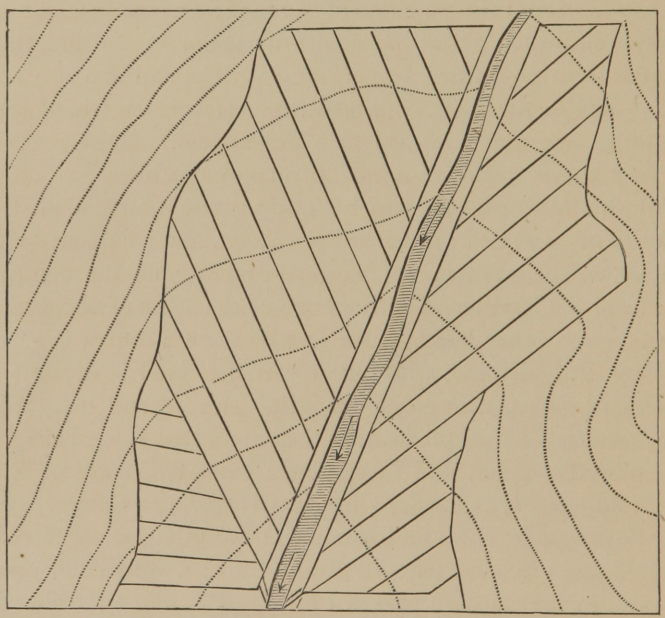
(6) In *the malarious district*, and on the farm of much malarious land, all this is reversed; the crops are so poor that there is no use for a big barn; the inhabitants are so poor that they are unable to build a good house, or even to keep their old hut in decent repair. The house has been built by some imprudent newcomer; he hardly raises any family, and probably he dies of the fever; one of his unfortunate children may inherit the place, to be sickly, poor, and wretched. Such farms are not much subdivided; the native population does not increase, and is not sufficient to keep up the occupation of the land; an occasional stranger becomes an owner, or two farms are united into one; and thus it goes on from generation to generation. The children are a sad sight,—sallow, dwarfish, deformed little creatures, a few of whom live to become very wretched men and women. Even the cattle, the very horses and cows, are dwarfish and worthless.

All this contrast comes of naturally gentle slopes, a moderate quantity of sand and gravel in the subsoil, and a sufficient elevation above the watercourses for good drainage, on the one hand; and, from the land being without one or the other of these advantages, on the other hand. The first of these pictures is seen in Byberry, Philadelphia, where nearly all the land is divided into very small farms, with elegant buildings, owned and occupied for six generations by people bearing the names that crossed the ocean with William Penn, and in similarly healthy districts of Bucks and Montgomery, and indeed nearly all over the country, except where overrun by cities and manufacturing villages. The second picture is seen in some parts of New Jersey; and in Pennsylvania it is seen in the southern part of Philadelphia, where the old township of Tinicum seems never to have had any barn at all, and but one farmhouse, and that never occupied by a family. The same picture of misery is seen in large districts of Delaware, Maryland, and Virginia, principally east of the main lines of railroad. All this flat country, except the pine barrens and the bluff banks of rivers, is full of misery, which the artist may occasionally admire for its picturesqueness. By careful study and systematic labor this may all be changed; this misery may be relieved; these ague-cakes and sallow skins, this sickness, poverty, and premature death.

(7) *Meadows and Valleys.*—It has been observed by Lind that

"*the most healthy countries in the world have unhealthy spots.*" The country of natural subsoil drainage is no exception to this rule. The rains that water healthy hills wash down some of the soil, and this settling in the hollows forms nearly level meadows along the brooks and rivers. The material thus deposited, the soil of these meadows, is mostly clay, scarcely permeable to water. The underdrain of these hills, in its natural channels, meets the clay at the side of the meadow; it can go no further underground, but it rises to the surface in elegant springs. Such meadows produce no good crops, not even good hay; they produce a great

FIG. 4.



Drainage Map of the Marsh Meadow.

variety of sedges and bulrushes of very little value. These meadows poison the air, causing malarial fevers, and thus they destroy the health of all who live within the range of their influence. The remedy for this is simple enough; it involves some labor and expense; it is merely underdraining, something equivalent to the hole in the flower-pot.

The drainage of meadows is most economically effected by a system of underground drains, made with drain-pipes of brick-clay; this is the cheapest material, and lasts for ages. The first thing is to survey the land; the surveyor, observing the neighboring lands

and hills, determines the lowest point of the meadow and measures the slopes. Between elegant sloping fields on each side there is a strip of *worthless marsh*, with a sluggish little stream through its middle; he draws a small map (Fig. 4), and, starting where the stream flows out, the lowest part, he traces dotted lines of equal elevation, each line being a foot higher than the preceding. The ground being very level, he must indicate lines for the drains nearly at right angles to these lines of equal elevation, in order to give the drains enough slope to make them work well. Commonly we may give all the drains enough fall by arranging them parallel with each other in two or three directions, as in the map. Thus we first trace a drain along each side, high enough on the slopes to catch all the springs; next, about twenty feet from our boundary lines, to drain our own land without interfering with our neighbor's; next, a drain on each side of the stream, nearly parallel to it, and thirty or forty feet distant; the rest of the land may have drains nearly parallel with each other, and as nearly perpendicular with the lines of equal elevation as possible, without too much complication of plans. In practice it seems sufficient to place the drains four feet deep and forty feet apart. Drains two feet deep have been found so inefficient that the work had to be done over again. Drains sixty feet apart did the work so poorly that it was necessary to make intermediate drains. Drains three feet deep must be nearer together, not more than twenty feet. A fall of six inches to the hundred feet seems quite sufficient for drains of this kind if the work is really well done, and there should be no part of the drain sloping the wrong way.

(8) In healthy countries we find other unhealthy spots, and consequent disease,—disease and death from very small marshes. Friedel mentions that, "in the Marine Hospital at Swinemünde, near Stetten, a very large day ward was used for convalescents. As soon as any man had been in this ward a few (?) days he got a bad attack of tertian ague. In no other ward did this occur, and the origin of the fever was a mystery, until . . . . . a large rain-cask, full of rotten leaves and brush, was found; this had overflowed and formed a stagnant marsh, of *four to six feet square*, close to the doors and windows, ... which, on account of the hot weather, were kept open at night."—PARKES.

We have an account of another small marsh: "At Kingston (Jamaica) three young men, recently arrived from England, took up their residence in a large, airy house, on a place thought to be

healthy. These young men were attacked in succession by fever; two died; the third had a severe attack of bilious remittent; he was removed, and eventually recovered. A large garden tank was found under the windows nearly filled with decayed vegetable matter; no one doubted that the malaria sprung from this."

Near our own homes we sometimes see a small marsh something like this though very much more abominable. Many of our country houses, and not a few in the cities, have no reasonable arrangement for getting rid of kitchen slops and garbage; the result is a *kitchen-midden* near the back door. This may possibly form an interesting subject of study for the ethnologists of the distant future; but at present it is disgusting and unhealthy; and it should disappear as soon as we can manage to educate our people up to a comprehension of the subject. Back yards and back streets, all over the cities, are constantly reported as nuisances by the sanitary inspectors.

We have another constant danger in the healthy country from frequent interference with the natural watercourses for manufacturing purposes. New mill-dams are made, ponds and marshes inconsiderately set up without care for the health and the lives of the people who are ignorantly dwelling near them; extensive public works, in the way of canals for drainage or navigation, have generally caused extensive epidemics in this way.

(9) *Heavy Land.*—In some places the earth to a considerable depth is composed of adhesive clay, such as is used in making bricks; it is almost impermeable to water, so that a shower of rain, instead of soaking away, must flow over the surface and thus keep it rather muddy; this is called heavy land. It sometimes occurs on the tops of pretty high hills, so that the highest land of a hillside farm is sometimes the most marshy and needs artificial drainage. The object in this case is accomplished in the same way as in the flat meadow; but we need not look for springs, and there is so much slope that there is no trouble in giving the drains enough fall without being quite so particular in giving them the exact direction of the slopes. But I am reminded that sometimes "experience teaches," and a few years ago I became interested in the condition of a small farm of this kind; about half of it was heavy land. *The first tenant* gave a very favorable account: "The place was well in with grass, and as I had work enough on my own place I took good care not to spoil the grass; the hay sold well and I had little to do, except to cure the hay and gather

the fruit for market. The back field had been in corn, and I knew that the land is too heavy there for potatoes, and so I put it in oats, to be followed in the fall with wheat and grass seeds. This succeeded very well; the oats was good, nothing to brag of, but the wheat was about as handsome a growth as I ever saw, and it averaged fully forty bushels to the acre; the grass was about the same as on the rest of the place, perhaps two tons to the acre; this with hay at twenty dollars the ton does pretty well."

The second tenant was a sheep butcher, and I never saw him to hear what he had to say about it. His sheep pastured on the place; he ploughed a part of the front field, perhaps for turnips, and the water from the rest of the place, running across the ploughed field in heavy rains, washed out a deep gully, some part of it four or five feet deep. During his last year he ploughed nearly half the place and sowed it with winter grain, so as to keep the tenant of the next year from any profitable use of the land.

The third tenant, a market gardener, on account of the poor condition of the place, had it at a very low rent for the first year, but he did not prosper. He says: "I like the house and its situation very much, and my family like it. But the land is not good; some of it is right poor, and in these upper fields it is so heavy and so soggy that it hardly pays for manuring. I have tried and cannot get a good crop of vegetables on it; it is only good for grass. This old orchard where we are standing is very good. I have fixed the gully in the front field so that the washings have nearly filled it up; that front field is a splendid piece of ground, and it brings good crops of anything you choose to plant. But I can hardly make a living for my family here; there is not enough good ground, and I lose money when I pay wages for planting and tending crops on that heavy land."

The fourth tenant was a teamster, and his farming operations were not very successful. He says: "I cannot make out much at farming, and so I do hauling for the lumber yards and coal yards. We have had a good crop of potatoes on the front field and in the old orchard every time, but the land is so low and so wet that we never can get on the other fields in the spring early enough to plant anything properly. We tried to plant the back field with corn, but it was too wet; the horses could hardly go on it till June, and then it was so late that the corn did not grow well, and it did not have time to ripen, so that we did not have the quarter of a

crop. The old fruit trees are very much in the way and the boys are all the time wanting to cut them down."

"But the trees must be useful to you; when the other crops are poor the fruit, at any rate, must bring you something; and even if you have no sale for it fruit is not a bad thing to have in plenty where there is a family?"

"Yes, that is so; but they really are much in the way in ploughing; some of them bear very little fruit, and some bear only half the time, every second year. You see that old pear tree, that Catharine pear? I sold the fruit on it last year for thirty-eight dollars ($38); the buyer picked them himself and was right well pleased with his bargain. The children, may be because they heard the men talk about chopping, tried to cut down the next tree, just like it, and I wanted to give them a thrashing for fear they would get at it again, but my wife would not let me."

"May be that was best, for children can generally see whether you are pleased or not with what they do. Did you ever hear about George Washington, when he was a child, and his little hatchet?"

"No, I never heard of it."

"Well, I have the whole story in a little book, and your daughter would like to read it to them. You can tell them what a good thrashing they deserve for cutting that tree, only, may be, they did not know any better. But you must not allow any tree to be cut; you might be prosecuted for damages and sold out by the sheriff for allowing a few trees to be spoiled. That Catharine pear tree is about fifty years old, and is growing bigger and better every year; fifty such trees may stand on an acre, so that if the place were only covered with such trees, and if we could get them to bear every year, every single acre of the place would bring us nearly two thousand dollars a year without any work; we would just walk out in the shade and let them pay us the thirty-eight dollars for each tree as they go to picking. I think that old tree is worth three hundred dollars ($300) just for its fruit. And shade is a good thing, good for horses, good for cattle, good for children, good for everybody; the place would not be fit to live on without the trees."

"That is so, but I have hard work to make a living for my family here. I want to stay and will do the best I can. The back fields make hay and pasture without much work; the front

fields will give crops and fruit; and if hauling is good we will get along as well as common."

The fifth tenant, a practical farmer, had long been living on farms rented by the year. He could "make both ends meet" almost anywhere, but he never did much more. He said: "I am tired of big places, many hands, and heavy work; the little place suits me exactly if we can make a bargain. I prefer to work on shares, so that when crops fail I need not get into debt, and if the crops are good I get well paid for my work. I have stock enough for a larger place than this, so that the landlord need not put in anything for stock and tools." The lease was arranged to suit. The back fields produced hay and pasture, and the old gentleman did some profitable trading in horses. He did not get a very good crop of corn on the back fields, and one season he actually had to buy corn for his cattle. The fruit was good, but most of the trees were old, not good for much, and very much in the way in ploughing; the young trees not big enough to bear much. But the little place suited; the large family occupied the place reasonably well contented for nine years, till the old gentleman died. The buildings and trees were well preserved, with a general appearance of neatness and order, but in other respects the arrangement was not profitable.

