Ignaz Semmelweis and a Logic of Science

notes on his method

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Ignaz Philipp Semmelweis was an Austro-Hungarian obstetrician and professor in obstetrics. At the beginning of the 19th century about 18 % of hospitalized women giving birth died to maternity fever. Semmelweis who for a while worked in a maternity hospital in Vienna noticed that the maternity ward-1, where teaching of medical students took place, had three times greater mortality of maternity fever than ward-2 and other wards where midwives were taught. The prevailing view of contemporary physicians on infection was that it was solely an airborne phenomenon. But Semmelweis noted that a significant difference was that the medical students often came straight from the section room to the ward-2 without having washed hands. Therefore, he introduced hand washing, whereby mortality fell from 18 % to 1 %. His insights and results were not recognized until after his death. He died in 1865.

His method, however, is interesting. Behind Semmelweis' findings we find a systematic investigation of possible causes of maternity fever, driven by making hypotheses and testing them, accepting or rejecting. I unfold this methodology further in this draft. The inspiration comes from Carl G Hempel's Philosophy og Natural Science and Karl Popper's Logic og Scientific Discovery.

1.The hypotheses and the reasoning

I. The first thesis is: Epidemic influences are the cause of maternity fever with high mortality

The claim 'an epidemic is the cause of maternity fever', can be said to express a kind of law: If there is an epidemic, then ceteris paribus, there will also be maternity fever. Epidemic is sufficient condition for maternity fever. Semmelweis presupposes this when he imagines that 'epidemic influences' may be the cause of maternity fever. He is not interested in testing the validity of this premise. His focus is not on the connection between epidemics and maternity fever. His starting point is the fact that there is maternity fever.

Semmelweis is interested in investigating what in Vienna or in the hospital that could explain the occurrence of maternity fever. The finding of maternity fever, however, has led to the general assumption that there must be an epidemic, and that it is epidemic

influences that causes the fever. It is this assumption he needs to rule out at first. If he can show that there is no epidemic, he would have removed a common explanation for maternity fever. Then he can embark on the next move i.e., to seek causes in the hospital that could explain the occurrence of maternity fever.

So Semmelweis must investigate whether there is an epidemic. It turns out that there is no epidemic. Semmelweis can therefore reject the claim that 'an epidemic is the cause of maternity fever'. But how does Semmelweis reason? He gives three arguments:

The arguments have the logical form modus tollens:

p => q
-q

-p

p => q: If there is an epidemic, ward-2 will also be affected
-q: Ward-2 is not affected
---: ----------
-p: There is no epidemic

p => q: If there is an epidemic, not only the hospital will be affected**,** but the whole city
-q: The city is not affected
---: ----------
-p: There is no epidemic

p => q: If there is an epidemic, women giving birth on the street will have the same mortality (or greater) as in the hospital
-q: The mortality of the women giving birth on the street is lower
---: ----------
-p: There is no epidemic

The evidences falsify the hypothesis. There is no epidemic. Should he have found evidence for an epidemic, he would be allowed to tentatively assuming the epidemic as an explanation for the occurrence of maternity fever. The hypothesis would then be said to be fortified or better corroborated, but not confirmed. Because logically he would not have identified the only possible cause of maternity fever. Although an epidemic is sufficient cause of maternity fever, it is not a necessary cause - other causes would be logically conceivable.

II. The second thesis: Overcrowding is the cause of maternity fever / high mortality

The claim is, that overcrowding is sufficient cause of maternity fever. But it also means that if Semmelweis can show that there is overcrowding while there is no high mortality, then the thesis is false. Here he does not want to determine whether there is actually overcrowding, but to test the connection between overcrowding and the disease:

p => q: If overcrowding causes maternity fever, then there will be maternity fever in ward-2, where there is overcrowding
-q: There is no maternity fever in ward-2

-p: Overcrowding does not cause high mortality

There is overcrowding in the ward-1, but it is less than in ward-2. It cannot be the cause of maternity fever because the ward-2 does not have a maternity fever / high mortality rate. Similarly, with 'diet' and 'care':

p => q: If the diet causes maternity fever in ward-1, then there must be maternity fever in ward-2, where the diet is the same
-q: There is no high maternity fever in ward-2