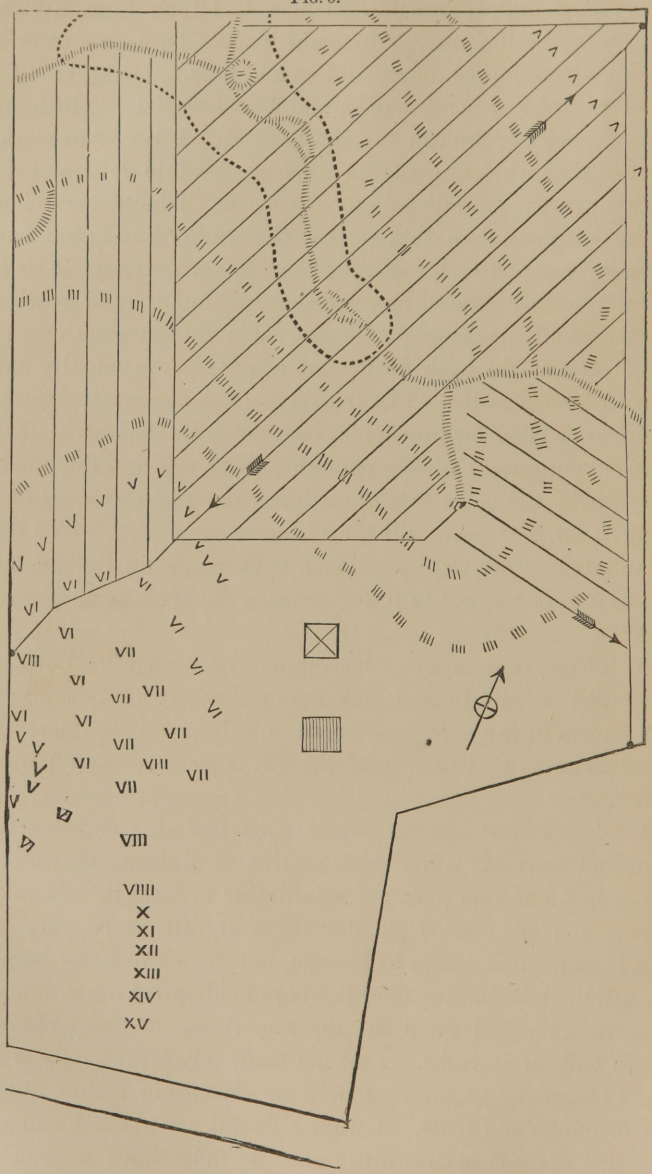
(10) These reports are remarkably consistent: "Some found fault with the fruit trees, which were either too old or too young, or they were in the way, and would only bear half the time. All seemed to agree that the top of the hill is wet and heavy, and not fertile."

The sixth tenant has no family with him, his children being grown and married; other relatives live in Maine. He said: "I like the looks of this place; I would like to farm it. It may be poor, as you say, but I do not think it can be so very poor. There is not much grass, to be sure, but the cows I saw here last fall continued wandering over the bare fields, after the ground was frozen, till they had eaten out the very roots. At any rate some manure will set it right. I do not want any wages, only what I can get out of the ground. I need an advance of money to buy a stock of horses and tools. I want a liberal allowance for manure, and if the place is so dreadfully poor we must have a good deal of it. I just want to show you the crops that will grow here."

"But they say that the back fields are so low and wet that

nothing hardly will grow; and no matter how much you manure, nothing grows well."

FIG. 5.



The Drainage Map for Heavy Ground. The surveyor, for the sake of variety, sometimes begins at the top of the hill and works down.

"How can it be low, right on top of the hill? How can it be

wet? it is a regular slope, and I see no place where a drop of water can stand on it."

"Yes, it is a nice slope; but the soil is clay, the same they make bricks of. You have seen men in the brickyards, in the beginning of winter, digging up the clay into heaps, to temper, as they say. It gets several freezings and thawings, and in the spring it is as soft and sticky as so much tar; and it remains soft and sticky till they mould it into bricks and spread them out to dry. How can you take horses on such land to plough for corn early in the spring?"

"I can find a time to plough it; only get me a manure-wagon and let me try. You will soon see something growing."

This is evidently the man for the place, with enthusiasm for the work. He received his first lesson in his attempt to raise a crop of corn. He ploughed and he planted; the corn sprouted and it grew with weak stalks, many of them broken down by the wind; the leaves were yellow in stripes—very pretty. As for corn, there was not much—only a few nubbins.

"Well, I told you so."

"I know that; but what can we do? We shall have no corn." . . .

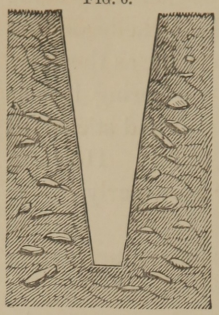
"I have ordered five thousand feet of drain-pipe, to be delivered in August, so that everything may be ready for digging trenches as soon as the corn is out of the way. You may begin by cutting rows of corn across the field where the trenches are to be. Here is the map all ready (Fig. 5). The drains may continue further up the slope, so as to make a field of three or four acres. Let us try for another crop of corn, but you need not forget the manure-wagon."

The next crop of corn was a success, with stout stalks, dark-green leaves, handsome large ears, and a very large crop of corn. Our present plan is to drain three or four acres each autumn, so long as we see the land to improve under the operation.

(11) We had much to learn in regard to the manner of doing this work. The first set of men employed to dig trenches made them so wide, finished them so neatly, and worked so deliberately that it soon became evident that it would cost more to dig the trenches than the land is worth. Discharging the workmen and employing others mended the matter; but still the cost was so great as to make the work impracticable—it would not pay. A clay-digger from a brickyard, out of work on account of the dull times, came along and proposed to finish the job himself for fifty dollars ($50). He made his trenches about half as wide as

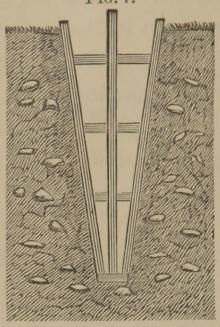
the others; he did not waste much time in trimming the sides; he finished the work in good time, and he earned fair wages.

Fig. 6.



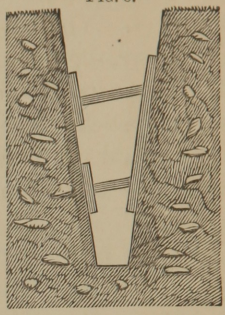
Form of the Trench.

Fig. 7.



Frame to Regulate the Size and Form of the Trench.

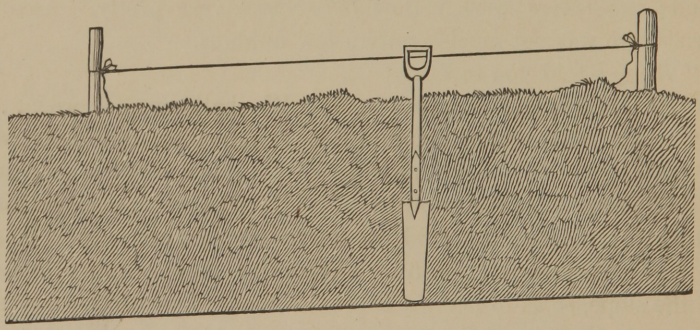
Fig. 8.



Propping the Trench in very Soft Ground.

To regulate the slope of the bottom of the trenches it is sometimes advised to use the mason's level, with some special addi-

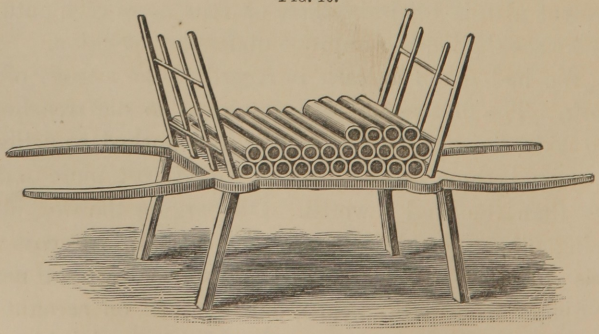
Fig. 9.



The Slope is regulated by stretching a line between two stakes and measuring with the spade.

tions, or to wait for water to run in the trench, so as to indicate the proper level. We find these things inconvenient; especially

Fig. 10.

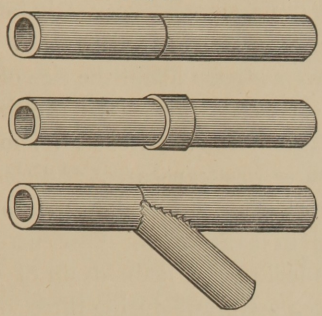


The Hand-barrow.

the water made a troublesome amount of mud and caused the sides

to fall in, so that the work had to be done over again. Our plan is to drive two stakes near the trench, at some distance from each other, and to secure a line to them with the proper slope, so that the workman with the handle of his spade can measure the depth from the string. When the land is ordinarily moist the water

FIG. 11.

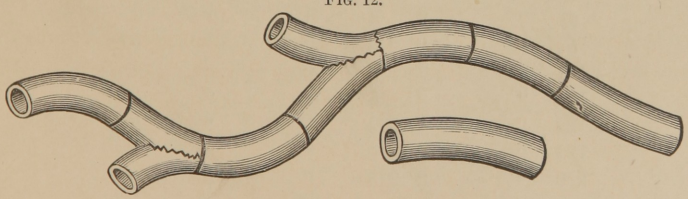


The pipes are simply placed end to end in contact, or they are united with collars, and the best Y joints are made by chipping with a very light hammer.

filters pretty rapidly into the trenches, so that we find it advantageous to put in the pipes close up, and to cover them with enough earth to secure them in position before the water has time to get in.

The pipes are of various shapes. We prefer the simple round form, so that, no matter which side is up, the pipes always fit. The common pipes are, in large proportions, curved, warped in the kiln. They need not be altogether rejected on this account,

FIG. 12.



Drain-pipes Warped in the Kiln, are very useful for making easy curves, and for connection of lateral drains.

as water does not refuse to flow very well through regularly curved channels. There is positive advantage in having a portion of them thus curved, so as to make easy curves, instead of angles, in changing the direction of drains.

The size of the drain-pipe is a matter of some importance. It should be large enough to carry all the water, and any larger size is a waste of material and a needless expense.

"Mr. Thomas Hammond, of Penhurst, Kent, uses no other size for parallel drains than one-inch pipe, having commenced with $1\frac{1}{3}$ inch; and the opinion of all the farmers who have tried them . . . . is that one inch diameter is abundantly large. A lot of nine acres sown with wheat was observed by the writer 36 hours after . . . . a heavy rain of 12 hours. The length of each drain was 700 feet; each drain emptied separately into a running stream, so that the discharge was distinctly visible. . . . One which tapped a small spring gave a stream about the size of a tobacco-pipe (?); the run from the others did not exceed the size of a wheat straw. The greatest flow at any time had not . . . more than half filled the pipes. The water was transparent and clear."

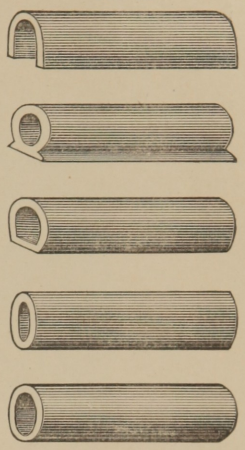
We have not tried these one-inch pipes, as our manufacturers are not accustomed to make them. Our smallest pipe, as well as our largest, is two inches. A main drain of this size discharges the drainage of seven acres, and during three years it has never had water enough to use its full capacity. Therefore our experience accords nearly enough with that of Mr. Hammond in this quotation, and with Mr. Waring's table of sizes. We have accordingly arranged the following table, assuming that the velocity of flow increases regularly with the cube of the linear dimensions.

For 1 acre or less use	1 inch pipe,	with 2 inch	collars.
2 acres	" $1\frac{1}{4}$	" $2\frac{1}{2}$	"
$2\frac{1}{3}$ "	" $1\frac{1}{3}$	" $2\frac{1}{2}$	"
$3\frac{1}{2}$ "	" $1\frac{1}{2}$	" 3	"
$5\frac{1}{2}$ "	" $1\frac{3}{4}$	" without collars.	
8 "	" 2	" "	"
$15\frac{5}{8}$ "	" $2\frac{1}{2}$	" "	"
27 "	" 3	" "	"
54 "	" 2 3	" "	"
64 "	" 4	" "	"
125 "	" 5	" "	"
128 "	" 2 4	" "	"
192 "	" 3 4	" "	"
250 "	" 2 5	" "	"

There is no real use for all these sizes; the $1\frac{1}{4}$-inch pipe can hardly cost more than the 1-inch, and may take its place. These small pipes, they say, should always have collars, as otherwise it may be difficult to keep the ends together with certainty, and the 2 or $2\frac{1}{2}$-inch pipe in short sections makes the collars. 2-inch pipe, or $2\frac{1}{2}$, will do for main-draining, till we come to a drain to carry the water of about sixteen (16) acres. Thus we need but three sizes,—1, 2, and 3 inches, or $1\frac{1}{4}$, $2\frac{1}{2}$, and 4,—for we are not

likely to meet with a case in which it may seem convenient to drain more than sixty-four (64) acres through one pipe. There is positive disadvantage in having the drains too large, for the only obstruction is by fine silt, which can lodge only in a slow current, and must certainly be carried through these small tubes by the rapid current produced by a rain-storm.

FIG. 13.



Pipes are made of various forms.

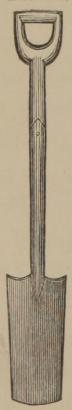
The circular form of drain-pipe is the best. The horseshoe tile, open below, is better than the old drain of stones or brush, and it is sometimes used with a board floor; but this is absurdly expensive. The sole-tile is a pipe with a flat surface below, but this flat surface is inconvenient, and of no use; elliptic and oval forms have been tried, but they have no advantage to compensate for the additional labor of placing them.

The plough is used to start the trenches, and we need a few peculiar tools; the curved clay-spade of the brickyards is useful, but it is much too broad for the bottom of the trench; a much narrower spade is needed, about four inches wide, not tapering much, or not at all, and curved laterally like the brickyard spade; a common flat shovel, with long handle; a much narrower shovel, curved laterally; a scoop, with long handle, to dress and clean out the bottom of the trench; a horse-shovel, or scoop, to fill the trenches by horse-power, always, of course, taking care that the pipes are secured by a light covering with the shovel, so as to run no risk of being displaced or broken by a falling pebble. There is no need of ramming; the frosts of winter and the rains of early spring pack and puddle the earth about the pipes, so that as soon as the land is ploughed the work is all out of sight.

The *outlets* of these drains are generally described as involving some care and expense, with solid masonry, and gratings fine enough to exclude toads and mice. So far we see no use for these things. The last six or eight feet of the drain is made of glazed and hard-burned pipe (terra-cotta), so as to resist frost or the trampling of cattle. The drain comes near the surface, where there is a convenient slope under a hedge or fence, or to the bottom of a surface-drain by the side of a road. The pipe terminates in a basin about a foot wide, as deep as the diameter of the pipe, and it is soon

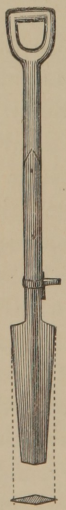
covered and concealed by grass spreading from the sides. This is the outlet. In ordinary rains no water reaches it; after a heavy rain a little water runs for a day or two; in the spring, from the melting snow, there is a full stream for a week or two. The water is perfectly limpid and colorless, apparently pure, notwithstanding

Fig. 14.



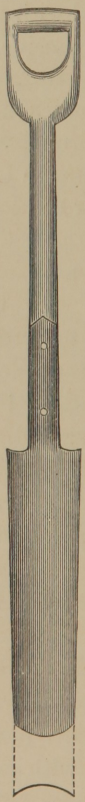
The Brickyard Spade.

Fig. 15.



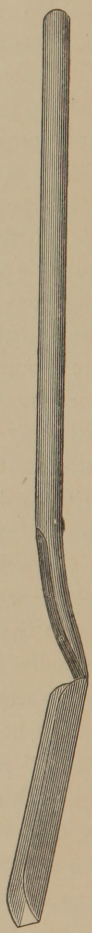
The Heavy Spade is not so good as a crowbar in stony ground.

Fig. 16.



The Drain Spade.

Fig. 17.



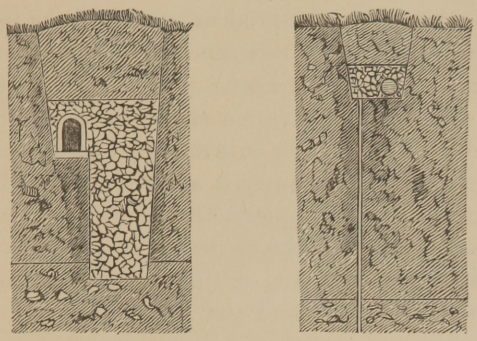
The Drain-finishing Scoop.

the ten or twelve tons of manure to the acre. If this drainage-water should become troublesome it can be discharged into a deep sink, in accordance with the plans represented in the margin (Fig. 18).

(12) This heavy land, whether underdrained or not, when regularly and sufficiently sloped, must be healthy. The small

farm here discussed has been occupied continuously as a separate farm for sixty-five (65) years, hardly ever by a family of less than six (6) persons, and much of the time by eleven or twelve—average perhaps eight. The deaths on the place have been seven, which is 13.46 per 1000 per annum. We are conscious that two of these deaths were by malarial fever, which may have been caused

FIG. 18.



Sinks to discharge water into permeable deep strata.

by a disgusting mud-heap, a little marsh or kitchen midden, near the back door (§ 8), for we know that such a nuisance at one time existed.

(13) *Sandy Loam.*—A large proportion of the malarious land of the United States is sandy loam, so flat and so nearly on a level with the ocean that it is very imperfectly drained. There is some of it in New Jersey, Delaware, and Maryland, and in Virginia; it includes nearly all the State east of Fredericksburg and Richmond. Some of the best farm-houses in this district are built of bricks imported from England by the early settlers. It still continues in farms of a thousand acres each, or even larger. The poor owner does not know how he can do any better, and he really has no means to improve his land. The healthy lands of this region are the bluff banks of rivers, the pine forests, and some sea-coast islands. This border of level sandy land extends along our coast from New Jersey to Texas, varying in width from twenty (20) miles to 150 miles. For half its breadth there is hardly any of it thirty feet above the level of the ocean. With an average slope of less than a foot to the mile it is not well drained, and it would seem nearly impossible to drain it; but even this desperate strip of land may be improved. The very worst of it can be cultivated in rice, but no one should think of fixing a dwelling near the rice-fields; the workmen can live in healthy villages at a safe distance,

and, if necessary, while planting and harvesting the rice crop they can sleep in barges anchored in the middle of the streams, merely landing for work in the daytime; for it has been abundantly proved that there is no danger of malarial poisoning in the daytime, and very little danger in a boat anchored half a mile from the malarious shore, even at night. And in this desperate strip of land there are healthy spots,—the bluff banks of rivers and the pine groves,—and in these spots villages of prudent people will be healthy.

(14) The western half of this sandy plain is considerably more elevated, some of it even reaching two hundred feet above the level of the sea. This is the region of pine barrens; it is too level and too much under water for cultivation without some system of artificial drainage. The country is sparsely inhabited by an unhappy malaria-poisoned people. The lumbermen, while in the forest, are healthy, but as soon as they clear a field for cultivation they have the fever, they die, or they become helpless invalids, and the weeds, the bushes, and the forest again gain possession. An attempt has been made to drain by open ditches along the roads, and in some places ditches are made to serve for boundary lines and fences. But there are not enough ditches to drain the land; they breed terrific swarms of mosquitos, and they rapidly fill with leaves and grass, so as to need a constant cleaning out.

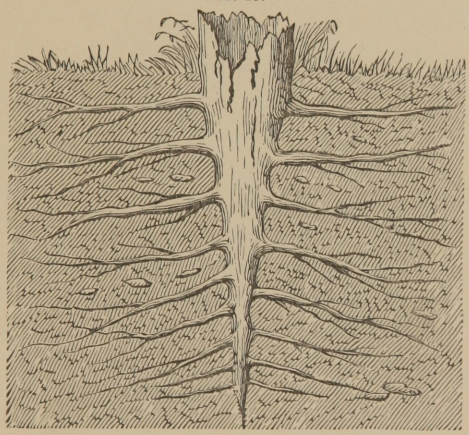
There are several ways to improve this land. In the first place we must insist on the fact that but for the growth of pine trees this country is deadly from malaria, and hence that the people must live in villages, in the healthy spots protected by groves of pine trees. They can walk to their fields in the morning and return in the evening; an occasional foolhardy one or a drunkard will remain in the fields at night, and he will have the fever in about fourteen days afterwards and will probably die, so that the rest will be admonished to keep good hours; thus we may secure health for the workmen. Next, instead of the few open ditches, which only half do the work and are more expensive, we must have drain-pipe and have it carefully laid from three to ten feet deep; we must have five times as many such drains as there are now of open ditches. These will be out of the way and out of sight; they will carry off all the surplus water, will breed no mosquitos, will need no repairs or cleaning out.

With these arrangements this land may be made productive, and when it becomes healthy the foolhardy will soon find it out and make the fact known. The mere swamps along sluggish

streams, though not habitable, may be made valuable as rice fields.

(15) *Pine Forests.*—There is something curious, something astonishing, about the salubrity of the pine barrens of this region, which, of course, are not barren at all. These immense tracts of flat land are occupied almost exclusively by pine trees. The trees grow close together so as to destroy side branches, and thus we have tall timber trees, and the earth is covered some inches deep with dead branches and pine leaves. The ground is quite dry, the water disappearing very rapidly after a rain. These forests supply the markets of the world with tar, timber, and turpentine. But the interesting matter to us is that they are quite healthy,—

FIG. 19.



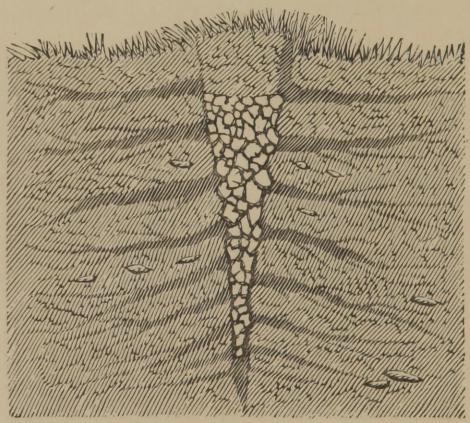
The Pine Stump—as it decays makes a good drain.

quite clear of malarial fevers. Some attempts have been made to account for this immunity, this good health. It has been suggested that turpentine is wholesome, and that it neutralizes in some way this poison, and, although there may be some truth in this notion, there is no exemption from fever about the turpentine stores except in the forest. The thick carpeting of pine leaves has been supposed to prevent the malarial poison from rising, and it doubtlessly is beneficial in this way.

It seems to me that the pine trees act principally by draining the land, and this they do by the peculiar manner in which the roots decay. When the trees of the forest get too thick to thrive the weaker die out and decay, root and branch; but the roots decay much more rapidly and more completely; thus the whole situation of the pine stump becomes a very effective sink. The roots

near the surface form a series of collecting drains, and the deep roots are distributing channels by which the water rapidly sinks to its lowest level. These stump-holes, with the cavities left by the large roots, are very nice dens for coons and foxes. There are some holes of this kind in the pine grove of the Naval Hospital at Norfolk, Va. These holes are four or five feet in diameter to an apparent bottom of twigs and leaves. I asked many questions and could only elicit the conjecture that they might have been made by the diggers for Kidd's money. This explanation would not do as there was no visible pile of dirt. A surface drain was opened into one of these holes with the expectation of filling it up, and after the next heavy shower I saw a stream of water, eighteen

FIG. 20.



Pine Stump Drain Improved.

inches wide and two inches deep, running directly into the hole and disappearing—a small Niagara. An explanation eventually came by accident. Trying my cane on an old stump it penetrated easily in any direction; the strongest part of the stump was its bark, the rest was black dust. All the men about the place seem to know that the pine stumps decay in this way, and very quickly, even to the ends of the smallest roots; thus the matter is plain enough. These stump-holes might be utilized as permanent drains and sinks by merely filling them with gravel or even good chips, except about two feet at the top, and finishing with earth like the sinks already represented (Fig. 18, § 11).

This action of pine stumps in draining land begins when the trees are quite small. The first year from the seeds the trees are a foot high; the second year they are four feet; the third year

they are eight feet, and more than half that started are dead and some of them decayed. Every year while the forest lasts there are trees thus dying and decaying with their deep tap roots. It seems easy then to make a healthy place for a village almost anywhere, as we have only to scatter a few pine seeds on any suitable soil and to wait three or four years. The Naval Hospital at Norfolk is separated from very malarious fields by a pine grove less than a thousand feet wide, and this is found to be quite sufficient.

The eucalyptus of Australia is just now exciting much interest as a malaria-preventing tree, but as yet there is no evidence of its being so good as our own Southern pines, which constitute these barrens. However, it is an elegant large tree, and there is no danger of too many such good things; and, besides, this tree may be suitable for situations where the pines do not flourish.

(16) *Flat Rock.*—Sometimes we find marshy land on a nearly level surface of flat rock. With ordinary tools not much is to be done, but the same general plan is adopted. The rock may be limestone, not very hard, so that with picks and crowbars the trenches are opened, not very deep or very far apart. Instead of drain-pipes in the bottom of the trenches we arrange fragments of the rock; the earth is filled in and levelled, making a French drain (Fig. 3, § 3), and thus the work is completed. This kind of draining is practiced at Sandusky, Ohio, and thus poor wheat land worth thirty dollars the acre becomes worth four hundred dollars for vineyards, and the country is becoming healthy.

(17) *Bank Meadows.*—In draining land subject to a regular overflow of tide, the water is collected into a pool near a sluice-gate and discharged into the river at low tide. These bank meadows along the Delaware, and probably everywhere, are dangerously malarious, destroying the health and the lives of nearly every person who attempts to dwell near them.

(18) It might be inferred that the malarial poison that kills so many thousands is the same that prevents our plants from thriving, but this would be a mistake. The marshy meadows of New England produce nothing but meadow hay, good to pack crockery, but malarial fevers of the severer types are scarcely seen in New England. The land occupied by the Panama Railroad has an abundance of marshy places, but not at all in proportion to the deadly character of the climate. The lives of more than eighty thousand (80,000) men were destroyed by malaria while employed

in building this railroad. One man died for every yard of the track, 1760 died for each mile, and in round numbers 81,000 lives were destroyed in building forty-six (46) miles of railroad, and it is to be feared that five times as many will be destroyed in a contemplated enterprise of building a canal in the same country.

There appears to be at least three distinct species of marsh poison removable by drainage: (*a*) There is the poison that interferes with vegetation, so that some meadows produce sedges and rushes instead of grass; (*b*) there is some influence which determines that typhoid fever is more prevalent on flat or marshy land, though not confined to such situations; (*c*) and most important of all is malaria, the poison of the periodic fevers, killing its hecatombs, say ten thousand (10,000) victims every day of the year, nearly one death for every tick of the clock, and keeping a very large portion of the earth's surface in the condition of a howling wilderness.

But possibly the marshy soil does not generate either of these poisons after all. Grass does not grow well in a marshy meadow, but this division of plants finds its appropriate nourishment on dry land; that it does not grow in water may be from the absence of something necessary for its nutrition. The mechanical difference between light soil and marshy soil seems somewhat similar to the conditions of a wet sponge just lifted from the water and of the same sponge partly dried by pressure in the hand. In the one case we have a continuous body of water with mingled particles of solid matter, without air-space; in the other condition there is moist solid matter, with intervening air-space. The air thus mechanically present in the light soil must expand and contract with changes of temperature; and consequently in the usual changes from day to night it must be drawn in and expelled, in a way comparable to the respiration of animals. Now it has been demonstrated that the atmosphere is everywhere full of minute objects, some of them living organisms, of many kinds, millions of millions of individuals—a typhoid fever germ, a yellow fever germ, a malarial germ, a scarlatina and a variola germ may be among them. When the light soil thus takes a long breath, myriads of these objects, these germs, are inhaled, and adhere to the moist interior of the air-spaces, and are thus consumed in this grand laboratory of nature. The marshy soil having no air-spaces to absorb and destroy the germs, they must remain at the surface or continue to float in the atmosphere. Whether this fanciful theory is true or whether it is mere fancy is comparatively unimportant to us; the facts on

which it is based are true, and are exceedingly important. Men and women are healthy, happy, and prosperous dwelling on this light soil or on well-drained land; they are sick and wretched, miserable and dying when they undertake to dwell on the marshy land—they cannot live there.