-p: The diet does not cause maternity fever in ward-1

p => q: If the care causes maternity fever in ward-1, then there must be maternity fever in the ward-2 - the care is the same
-q: There is no maternity fever in ward-2

-p: The care does not cause maternity fever in ward-1

III. The third thesis: Rough-handed examinations are the cause of maternity fever

Semmelweis gives two arguments against at first: a) Natural wounds from the birth itself are more extensive than wounds from rough-handed examinations, so the fever must be due to the more extensive wounds. The wounds from examinations cannot be the cause of fever. b) Midwives examine in the same way as medical students without the onset of maternity fever, ergo examinations cannot be the cause. In the test of the hypothesis that Semmelweis

makes, he examines the connection between rough-handed examinations and disease, not whether there are rough examinations:

p => q:	If rough examinations cause maternity fever, then a minimization of rough examinations reduces maternity fever
-q:	There is increasing maternity fever
---	---
-p:	Reducing rough examinations do not reduce maternity fever

IV. The fourth thesis: The priest with the bell is the cause of maternity fever

Another possible cause of maternity fever is thought to be that a priest, who was tasked with imparting the last sacrament to the dying, had to pass through the entire ward-1 to reach the dying. His arrival was announced with a ringing bell, which frightened and weakened the patients. Therefore, they were susceptible to maternity fever. The priest was asked to go another way.

p => q:	If the priest with the bell causes maternity fever, then the absence of a priest must lead to a decrease in maternity fever
-q:	There is unchanged maternity fever
---	---
-p:	Priest with bell does not cause maternity fever

V. The fifth thesis: Birth position is the cause of maternity fever

In ward-2 the birth position is lateral and there is no marked maternity fever / high mortality. In ward-1 the position is supine.

p => q:	If supine position causes maternity fever, then change to lateral birth position must cause a decrease in maternity fever
-q:	There is unchanged maternity fever
---	---
-p:	Supine position of birth does not cause maternity fever

2. The logic of arguments and the research logic

The logical form of these arguments is as mentioned, the modus tollens. This form is related to the basic form modus ponens. With the commonly used symbols, the modus ponens scheme looks like this:

p => q	the implication p => q both horizontally and vertically
p	p is called the 'antecedence'
--	the line -- equals the =>
q	q is called 'the consequence'

A certain basic rule applies to this scheme:
If a deduction or argument is logically valid 'no more is claimed in the conclusion than what has already been stated in the premises.'

Or what is the same:

The truth of the conclusion is contained in the premises.

Or:

If the premises are true, then the conclusion is also true.

This means:
That one cannot assert the premises and at the same time deny the conclusion without contradicting oneself.

And that means further:
That one may transfer the falsity of the conclusion to one or more of the premises.

When a valid deduction or argument presupposes the rules, then it implies that if the conclusion is false, then at least one of the premises is also false, i.e., modus tollens:

modus tollens:	p => q
	~ q
(implication)	----
(conclusion)	~ p

This logic is basic research logic in much science, and as we have seen in Semmelweis. This fallibilist way of thinking can be further illustrated: Certain claims are universal, i.e., they have infinitely many consequences. Therefore, one cannot definitively establish the truth of a universal claim. That would be tantamount to confirming the consequence. But one can establish the falsity if only

one counter example is pointed out, i.e., the truth of the claim can be tested indirectly. Example: If someone state the universal claim that all snakes lay eggs, it will be insurmountable to examine all snake species (how do you know that you have examined them all?). But you could in instead look for a species that gives birth to live offspring. You only have to find one single species.

This applies to universal scientific theories. They are universal and must therefore be tested in an indirect way. It happens by means of the logic to derive concrete consequences from the general theories, and then compare them with reality. If the consequences turn out to be false, one must conclude that the theory is false or partially false.