(19) I hope to be excused for a little more persistence on this important subject. In all parts of New England hundreds of people are dying of typhoid fever; a large tract of the city of Boston is now building on made-land nearly as flat as the prairie around Chicago, and in a few years it will probably have to be regulated and rebuilt to get rid of the pestilence. From Maine to Pennsylvania there are undrained fields nearly as bad. All over the country further south, but principally in the Mississippi Valley and in the flat country bordering the ocean, the undrained land is infectious with intermittent fever and the other malarial pestilences to such an extent as to destroy many thousands of lives every year; so that in spite of constant immigration extensive tracts of country continue as sparsely peopled as ever, with very unhealthy, very unhappy people. Some part of this desert is the most fertile land in our country, and the most easily cultivated but for the failure of health among those who undertake to occupy it. In 1843 I became acquainted with some men who had purchased tracts of this land remarkably cheap—the crops of the first season more than paid for the land; but before Christmas one or more of each family were dead, and the rest were so broken down in health that no other good crop was ever raised by them. The migrations to this pestilential region are constant, so that on visiting the same region a quarter of a century later, in 1868, the same desert was found, the same paradise of mosquitos, the same style of man, with apparently the same gun, the same ox, same cart, same children,—and the same kind of new immigrants as hopeful as ever over their first crop of peas and cucumbers, and older settlers bemoaning the loss of relatives. It is best not to hint to these poor people that the country is not the most healthy in the world, or the man that leads the ox might shoot you for abusing his country; discretion is much better than either dogmatism or argument on this subject till you get well beyond musket range. He knows very well that they have no sickness but the chills, and "any fool knows" that is no sign of an unhealthy country, for people have the chills everywhere. These people seem to think a good shake every second day an evidence of good health; and in

this they are probably so far in the right, that a person having a regular tertian ague may be less likely to suffer from the more fatal forms of malarial disease. (See frontispiece.)

It would be well if the migrations to these beautiful and fertile fields could cease until it can be undertaken with a fair appreciation of the difficulties; but it will not cease, it cannot be stopped, and any great change for the better must come by improving the sanitary condition of the country. I am confident that it will eventually become the happy home of millions of prosperous people, and groves of long-leaf pine (*Pinus tæda*) will protect and adorn the villages.

Thus the unhealthy country is known by the geological character and conformation of the land; by the repulsive sallow look, slim bodies, and shabby clothes of the people; by the poorness and small size of the cattle; by the fantastically primitive farm carriages; by the absence of capacious barns. The remedy is drainage. The *one great thing* would be a grand canal, similar to that of China, to connect Boston harbor with the Rio Grande—inland navigation half way between the hills and the ocean; and as soon as we may be conveniently annexed to Mexico it may be continued to the Coätscualcos, so as to have a double outlet at the south by way of the Tehuantepec Canal.

The drainage of the house and the garden is nearly as important as that of the fields, and will form the subject of the next chapter.

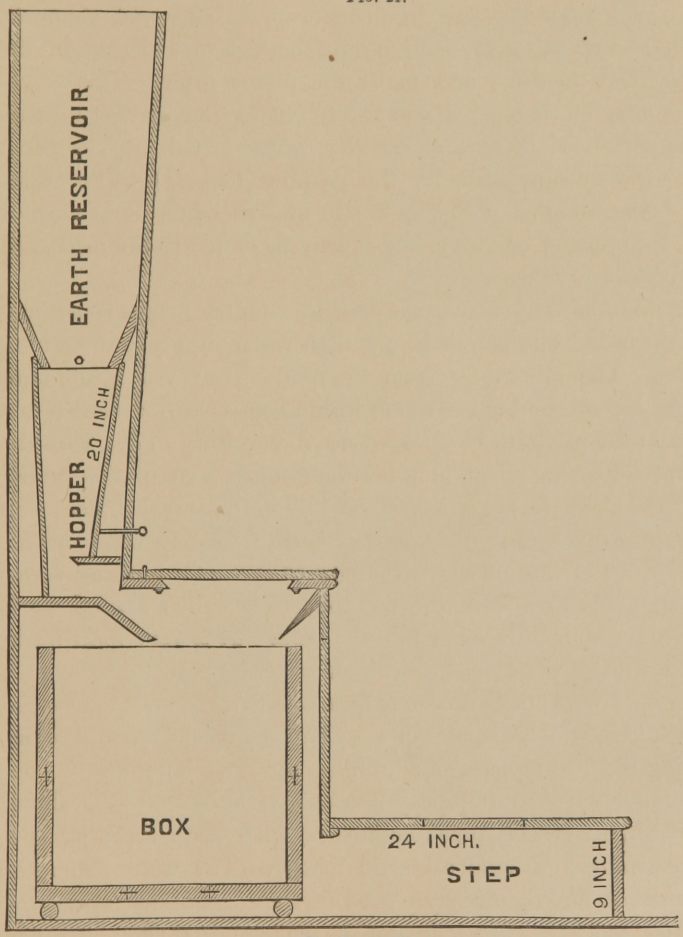
CHAPTER II.

THE DRAINAGE OF THE FARMHOUSE AND OF THE VILLAGE.

(20) THERE is some care to be used in the selection of building sites, and the plans must be suited to the situation, to the character and conformation of the land. A favorite situation is on a slope of high land, and this as the rule is certainly the best, as, other things being equal, it gives the best natural drainage. But this needs examination, and if the soil is of pure clay the building lot needs the same sort of draining that we have indicated for the fields. Sometimes there is a seam of sand or gravel, and if this is of the proper depth it drains the foundations nicely; but it may be so situated as to bring a portion of the drainage of the hillside

into the cellar walls. This of course makes the cellar wet every time there is a heavy rain. The common remedy for this is to make a drain from one corner of the cellar down the hill, thus receiving water into one side of the cellar and draining it off at the other side. This arrangement, with a stream of water running

FIG. 21.



The Earth Closet.

through the cellar, is not very nice. An effective remedy, perhaps the best plan, is to dig a trench a little deeper than the cellar on the up-hill side, about ten feet from the walls, continuing it down the hill, and to lay a drain of common pipe. The trench should be nearly filled with gravel or sand, so that any intercepted channel may continue to find its way down into the drain.

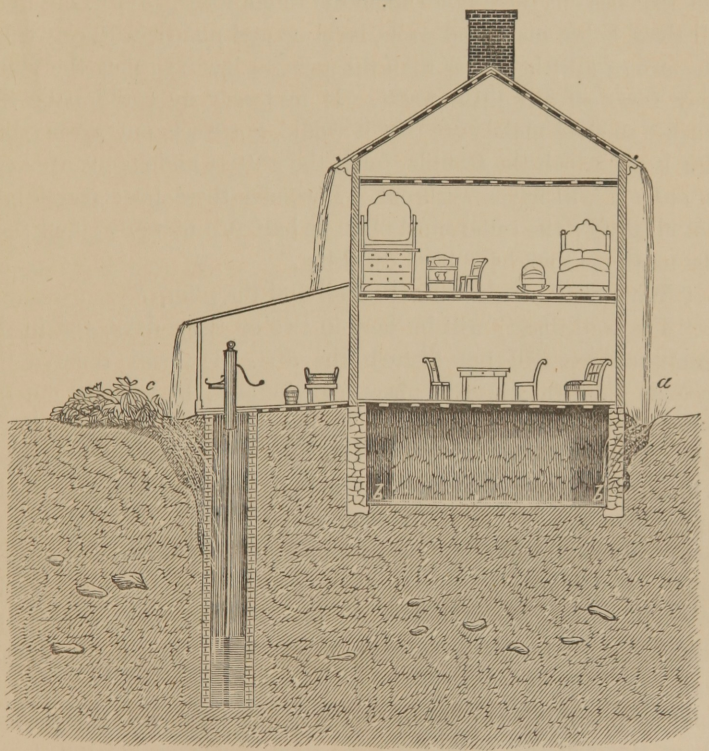
If the water-supply is by wells, in a light or gravelly soil, there can be no dirt-vault anywhere near without contaminating the water. Even in soil of the stiffest clay there is danger of the same nuisance. The vaults are sometimes so deep as to be really wells, the water mingling freely through the channels on the underlying rock. It is not hard to understand that typhoid poison may and does travel long distances in these deep underground channels. The safest way seems to be to mingle the dirt with the soil of the garden, there to decay and make the plants grow. The conveniences may be changed about from time to time, so that no particular part need become excessively contaminated. "The earth closet" is very convenient for this purpose (Fig. 21). The excrement being mingled with dry earth, or coal-ashes, or plaster of Paris, is no longer offensive, and it may be carted to the fields and spread like any other compost.

(21) Without any very great expense country houses sometimes have the usual city conveniences, with water-supply and bathing fixtures. The rain-water from the roof is conveyed into a tank near the top of the house; the excess in rainy weather runs into a cistern in the earth, to be pumped up if necessary in dry weather. If a fire is kept up all night, a hot-water tank, a circulation boiler, is so placed as to prevent freezing. The only real difficulty in keeping up this arrangement is the habit of wasting water, allowing it to run to waste without thought or care; for nothing seems more annoying to a man or a boy than to be called several times a day to pump a little water into the tank. It is very light work, but it is a most vexatious interruption of either work or play.

The fluid waste of these conveniences is carried off by a special arrangement, which disposes of the kitchen slops at the same time, by using them to irrigate an adjoining garden. The fluid is confined at first in iron drain-pipe, joints made tight by lead well calked; next in glazed earthen pipe (terra-cotta) with water-tight joints to a trap arranged to stop all solid matter. The water from the kitchen sink, having already passed through a similar trap to stop its grease and some dirt, increases the current, and the whole now at a sufficient distance (100 feet) from the house is turned into a channel of drain-pipe, with loose joints, about a foot deep (see Fig. 23). It thus mingles with the soil and makes the grass grow. This arrangement is easily made in a suitable situation, and requires very little care. But I will relate an incident, something that happened to myself.

(22) A few years ago I visited a farmhouse with a view to improvement. The diagram (Fig. 22) is intended to indicate the state of things—the usual condition on such occasions. There was a heap of mud and garbage—a kitchen midden—near the pump, evidently draining into the well. The farmer's wife urgently requested us to taste the water and to say whether it was fit for use; but we were not in the least thirsty. The mason who was to make the repairs was induced to express himself quite freely:

FIG. 22.



The farmhouse as commonly found when occupied by tenants, not the owners: (*a*) drippings from the eaves, cut holes partly filled with gravel, from which water filters into (*b*) the cellar; and (*c*) a heap of garbage, with kitchen slops and soap-suds, drains into the well.

"It seems that the water is nasty and not enough of it; the water on this place must be naturally good,—on this kind of land it is always good. Perhaps it would be a good thing to deepen the well?"

"Yes, we have decided to deepen the well, but what is to be done with the mud and dirt?"

"That is an easy matter; you can haul water in casks for the use of these people so as to relieve them of this nastiness; the water of this well will do to mix mortar till the well-digger comes. But well-water is a little hard for washing clothes. I would like to begin by building a small cistern about eight feet in diameter, to hold some of the rain-water from the roof, two or three thousand gallons?" . . . .

"Very well, we will have the cistern."

"There is no other doubtful question. You see the water from the roof has cut these holes about the cellar walls. I will clear out all these holes, mend the walls, level up and puddle with clay from the cistern a little higher than the general level, so that the slope may carry off any little water. If necessary we could pave the surface so as to make sure that it would not wash out again; but this is not worth the trouble, for if the gutters and spouts are kept in order it will never wash out. I wonder these poor people are not all dead; the cellar must often be half-full of water; and then the nastiness they have been drinking."

"What shall we do with the well and the pump?"

"The well-digger will be here in two or three days, and in the meantime we will not disturb the dirt. He will remove the wooden platform; he will place his windlass; he will lift out the pump, remove the entire wall, deepen the well, and wall it up again to within four or five feet of the top. The pump-maker will put in a suitable pump; the masons will finish the wall, the upper five feet in hydraulic cement, narrowing as they finish, so as to leave an opening only large enough for the pump and a man-hole. The whole of this upper part will be as tight as any bottle. We will select some earth from the bottom of the well, or from the cistern, to fill in and puddle up to the top. The material that comes of deepening the well must be carted away, and the present mud-heap will be so mixed up that it will be nowhere. The ground about the well will settle for some time—some years; but I can arrange the slope of the pavement so that with all the settling there will be slope enough to carry off the waste water. Some of the pavement and a paved gutter, twenty or thirty feet long, must be laid in hydraulic cement. Beyond that distance you can have a wooden trough across the garden, to leak and water plants as it goes. It will be nearly as it was when the house was new, but there will be hard brick and cement for thirty feet, instead of wood. With decent care it will be good for a hundred years."

This plan was substantially adopted. But the leaky wooden trough was omitted, and its place was supplied with an irrigating channel of terra-cotta pipe, about a foot deep, nearly if not quite in accordance with the plan described by Mr. Waring in the *Report of the Bureau of Agriculture* for 1871. We omitted the ventilating arrangement and cemented only the lower half of the circumference of the pipes, so as to ventilate into the soil and to receive drainage on occasions of heavy rain. The grease trap and the dirt traps are of plank, instead of bricks. This arrangement has been in use for several years without repairs or any care, except removing mud from the inlet occasionally, and cleaning out the traps.

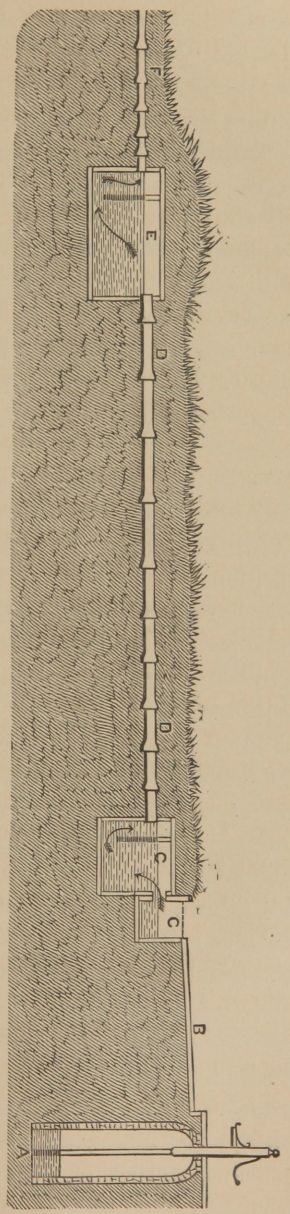


Fig. 23.

Farm and Village House Drainage. B, the gutter paved in cement; C, C, inlet and slush trap; D, D, cemented drain-pipe; E, dirt trap; F, drain, with loose joint.

(23) The situation of this house is excellent; its condition was disgusting. A young girl had recently died in the house. The masons wondered that they were not all dead. The heap of garbage was higher and wetter and nastier than either of the small marshes described on a preceding page as the cause of fatal malarial fevers (§ 8).

(24) The pestilence that seems especially to attach to such contamination of the water-supply is *typhoid fever*. In 1843, in the days of stage-coaches, a young man who had been to New York to purchase a supply of merchandise, was on his way home in the mail-coach, swinging about and dozing as the wheels bounded

over the rough road. He became very tired; he was sick, and he could go no further. The coach left him at a little wayside tavern in the little village of New Boston, Erie County, N. Y. In a few days he died; others died in pretty rapid succession. Of forty-three (43) persons in the village, twenty-eight (28) were sick, and ten (10) died. Three families escaped the pestilence; two of these families lived a little way out, and had their water from a brook; all the rest had been in the habit of getting their water from the tavern pump. One family in the midst of the village had a quarrel with the tavern-keeper and would have nothing to do with him or his pump. This quarrelling family were accused of poisoning the well. Austin Flint went to the village and investigated the matter. The families who had been so sorely afflicted with disease and death suffered from an expensive lawsuit and paid a fine for slander. This happened a very few years after Louis, in Paris, had demonstrated the existence of typhoid fever as a specific disease, and after Gerhard and Pennocke, in Philadelphia, had taught us the same thing. This is perhaps the first hint on record of the possibility of typhoid infection being conveyed by water.

(25) The reports of such incidents are common enough since attention has been called to the matter. Epidemics of typhoid fever have been propagated by milk to whole rows of city houses, and it is suspected that many cases of this "mysterious providence" have been caused by watering the milk, by "milking the cow with an iron tail."

(26) A few years ago, at one of the Croton reservoirs, there was established a boarding-house replete with sanitary appliances and elegancies. It was advertised as a *sanitarium*. People sometimes pay extravagantly for such care of their health. The house was abundantly supplied with water by a pipe from the lake and stored in a cistern, so that a small pipe kept on hand enough for any probable emergency; another cistern was built so as to have water convenient for the steam-engine, and another for the laundry, all connected by small pipes, very convenient. There was some trouble in disposing of the sewage from water-closets, and the unhappy thought reached the sharp intellect of one of the proprietors that a disused cistern might be adapted to this purpose. The consequent "Mahopac disaster," mysterious providence, dirty trick, epidemic, murder, or whatever people may choose to call it, caused about fifty (50) deaths of guests of the house by typhoid fever, and a large amount of life-long decrepitude and suffering. The business of the *sanitarium* was ruined for the season.—*Sanitarian.*

CHAPTER III.

THE DRAINAGE OF CITIES.

(27) "PARIS throws five millions a year into the sea, and this without metaphor. How? In what manner? Day and night. With what object? None. With what thought? Without thinking. For what return? For nothing. By means of what organ? By means of its intestine—its sewer.

"Thanks to human fertilization, the earth in China is still as young as in the days of Abraham. Chinese wheat yields a hundred and twenty fold. There is no guano comparable in fertilizing power to the detritus of a capital. . . . .

"We fit out convoys of ships at great expense to gather up at the South Pole the droppings of petrels and penguins, and the incalculable element of wealth which we have under our hand we send to the sea. All the human and all the animal manure which the world loses, restored to the land instead of being thrown into the water, would suffice to nourish the world.

"These heaps of garbage at the corner of the stone blocks; these tumbrils of mire jolting through the streets at night; these subterranean streams of fetid slime, which the pavement hides from you—do you know what all this is? It is the flowering meadow, it is the green grass, it is marjoram and thyme and sage; it is game, it is cattle, it is the satisfied low of huge oxen in the evening; it is perfumed hay, it is golden grain, it is bread on your table, it is health, it is joy, it is life. Thus wills that mysterious creation, which is transformation on earth, transfiguration in heaven. . . . .

"Imitate Paris and you ruin yourself. Moreover, in this immemorial waste, Paris herself imitates. These surprising absurdities are not new; there is no young folly in this; the ancients acted like the moderns. 'The Cloacæ of Rome,' says Liebig, 'absorbed all the well-being of the Roman peasant.' When the Campagna of Rome was ruined by the Roman sewer, Rome exhausted Italy; and when she had put Italy into her Cloaca, she poured Sicily in, then Sardinia, then Africa. The sewer of Rome engulfed the world. This Cloaca offered its maw to the city and to the globe. Eternal City! unfathomable sewer! In these things, as

well as in some others, Rome sets the example. This example Paris follows with all the stupidity peculiar to cities of genius."

Liebig very earnestly called attention to his views of the economic bearing of the present system of sewers for large cities; and Victor Hugo stated the case very emphatically. These opinions, though susceptible of some criticism, must in the main be received as correct by nearly every thoughtful adult person of average intelligence. But questions of mere economy do not belong to our present subject except as prosperity is promotive of health.

(28) In a previous chapter (§ 26) we studied the Mahopac disaster caused by draining a laundry and some water-closets into a cistern; the sewers are causing similar disasters every day. A sewer carries the drainage of numerous laundries, numerous water-closets and stables, manufactories and slaughter-houses; the contents of the sewer after reaching the river are pumped up into reservoirs for domestic use; this dirty water distributed to every dwelling-house, causes death and destruction. This unpleasant subject is ignored as much as possible; perhaps it may be thought immodest to allude to it; but to ignore it is death. The chemists are analyzing the dirty water; the microscopists are looking at it; and they are doing most important good work; but more progress must be made in these studies before we can introduce them into our "easy lessons." Boston has her Cochituate Lake and Pegan brook, and there is no actual need for chemistry to tell us that the brook is dirty. New York has her Croton River and lakes, and there is no need of microscopy to tell us that the hotels, the sanitaria, and the manufactories discharge dirt into the reservoirs.

And Philadelphia has her Schuylkill River and her Fairmount Park, where it is only necessary to walk about with the eyes open in order to see that sewage enters the river at Manayunk. The Delaware likewise receives sewage at Trenton, Bristol, Burlington, and Holmesburg, as well as at Frankford and Kensington. The pollution of rivers is the great difficulty with sewers; all other inconveniences the engineers are rapidly removing.

(29) Many persons seem to think that the principal use of sewers is to carry off excremental dirt; but this is really the reversal of the order of things. Before the cities there were streams of water, which were bridged for roads and streets; the bridges were gradually extended to cover over the streams till they became continuous culverts; these necessarily carried the natural

contents of the streams, together with anything solid or fluid that might be thrown in.

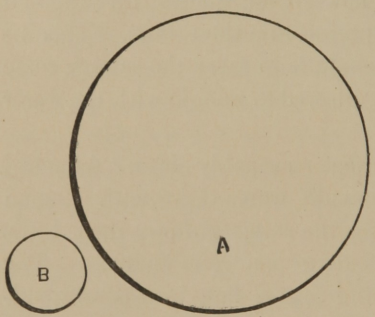
The sewers of Rome, the Cloacæ, were so large that a load of hay could pass through them—*vehes fœni large onusta.*—LIVY. The city was supported in the air and navigated beneath—*urbe pensile subternavigata.*—PLINY. These great arches were never built merely to carry dirt into the river. In London it was formerly a penal offence to discharge excremental dirt into the sewers, which meant of course into the Thames, from which the whole city received its water; but the police could not prevent it, and it was eventually legalized, so that now all the houses are supposed to have soil pipes and drains emptying into the sewers. This involves an enormous expense for conduits to carry the sewage some miles towards the sea, before it is allowed to mingle with the water of the river.

In Paris the river seems to be kept reasonably clean. Attached to the houses there are tanks, made water-tight with Roman cement, and emptied periodically; the *voitures* dump their loads into barges, which carry the contents to poudrette factories. The comparatively clean contents of the sewers flow in separate conduits to irrigate many gardens, so that the water filters some distance through the soil before it can enter the general channel of the river.

(30) In the United States we are stupidly imitating London and Paris; and we follow with such tottering steps, that while they are trying to prevent the pollution of their rivers, we are trying how much dirt we can manage to throw in. We seem not to care to dispose of it in any other way. The sewers are written about as if they had been designed exclusively for the transportation of excrement to the river. It has even been proposed in official reports that storm-water should be carried off in some other way, and that the drainage of the soil should be excluded by making them water-tight. Of course those who write thus have not thought much about the matter. It is impossible with any known material to make a sewer really water-tight, as the settling on the irregular surface cracks any rigid material. The very most important function of the sewer is to drain the soil so as to render cellars partly under ground possible. Whole squares of land in the suburbs remain unoccupied, waiting for sewers to be built near enough and deep enough to drain the foundations. Our laws re-

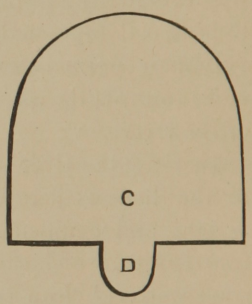
quire the sewers to be placed deep enough to drain the soil four or five feet deeper than any ordinary cellar floor. The size of the sewers is especially calculated to carry off the storm-water. "They are designed to carry off one inch of rain . . . . in two hours, ... half a cubic foot per acre per second of the area drained," 1800 cubic feet per hour. "The sewage proper is 25 cubic feet per acre per hour." It follows that our sewers have 72 times the capacity required for the "sewage proper." Let us not think of excluding storm-water from the present sewers; and if separate

FIG. 24.



The Relative Size of Sewers. (A) to carry the water of rain-storms. (B) to carry sewage proper.

FIG 25.



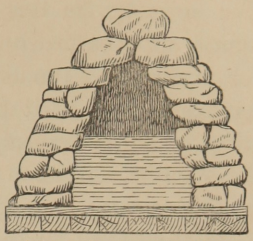
The Form of the Paris Sewers. (C) to carry the water of rain-storms. (D) to carry the ordinary drainage.

channels were a necessity in order to stop this pollution of rivers, we may construct new sewers for the "sewage proper." They may be very much smaller, of iron perhaps as a material better suited than earthen pipes or bricks.

(31) The sewers calculated to remove storm-water are deeply situated, and commonly drain the soil so effectually that the importance of this soil drainage seems hardly to be thought of; but there are situations where this action of the sewers needs to be supplemented. In grading for streets there is sometimes made-ground; it is generally low ground, and the sewers are not always low enough to drain it properly; hence houses on made-ground are likely to be unhealthy. Now, the hollows thus filled up are not always in proper situations for sewers, and they may be quite neglected in planning improvements. In the lowest part of these hollows there is sometimes a small stream; it has been proposed to construct a rough arch of boulders or any convenient rough stone, very strong and covered up no matter how deep, so as to act as a

deep drain; thus it is expected to keep the made-land in good condition perpetually without further care. This drain is supposed to be strong enough to bear the weight of any buildings that may be placed over it. With this drain perhaps the houses on made-ground would be as healthy as on any other ground. Certainly there is so much benefit to be expected that any cheap material at hand should be arranged with this object in view.

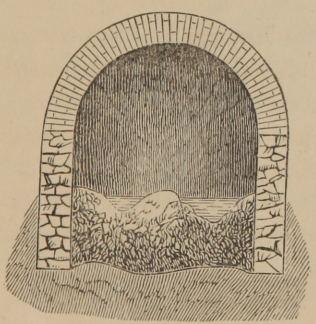
FIG. 26.



A Deep Drain of Boulders. (Sanitarian.)

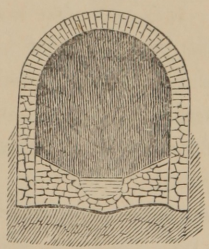
(32) The form of the sewers is a matter of importance. Whether the stercoral pollution of streams is to continue and increase or not, these drains must be continued. They must carry off the water of rainstorms; they must carry the continuous small stream of soil drainage; they must carry the water of the rivulets that flowed over the surface before the city existed; they must carry any additional waste water from no matter what source. Hence, the sewer must accommodate a continuous small stream, and it must be so arranged as to carry an occasional flood. A common form is the *simple arch* across the stream, a mere extension of the bridge. This for a sewer carrying a continuous large stream, large enough to keep the floor covered,

FIG. 27.



The Common Sewer,—a simple arch.

FIG. 28.



Parisian Sewer,—a great improvement of the simple arch.

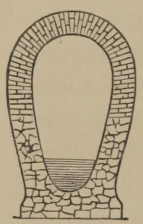
may be well enough, but for the ordinary sewer it is the very worst. The dirt accumulates in this kind of sewer, and a small stream of dirty water meanders on top of the slime.

A better form, perhaps the best, is that which prevails in the city of Paris. This has a floor of masonry with a deep channel for ordinary drainage, and there is the arch over it of sufficient

capacity for the storm-water. The ordinary flow is confined to its small channel; the rest of the internal surface is dry and clean till the rainstorm comes to give the whole arrangement a good washing. For large sewers this is certainly a desirable arrangement, as it affords a dry surface on which workmen may walk when entering for repairs, and the old single arch may be greatly improved by having its floor built up into this form. Perhaps even telegraph wires and gaspipes might be carried all over the city inside of these sewers, and thus be accessible for repairs without disturbing street pavement.

The best form for smaller sewers is the oval, narrow below and broad above. This has a narrow space below for the ordinary flow, without allowing much surface for the adhesion of dirt, and it has space above for the flushing when the flood comes.

Fig. 29.



The Oval Form of Sewer.

The circular form is bad, as it affords more space for ordinary accumulations of dirt, so that it is more likely to be half filled with rags and obstructed in time of floods. The ellipse flattened from above is much worse, and the oval, wrong end upward, not quite so bad.

For the smallest sewers glazed earthenware pipes of the circular form are best, on account of the smoothness of interior surface, and the facility of placing them.

It is probably best that the floor and the lower part of the sewer, the part occupied by the ordinary flow, should be made as nearly water-tight as possible, as tight as stones and hydraulic cement can make it; the upper part, too, should be laid with hydraulic cement, for common mortar of lime dissolves out in many situations. The porous bricks of the upper part, with unavoidable defects of workmanship, cracks from settling, and openings for small inlets afford sufficient inlets for the drainage of the soil.

(33) The word *sewerage* is generally used to indicate the sewers themselves, the aggregate of bricks, stones, and mortar as just described. *Sewage* is the dirty water that passes through. *Sewage proper*, or rather sewage improper, is the mixture of dirty water and excrement, which through various domestic conveniences is made so liquid that it is floated off more cheaply than it could be carried in carts. As these conveniences are often death-dealing nuisances, we cannot avoid some description of them.

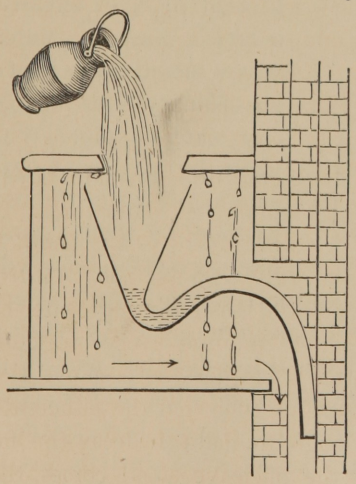
On entering an ordinary city house after a short walk in the

open air, we mostly perceive a disagreeable smell that we call closeness; it is quite indescribable, a weak mixture of many smells; it comes partly from cookery, partly from the dressing of new carpets; it comes from kitchen-sink and water-closet; from slop-sink and bathroom; from laundry, from cellar, from sewers. It is sometimes called sewer-gas; it varies in smell and in chemical properties; it is simply foul air, dirty air. It may come from the sewer if any of the traps are defective; it much more commonly comes from decaying dirt in some part of the house.

(34) The *kitchen-sink* is faultless in mechanism; it is usually a simple cast-iron basin with a trapped outlet to prevent the passage of air from the sewer. But nothing seems too dirty or too clean to be washed in the kitchen-sink; at one time it is heaped full of dinner dishes, at another it is used to wash baby clothes. This is not as it should be; the fixed wash-tub is no remedy; the disgusting dirtiness might be mitigated by making the sink inconveniently high or of inconvenient form; but there is no remedy until people can be taught the constant habit of cleanliness in all things.

(35) The *slop-closet* has generally a cover of wood large enough to hold a bucket and to catch a little of the dripping that may be

FIG. 30.



The Slop Closet. The water instead of entering the funnel partly drips about the floor and soaks into the wall.

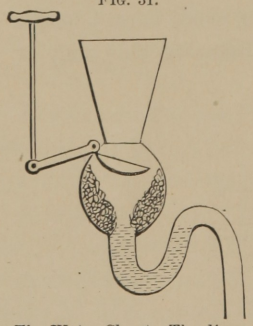
readily wiped up when thus visible. This is generally arranged by the plumbers and builders in such a way as to be a great nuisance: the wooden cover is made flat on both sides, so that when it gets wet the slops on the lower side drip about without enter-

ing the funnel at all; inclosed in a box this drip runs about the floor of the room, and even down the outside of the drain-pipe into the wall. This may be remedied by removing the box altogether, so that the drip may be seen on the floor and wiped up, or the cover may be changed somewhat to the form of a short funnel by tacking a string of caoutchouc around the lower side of the opening.

Dr. Andrew Furgus, of Edinburgh, has demonstrated that ammonia and other gases do pass through traps such as are ordinarily used; not only these gases but all kinds of dirty air pass and are diffused much more rapidly where there is no trap to be passed. The smell of these things does not come altogether through traps from the sewer, it comes more commonly from dirt or a slop of dirty water concealed about the sink.

(36) The *water-closet* contains all the nuisances of the slop-closet and some more. Besides the simple funnel that might empty directly into the trap, there is generally another compartment partly concealed by a movable screen, a pretended valve, to hide the retained dirt. It would be hard to imagine anything worse than this; and the attempt is made to deprive it of offensive smell by such a lavish waste of water through leaky valves intentionally kept out of order, that no ordinary river is big enough for the city water-supply. We talk of wasting water by pavement washing; but this running of water through the wash-pave hydrant by some families for about ten minutes a week, is but a drop in a bucket as compared with the universal waste through water-closets by almost every family, for 10,080 minutes every week, throughout the summer. But all this waste does not remove the smell, for the shape of the receptacle is such that the adherent mass of dirt is only kept moist enough to make it decay the faster. It is not from the sewer that the offensive smell comes, the sewer-gas, the typhoid fever, the yellow fever, the cholera, the dysentery.

FIG. 31.

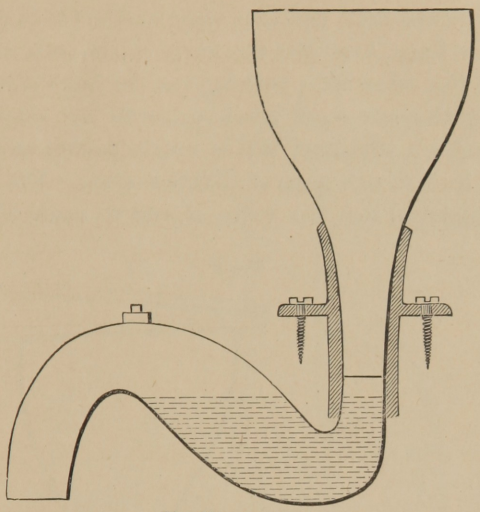


The Water Closet. The dirty arrangement.

Perhaps the best arrangement in common use for even the interior of houses is the *common hopper* as used in the back yard; it is a simple conical vessel attached to the S trap, so that there is scarcely any surface above water except white porcelain; it cannot

be dirty much of the time among people with the ordinary instincts of cleanliness. It may have ventilation flues downward

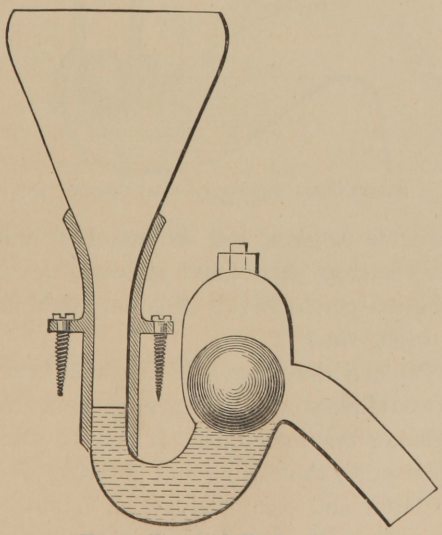
FIG. 32.



The Hopper Closet.

through the box, downward through the funnel, and from the discharge side of the trap; but such flues should be kept separate till

FIG. 33.



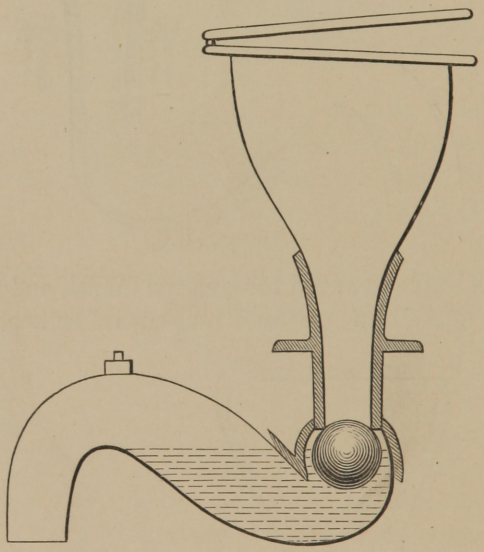
Hopper Closet with Check-valve.

they discharge into the open air, for otherwise the foul air may go up one flue to come down into the room by another. There is no

real necessity for a wooden box to conceal the arrangements, for the seat may be suported like a chair on suitable feet.

If offensive gases pass through these traps, as the experiments of Dr. Fergus demonstrate that they may, or if typhoid germs, like so many minute frogs, hop into the water of the trap on one side to jump out at the other side, nothing can be more effective than a check-valve, the sewer-gas check-valve as we see it advertised among plumber's supplies: this is nearly perfect and only wants enlarging a little to suit traps of different sizes. For durability it has been suggested that the valve should be made of hard mate-

FIG. 34.



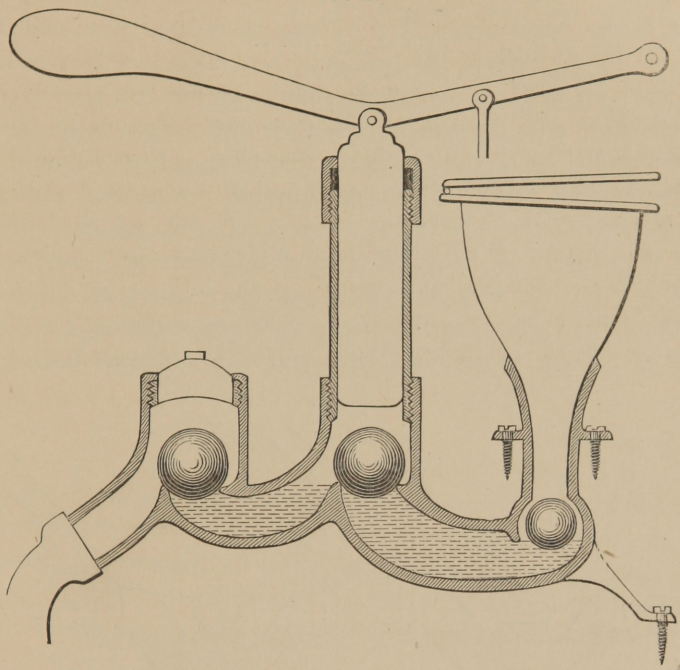
Hopper Closet with Hard-Rubber Floating-valve.

rial, such as marble or glass, and its socket of brass; so that the wear of use may tend to perfect and maintain the exact form, but a good ball of gutta-percha in this situation would answer the purpose and last a long time.

(37) *The Ship's Water-closet.*—If anything better than this is called for, we would recommend the arrangement common on shipboard for use below the water-line. It may be placed even in the hold, and only requires the raising and lowering of a pump handle to empty the basin and completely wash it out. If used in a dwelling-house, the valves may be merely check-valves of suitable size, so that if the water fixtures leak, the surplus may flow through without material damage. This machine, with its two valves and

its plunger, its stuffing-box and its pump-handle, may be rather expensive; but it can hardly cost as much as the lives of people are commonly worth.

FIG. 35.

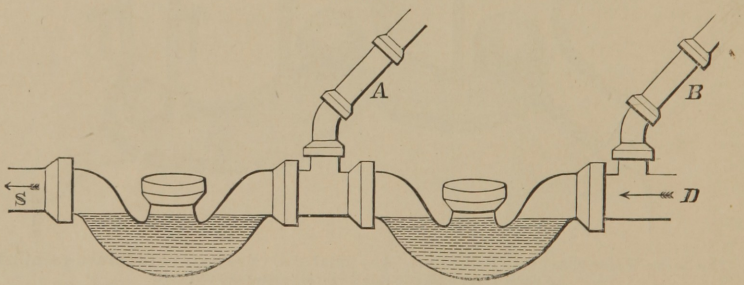


The Ship's Water-closet with Ball-valves. Any number of valves may be added and a ventilator to each trap, and the floating-valve may be omitted.

(38) *The house-drains* are expected to carry off all the dirty water and fluid waste from the house. When of small size, from wash-basins, bath-tubs, and kitchen-sink, they are best made of lead pipe; and when larger they are of cast iron with leaden joints. Terra-cotta pipe is used to connect these drains with the sewer, but should not be allowed inside the walls of the house. These drains should never enter the cellar floor, but should be carried by the shortest possible course beyond the walls. If a drain must cross a cellar, it is best to arrange a shelf for it on a wall where it is constantly in sight. Even royal perfection of plumbing cannot make these things quite safe in a dwelling-house, for Prince Albert lost his life by a defective house-drain under his library, and his son, the Prince of Wales, suffered a serious illness and a narrow escape with life by a similar incident. Quite recently we see a material change in these arrangements; formerly the drainage from the

kitchen went by a pipe through the cellar, in the cellar floor, from rear to front, and so on to the sewer, or near the outer wall there was a culvert leading to the sewer. The culvert was so large that it might be entered for cleaning, two feet wide by four feet high, but it was never cleaned; the filth accumulated from the dirty water till the culvert was full, and then the water kept a little channel for itself on top of the slime, and for that matter these streams are still flowing through their little channels in the accumulated slime of these culverts, that have not been cleaned out for a hundred years. This is one cause of the great mortality in some parts of the older cities. This is all changed, or changing for the better. Well-jointed pipes of lead and iron pass directly through the rear wall into a small garden, where they are united with pipes of glazed earthenware; these are continued across the rear of the lots, at sufficient depth and with sufficient fall, to the

Fig. 36.



Ventilated Traps. *A*, *B*, ventilators; *D*, drain; *S*, sewer end of the drain.

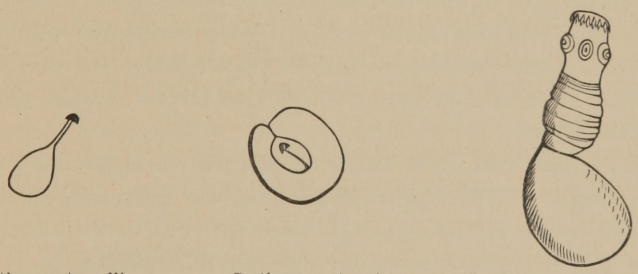
public sewer. The building laws of our cities require the reservation of sufficient land for these small gardens, and the builders generally favor them; but old buildings are not easily changed to conform to the plan, especially as it requires a right of way for a drain across a neighbor's land. It seems difficult to carry out this improvement in small houses, as it is perhaps impossible to prevent the people from forcing rags, broken glass, and other improper things into the drains. When the drain is through their own cellar they sometimes learn to do better. Whether these drains should be trapped or not is still a question under discussion. The traps themselves are pools of dirt, but if there is any necessity for them, there is no difficulty in having any number and all ventilated, as in the diagram (Fig. 36). The principal use of the traps is to catch rags and broken bottles before they get too far from the persons causing the nuisance.

(39) *The ventilation of sewers* and drains is a matter of importance. The large drains and sewers cannot be made air-tight, but the metal pipes inside the house may be made water-tight by good mechanical work. The air of any ordinary room with doors and windows closed, notwithstanding the porous material of the walls, becomes unpleasant in the course of a few days, smells musty, and is unfit to live in till the room is opened for ventilation, and perhaps warmed. Drains and sewers, besides the confined air, contain dirty water, decaying and giving off a much more offensive smell. Now, this dirty air may be diluted by constant ventilation, or it may be concentrated by constant shutting up, so as to cause sudden death if incautiously or accidentally entered. We really have no means of getting rid of this offensive air except by infinitesimal dilution, and this we are apt to call "getting rid of it altogether." The natural movements of ventilation, as produced by changes of temperature, must be borne in mind. Warm air is specifically lighter than cool air, mere foulness affecting the weight so slightly that, as influencing movement, it need not be considered at all; hence, when the sewer-air is cooler, as in a summer day, it tends to remain in the sewer or to flow out at the lower end; but when the sewer-air is warmer, as in winter, it ascends by every possible opening, being displaced by the heavier cold atmosphere. This foul air does not mingle instantly with the cooler pure atmosphere, but in obedience to the laws of gravitation it ascends to the higher regions of air, quite out of harm's way. Apertures larger than the pores of bricks are desirable, but where or how many we are not prepared to say. A separate ventilation-flue in every chimney-stack is a good thing for houses, but certainly sewer-air of the public sewers should be carefully kept out of it. Openings for other purposes act as ventilators, such as inlets, outlets, and entrance openings for repairs. It has been suggested that manufactories using much fuel might draw air for the furnaces directly from a main sewer, but the air would enter by the nearest opening, so that the effect would be small unless a large furnace could be used near the outlet in such a way as to capture the foul air in the last section of the sewer just before its escape. Such, then, is perhaps the present limit of our power in this matter. We may make as many man-holes as we please along the central line of the street for the escape of sewer-air in cool weather, and we may have a furnace near the outlets to capture and burn up the dirty air just before its escape in warm weather.

(40) The stercoral pollution of rivers, besides the disgust, is a very serious cause of disease and death, and perhaps this subject may be usefully illustrated by a brief reference to the natural history of some of the entozoa, such as the tapeworm. The *tæniadæ*, tapeworms, vary much in size and form, and about ten species have been found infesting the human body. The species in nature are very numerous and infest nearly all vertebrate animals; they are perhaps not so numerous as the butterflies, but they are developed through about the same number of similar changes in form. The eggs of the butterfly hatch, and we have caterpillars crawling about, doing mischief, and changing coats (moulting) till they get old enough to wind themselves up in cocoons of silk or to hide away in a corner. They are now called *pupæ* or *chrysalids*, till their time comes to show themselves as full-grown, full-fledged butterflies. Similarly, (*a*) the *ova*, the eggs of the tapeworm, when received into the stomach quickly hatch, and (*b*) the young, called *cysticercus* (bladder-tail), penetrates to nearly all parts of the body; he is made up of head and tail, the tail being a bladder full of water, his head is nearly hemispherical, but he has no mouth, and his teeth, if he has any, are on the top of his head. His tail must change much in form and even be drawn out into a string sometimes, so as to get it through the small hole made by his gimlet of a head. He probably starts on his travels without the bladder, a mere string pointed at the ends, and penetrating a bloodvessel he is carried to the liver or to some other part of the body, accordingly as he first falls in with a branch of the *vena portæ* or with some other vein, a threadworm in the blood (a *filaria hæmatobia ?*). The *cysticercus* may cause death by penetrating the heart, the eye, the brain, or the spinal cord; he gets too old to travel, and he stops for a rest; he turns his neck inside out, and his head settles back into the middle of his bladder. If he finds himself too near a joint so as to be much disturbed and pinched, he stretches out his head and starts off again till he finds a more suitable place, and then he remains a little bladder of water with a dimple on one side. He has now reached (*c*) the third stage of his existence, corresponding to the chrysalis of insects; and as caterpillars do not all make cocoons, so the cysticercus at rest assumes various forms and receives various names; they may be called hydatids as a general name. The *hydatis cellulosæ* in pigs is called measles; the *hydatis mediocanellatæ* (= *echinococcus*) has been found in the human liver, and has been produced in young cattle and in some other animals by mixing the ova with their food;

the *hydatis marginatæ* (*= cœnurus cerebralis, braxy*) has been found in the brains of sheep, causing staggers. Even the same species varies much in form: the ova of *tænia serrata* develop into *cysticercus pisiformis* in puppies, into *cœnurus cerebralis* in lambs, and into something very like *ascarids* in the liver of rabbits. Cruel Dr. Leuckhart, to coax these lambs and rabbits to eat bits of tapeworm and then to knock the poor things on the head, and cut them into such little pieces merely to see what had become of the hateful mess! The most dangerous form is the *hydatid tumor*. The echinococci of several species—tenuicollis, marginatæ, pisiformis—possess the faculty of *parthenogenesis*, and thus multiply within their thickened sac till they constitute large tumors, even as large as a child's head. The next event in the history of these creatures is to be eaten up, when they quickly develop into (*d*) the regular tapeworm; and with the teeth or hooks on top of his head he just

FIG. 37. FIG. 38. FIG. 39.



The cysticercus travelling. Cysticercus at rest. Cysticercus mediocanellatæ.

hangs himself up. He does not even swallow his food, for the surface of his body does duty as stomach; he just hangs and drops eggs for new generations of (*filaria hæmatobia?*) cysticercus, hydatids, and tapeworms. Many other things, however, may be in the blood and be mistaken for filaria. The young of the *filaria medinensis* must be carried in the blood; the *trichina spiralis* reaches nearly all parts of the body by the current of blood; nearly all the *entozoa* infesting the liver must be carried there from the intestines by the vena portæ; besides, there are such vegetable organisms as the threadlike bacteria (*bacillus, anthracis*, etc.), which besides causing other deadly diseases, appear to block up one minute artery at a time, and thus one finger or toe after another, nearly all in succession, are destroyed in that awful condition called *lepra anæsthetica*, till fortunately a knot of them plug up a large artery and end the misery.

(41) Among the more noted species of tapeworm may be mentioned the following:

Bothriocephalus latus, the broad tapeworm, tænia lata, t. vulgaris, t. grisea, t. membranacea, t. tenella, t. inermis, t. prima, t. acephala, lumbricus latus, halysis lata, dibothrium latum, comes first because he is the biggest and has most names. He is about an inch wide and wonderfully long. He is not common with us, but is occasionally found among new immigrants. He flourishes in the North of Europe. The cysticercus and hydatid of this species have not been recognized; and not having the hooklets on the head, necessary under the microscope for the certain recognition of echinococci, we should find them difficult to determine even if we had them in our hands.

Tænia solium, the solitary tapeworm, t. longa, t. cellulosæ, t. cucurbitina, t. secunda, t. articulos demittens, is perhaps the most common species in this country. Its hydatid in repose, hydatis cellulosæ, gives the peculiarities to measly pork. The stories told of the length of this creature are really wonderful, reminding us of the person who was so very sick that he threw up three black crows. Dunglison says: "It is said to have been met with 600 feet long."

Tænia mediocanellata, Leidy thinks, may be as common as the preceding. It infests principally the Abyssinians and others who eat raw beef. Hydatids of this species, found in a human liver, were fed to various animals, and the following were infected, mostly by this means: Ass, cat, and camel; cow, chamois, and deer; goat, giraffe, and horse; kangaroo, monkey, and pig; ox, sheep, squirrel, and zebra.—*Cobbold.*

(42) The fully developed tapeworm causes much pain and discomfort, but it does not seriously endanger life in this form, and it is so rare that to meet a patient suffering from it seems to afford a real gratification to the physician, for he knows that by a little judicious starving, alternated with an occasional dose of pumpkin-seeds and castor oil, this curious animal will soon be laid out on a board, to be put into a vial of glycerin and water for preservation. Gamgee thinks that fully three per cent. of all the pigs in Ireland are affected with hydatis cellulosæ, measly. Thudichum a few years ago reported that nearly every sheep slaughtered in London was affected with braxy, hydatis tenuicollis. Hjaltelen calculated that twenty per cent. of all the deaths in Iceland are from hydatid tumors (echinococcus marginatæ) and tapeworms; while others

have estimated the proportion at about fourteen or fifteen per cent. There are about six times as many dogs as men in Iceland. Every dog is affected with tapeworms, and the eggs soil the grass and water and nearly everything. The sheep must eat the eggs on the grass, and hence the universal braxy. The sheep are slaughtered and the braxy part thrown to the dogs, and the perpetuation of the race of tapeworms is thus provided for. The people probably do not eat braxy mutton without cooking, but they drink water without boiling, and some vegetables without cooking, and hence twenty per cent. of the deaths are by tapeworms and hydatids.

But what is to be done about this matter? Market inspectors should be able to recognize braxy mutton and measly pork; but the butchers may cut off the conspicuously diseased part and conceal it. In Iceland it has been proposed to treat all the dogs regularly with tapeworm medicine; but the dogs resist and the people are careless. Perhaps in time a habit might be inculcated of feeding the dogs exclusively on cooked food.

(43) The human intestines, and nearly all parts of the body, are infested by very many deadly animals besides tapeworms. Some of them, as trichina, strongylus, bilharzia, and filaria, are pretty well known; others, from their minuteness rather than their rarity, are seldom seen, and their manner of life is unknown. But, enough! is it really necessary, in an enlightened country, in the latter part of the nineteenth century, to pursue the natural history of these animals further, merely for argument to prove that stercoral matter is dangerously poisonous, and, if swallowed, capable of producing disease and death?

(44) There is an effort to stop cesspools from leaking into the cisterns; but this is done by emptying the cesspools and sewers into the rivers. We are told that organic matter (stercoral matter) thrown into the river is quickly diluted and oxidized, so that if the water flows a mile or two it becomes sufficiently pure. There is some truth and much fallacy about this statement. The ova and embryos of tapeworms and some other entozoa do perish and decay in the course of time, if cast into the river; but some of them are a long time before they perish, and some probably live in this situation long enough to become the parents of millions, and thus to continue indefinitely. Physicians cannot resist the accumulating evidence that typhoid fever infection is composed of definite organisms, "probably living." Dilution separates the infective germs, so that any particular cup of the water is less likely

to contain the deadly portion ; but the numerous cases of typhoid fever prove that the poison is still present and in such condition as to cause disease and death. The deaths from this disease, caused in this manner, in each of the large cities, amounts to several hundreds every year.

(45) The problem for engineers is, How are the people of large cities to be supplied with tolerably pure water? with water not polluted by the drainage of filth from their own homes?

In London some wealthy people solve this difficulty for themselves by drinking only mineral-water—not nauseous doses of Seidlitz or Saratoga, but the purest sparkling spring-water that can be found. It is good table-water, good mineral-water for the table, the queen of table-waters. There are large bottling establishments, where the water is duly corked, sealed, and labelled, with every possible precaution to prevent deception. Sometimes the water is charged with a little more gas, so that when the cork is drawn it pops like champagne. Some of our apothecaries sell these pure table-waters from across the ocean. This supply of pure drinking-water to a few wealthy families by carting it around in bottles and demijohns is possible, but it is not possible to supply the people of a large city in this manner.

In some large cities, notably in London and in Paris, the attempt is made by means of large sewers parallel with the river to intercept all the sewage and thus conduct it to a safe distance, and even to utilize it as manure in the fields. To discharge the dirt thus at a distance might do for a seaport, but for any interior city it would be a gross outrage. It would be to recklessly pollute the water-supply of the next city.

The utilization of sewage for manure, heretofore, has not been profitable, because of the profuse wasting of water, which so dilutes the material that *it has not enough money value to pay for the labor of applying it to the fields.* If this diluting can be checked, by the use of water-meters, for instance, perhaps manufactories of manure and hydraulic cement, with facilities for irrigating gardens with the comparatively clean water, may be made to pay—may be possible.

(46) Another device that seems plausible is in use at Lowell, Mass. (*Report of State Board of Health*, 1874.) This is to filter the water before it enters the reservoirs. A suitable location is selected, a bank of sand or gravel, a mile or so wide, near the river from which the water is to be drawn. A series of wells may be

made at sufficient distance from the river to insure perfect filtration, and of sufficient depth so that the water will flow as fast as pumped out; or, instead of the series of wells, there may be one or more elongated structures, *filtering galleries*, extensive enough to filter all the water of the river if needed. The river must be very bad if it cannot be made to supply good water in this way. At Lowell the filtering gallery is but one hundred feet from the river, and the water is abundantly supplied with the usual inorganic salts of well-water, so that probably very little of it comes from the river. But, as we have said, this is a question for the engineers. We insist that water should be supplied without systematic pollution with sewage.

(47) Another kind of water pollution occasionally receives more consideration than it is fairly entitled to. Various manufactories discharge into the rivers waste material. Tanneries discharge large quantities of exhausted bark, mixed with hair and filth of their peltries, with some little dye-stuff. Exhausted bark is about as innocent as any organic material can well be—no worse than sawdust. The filth and hair are worse, being offensive by their decay; but the inorganic germs of disease can hardly be imagined to maintain their virulence through the operation of the tanners' vats. Dyeing and bleaching establishments discharge quantities of colored material. Indigo, with its frightful color, is about as innocent as starch or flour. Logwood and brazilwood are about as poisonous as oakwood, and their chips and shavings are about as bad as the sawdust from the lumber mills. Turmeric, in the quantities present, cannot do much harm, as, alternating with annotto, it is used to give color and flavor to oleomargarine and high-colored butter. Such material should not be thrown into the rivers, especially as farmers gladly haul it away to enrich their fields—even pay for the privilege. Similarly of the mineral waste, iron and tin, lead and copper, arsenic and bismuth, calcium and chlorine, chromium and iodine, magnesium and manganese, mercury and phosphorus, potassium and silver, sodium, sulphur, and zinc. These, in the relatively small quantities present, with time and circumstances favoring, unite in accordance with their chemical affinities. In part they precipitate, and in part form about the same inorganic salts that are always present in all *good spring-water*, and serve to distinguish it from distilled-water or rain-water. It has even been objected to the use of water that does not contain those salts necessary for healthy nutrition. It is quite possible to conceive that a

manufactory of Paris green, or the like, might dangerously poison a stream of water; but the organic germs of disease, amœba and bacteria, trichina and filaria, bilharzia and strongylus, cysticercus, echinococcus, tapeworm, and the like, could hardly pass through the dyer's vats and live. The danger from manufactories is from the sewage of their villages.

CHAPTER IV.

ABOUT PLUMBING.

(48) SOMETHING about plumbing has been learned in the school of experience, and following illustrious examples it may be well to redintegrate a little and tell all about it.

Some years ago a naval medical board were sitting among books and papers discussing "What shall we do next?" when there arrived several telegraphic orders, all worded as follows: "You will report immediately to the commandant of the navy-yard for duty in reference to cholera." It was suggested that "We may as well shut up our books and put on our hats; but *while we are all here* let us sign up the record of proceedings." The commandant was glad to see us. "There is cholera on board the receiving ship. Suspicious cases were reported yesterday with one death, another death last night, and several undoubted cases. The surgeon of the ship is pretty tired, and has enough to do with the rest of the crew. About fourteen doctors are ordered by telegraph, but as yet only one has reported. On the recommendation of the surgeon, the yard tug has moored two other ships in order that the men may be removed and distributed, and has now gone for another to be used for a hospital ship; this will take nearly all night, and you can inspect her in the morning and report as to her fitness for the purpose. If this meets your views we can transfer the sick, and if one vessel is not enough we will have another as soon as possible."

"This seems to us the best possible arrangement. We will now go and see the sick on board, and we will be ready to occupy the hospital ship as soon as it can be properly moored." . . .

The next morning a dispute is heard in front of the commandant's office, near a bier sitting on the footway.

"But it is my husband," the woman persisted.

"I cannot help it; he is dead, died of the cholera, and I have orders to remove the body. I must start with it to the cemetery as soon as the other arrives, for which I am waiting."

"But I want to have a funeral."

"If the undertaker were here I could deliver the body to him, but it must not remain here."

"But I want a little time to get money to bury him."

"If I take the body to the cemetery it will cost you nothing; everything is paid for, and you can follow in carriages with your friends and have your funeral services in the chapel at the cemetery." . . .

A number of carts arrive with strange-looking loads, and the head teamster advancing touches his hat to report: "Sir, I have been ordered to deliver some hospital furniture." There are four or five carts. The bedsteads are painted red, and have been screwed together in the night to save time. Each cart has some bedsteads, and the mattresses and blankets, sheets, pillows, and pillow-cases are packed in below.

"Very well, the furniture is to go aboard the hospital ship; go as near the end of the wharf as you can without getting in the way, and wait."

An officer arrives to report: "The captain of the tug sent me to report that the mooring of the hospital ship is nearly completed, and to ask if there are any further orders for him."

"Thank you; we will go on board with you."

We start for our inspection. The ship is in excellent condition; she has come in from a short cruise, and is as clean as scrubbing can make her; she has a donkey boiler and steam pipes to warm throughout, gun-deck space enough to accommodate twenty-five beds nicely.

"Well, captain, you have her secured?"

"Yes."

"No rattling of chains, then, for fear of dragging in case of a gale?"

"She has anchors enough to hold a line-of-battle ship."

"Thank you, captain, and now there are some bedsteads at the wharf; please bring them aboard and the hospital stores—everything that is in the carts." . . .

"Well, we are getting on bravely; the engineer is firing up and we shall soon have steam in these pipes nice and warm; and

see here, this extra boiler, with its furnace just in the right place to burn up dirty bedding; the cooking galley in complete order; nice rooms for the officers, all the better for being without carpets or bedding."

"While we have the tug at our disposal let us bring the patients aboard."

"Yes, everything is ready as soon as the beds are made up, and if once this tug gets away from us she will be off elsewhere, and it may take us a whole day to get another."

"I noticed yesterday that the captain of the receiving ship thought the sick very well situated where they are now that the crowd of men are away, and I feel that he will give us trouble unless we go to him with a peremptory order."

"As I am the youngest, I will stay to fix up the beds and the furniture while you hold the tug, and the order will do no harm even if we should not need it." . . .

"Commodore, we are ready for the patients aboard the hospital ship, and would like to have your permission to make the transfer."

"Is the vessel sufficiently warmed? Captain —— has been here and suggests that the receiving ship is right comfortable, and to remove men exhausted by sickness to a vessel that has not been occupied for months before it is well warmed would be dangerous; it might be fatal to some of them."

"Certainly, but to move these men quietly takes time. The fire is lighted, steam is up, the vessel is warming, and before the men can be moved she will be warm. We think it important to make the transfer during the warm part of the day."

"Well, then, transfer them as soon as you conveniently can." . . .

"The beds are ready, the vessel is warm, but our fireman reports some small leaks about the pipes. He has shut off steam and has gone to the plumber's shop to see about some little repairs that he thinks may take an hour."

"I go for the transfer at once, even if we cannot use the steam-heaters for a week."

"Probably it will not be so bad, but even if we had no steam-heater at all, I presume there would be no want of unanimity on this question." . . . . .

"Captain, we are now ready to go with you to the receiving ship; we expect to bring the sick aboard on the deck of your tug."

"Aye, aye, sir." . . . . .

"Captain, I have come to relieve you of the care of the sick,—to transfer them to the hospital ship."

"But when I saw the commandant this morning he agreed with me that the ship could not be properly warmed for sick men in one day, and that they had better remain here till the vessel could be made comfortable for them."

"I have just been to the commandant's office to report the hospital ship furnished, warmed, and all ready; and he has given me the order to make the transfer at once, so as not to lose the warm part of the day." . . . . .

"The officers have all gone to the new receiving ships, so that the transfer will not be very regular."

"We will not be particular about muster-rolls; there are enough willing, strong hands among the nurses; the assistant surgeon ordered for duty with the sick we will take with us." . . . . .

"All ready."

"Now, men, we are going to take you to the hospital ship that we have been getting ready for you. No, my good fellow, do not look about or think of getting up; there are plenty of men here to carry you; shut your eyes if you can; do not be afraid, and do not lift a finger. Here, take him up quietly, bed and all, that is right." . . . . .

"Come this way; plenty of time; steady now."

"Here; lay him quietly; just here. Lie still and let me fix you a little. There, that will do—and I will put this over your face to screen your eyes a little. Here now, put him right alongside of this one—that will do. Another one here, so as to make a line right across the deck." . . . . .

"The sick are all aboard."

"Their clothes?"

"The nurses have gone for them."

"Bring them along, nurses and all." . . . . .

In three minutes we were alongside the hospital ship, and a gang of frightened plumbers left in some haste from the opposite side. The sick were soon nicely in their beds, apparently improved by the trip.

"We have done a good day's work, and as we have no further use for the tug I will just give the captain our unanimous vote of thanks, and let him depart for other fields and victories. I shall bargain for him when we take the hulk to the quarantine station for disinfection." . . . . .

Our fireman reported that: "The plumbers took the pipes apart, and in their hurry carried away one piece. They wanted to put in new pipe, so that they would not have been ready to warm the vessel for a week."

"What can be done?"

"I have put the pipes in place, and if I could only find the missing piece there would be no trouble. The pipe was arranged for the steam to circulate so that the condensed water returned to the boiler. The loss of one piece breaks the circuit, but it may not take long to fit another piece of pipe."

"You must do the best you can while I go ashore and see what can be done." . . . . .

We soon found the chief engineer of the yard. "Trouble?" "Yes."

"I saw the plumbers running as if there had been a mad bull after them; and I sent a foreman to see about it. He reports that there really was nothing the matter at first, only some little leaks, that the fireman would have repaired by painting the cracks and wrapping with twine; but, unfortunately, he went to the plumber's shop for the paint and ball of twine. The foreman who went aboard with him wanted to make a good piece of work, and so set a gang of men to take things to pieces. I have about a dozen men hunting for the lost piece of pipe, and two men making a new piece. This is slow work, as we have delays for want of a boat to carry them aboard for measuring, etc."

"Are not your men afraid, the same as the plumbers?"

"No; they are firemen and coal-heavers of the navy; and you know they will not flinch when ordered on duty, especially as there is a medical officer aboard to notice and encourage them."

"I thank you in advance for carrying us through this trouble, and I hope you will succeed in establishing the circuit of steam-pipes before the ship gets chilly." . . . . .

The next morning was bright and pleasant. "We did very well during the night, but towards morning it was a little chilly. About sunrise the ship became nice and warm. We had one death this morning." . . . . .

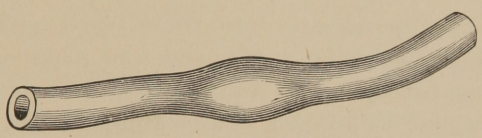
The rest of the history of the hospital ship is as dull as the history of a country without any wars. There were four deaths after the transfer. Some new cases of cholera and diarrhœa came from the receiving ship, but all recovered. We towed the old receiving ship to the quarantine station. We treated her to two large carboys

of crude carbolic acid, and three barrels of iron sulphate (copperas), enough as we judged to endanger the lives of any amœba or bacteria that might be aboard; and there we left her. With our present views we would have treated her to the fumes of a few pounds of burning sulphur. Thus ended the cholera epidemic.

(49) Hence we know that *steam-pipes, gas-pipes, and water-pipes, all kinds of leaky pipes of moderate size, may be instantly repaired by giving them a coating of paint and a wrapping of twine; and if by any chance a small piece of pipe is missing, a piece of gum-hose may be cut with a jack-knife to connect the open ends of remaining pipe so as to complete the circuit.* If we had possessed this "little knowledge" a few hours sooner, it would have prevented some suffering and perhaps it might have saved one or two lives.

(50) Our second lesson in plumbing was not so interesting; there was nothing tragical about it The water-supply of the Naval

FIG. 40.



The Wipe-joint.

Hospital . . . is rain-water collected in large tanks near the roof; the overflow is received into cisterns, from which it is pumped up in case of need in dry weather. The engineer is a tinsmith who has had the care of a small lathe and a planing machine at the navy-yard; he was recommended by the chief-engineer of the yard as a good jack-of-all-trades and just the man for the place; and having been instructed that he would be expected to do all the small repairs himself, not many days elapsed when he produced specimens of his plumbing work; he was evidently proud of his wipe-joints.

Dry weather brought trouble. "I am afraid I have an enemy somewhere."

"Why so?"

"Last evening I pumped up 3000 gallons of water and the tank was empty this morning; no water used in the night."

"Well, pump up half as much to night; keep your eyes and ears open." . . .

"I have found out about losing water from the tanks. . . . I went tip-toeing around after midnight. I shut off the water, and

started it in one pipe after another till I thought I had traced a leak in the vacant ward of the south wing; at last I heard a buzz like a big fly, in a water-closet occasionally used by officers. It was a very small leak, but there is no loss of water since I repaired the valve."

Hence we know that *a very small leak in a water-closet, such as no plumber discovers in a common inspection, may waste as much water as a hundred families can actually use.*

(51) The third lesson was little more than a repetition of the second. A naval hospital . . . . is supplied by the city water-works through a meter that says "click-click" as each gallon enters the building; the engineer is a capital blacksmith and does all small repairs in his line, but the plumbing and gasfitting were done by regular workmen called in as required. It is easy to see that more time was spent in coming and going than in doing the work; thus a change became necessary in the interest of the hospital fund as well as for economy and morality in general. An expensive set of tools was purchased, tube-cutters, taps and dies, and wrenches. These had to be tried; joints were unscrewed, cleaned, oiled, and screwed up again; leaky valves were found and repaired or new ones substituted. The steam-pipes and the engine, the gasfittings and the plumbing were greatly improved in appearance, and the saving of money was quite considerable, as the expense was now reduced to little more than the interest on the moderate sum invested in tools.

The end of the quarter came around when the bill for water should have been presented at the extravagant rate of three cents per 100 gallons; the bill did not come; the hospital purveyor called for it, and they promised to send it "to-morrow;" he called again and again; there was "something the matter," the meter did not register properly, and they did not know how much water to charge for. The meter, however, had been saying "click-click" quite punctually, but it had registered less than half the usual quantity of water.

Hence we infer with a degree of probability that comes little short of demonstration that, *about two-thirds of all the water pretended to be used in our cities, is mere waste through defective plumbing, so concealed as not to be found in the ordinary inspections.*

In order that housekeepers may know how much water they are wasting, all the water *except that of out-of-doors hydrants* should pass through water-meters.

INDEX.