3. Confirming the consequence

VI) The sixth thesis: Blood poisoning with corpse matter is the cause of maternity fever / high mortality

It might be the doctors and students that transfer corpse material because of poor hand hygiene, and therefore maternity fever will drop if doctors and students wash hands.

p => q:	If doctors and students transfer corpse material due to poor hand hygiene, then maternity fever drops if doctors and students wash hands in a chlorine solution
q:	Doctors and students wash hands in chlorine solution and maternity fever is falling
---	---
p:	That doctors and students transfer corpse material due to poor hand hygiene may be the cause of maternity fever

But it turns out that also the transfer of 'rotten matter from living organisms', can cause maternity fever / high mortality. And today we could add all kinds of bacterial sources. Logically we cannot conclude from a confirmation of (q) to the truth of the hypothesis (p). That would be the fallacy of ‘confirming the consequence’. Even a false hypothesis could 'explain' the diseases, e.g., a thesis like 'sterilized (bacteria-free) instruments transmit bacteria to the doctor's hands, which are the cause of the diseases':

p => q:	If sterilized instruments transmit bacteria to the doctors hands, then maternity fever decreases when the doctors wash hands in chlorine solution
q:	The doctors wash hands in chlorine solution and maternity fever decreases
---	---
p: ?	The fact that the doctor transfers bacteria from sterilized instruments may be the reason for the diseases

We cannot conclude anything, there is no conclusion. This is because the existence of (q) is neither a necessary nor sufficient condition for (p).

Confirming the consequence - expanded:

In the history of Semmelweis, the following applies:
p = epidemic, overcrowding, rough treatment, diet, care, priest with bell, birth position, corpse matter and / or rotten matter.
q = maternity fever.

'P' is sufficient condition for 'q', i.e., each time p occurs then q follows. -q is necessary condition for the falsity of p, i.e., if -q, then p is necessarily false. But q is neither sufficient nor necessary condition for p. Because if q occurs, we cannot conclude that p is there, i.e., from the fact that there is maternity fever, we cannot logically conclude that there is an epidemic, because logically there are other possibilities. And today we know that the explanation for a specific occurrence of maternity fever can be bacterial transmission of any kind. Thus, logically, there are infinitely many possible explanations. One could say that Semmelweis delimits the logical universe to the 9 above (p) and then excludes a number of them by systematic testing and falsification. The scientific explanation consists in finding one or more sufficient sets of conditions for the phenomenon to be explained, i.e., stating the cause or causes of the phenomenon.

The erroneous conclusion 'to confirm the consequence' is a typical conclusion, the frequency of which may be due to a psychological need for confirmation and predictability, but which is scientifically problematic. If, for example, I claim that reflexology can cure enuresis and I carry out a treatment of a patient and his illness ceases, then I quickly conclude (but erroneously) that my treatment is the cause, but how do I rule out that there are other parallel-acting causes to the disease disappears?

In practice, healing could come about by the patient's bladder increasing its capacity at the same time as, but independently of my treatment, or by him at the same time as, but independently of my treatment starting to produce the hormone which at night usually lowers the production of urine. I must be able to rule out these two healings. So, I have to narrow down the logical universe in practice and systematically rule out other causes of healing. I have to carry out my treatment as an experiment under controlled circumstances, which excludes other sources of cure.

This is difficult when it comes to cure. How to test a concrete cure? You cannot do that. Logically there are only good reasons to assume a cause, never sure evidence or proof.

The implication:
Definition of the implication (=>): (A => B) =d -(A and -B), which is read: 'A implies B' by definition equals 'it is false that A and non-B appear'. In other words: If A then B (modus ponens) and if non-B then non-A (modus tollens).

The Truth table	p q	p => q
If p and q are true, then (=>) is valid:	tt t	va
If p is true and q false, then (=>) invalid: (falsification)	tt f	inva
If p is false and q true, then (=>) valid:	ff t	va
If p and q are false, then (=>) is valid:	ff f	va

From the table we can see that if q is true, then there are two possible situations: In one p is true and in the other p is false. So, we cannot say anything certain about p based on knowledge of q's truth. There is no conclusion. Therefore, confirming the consequence is a fallacy.

t All humans are mortal	*t* All snakes lay eggs
t Socrates is a human	*t* A garden hose is a snake
---	---
t Socrates is mortal	*f* A garden hose lays eggs
f All trees move in ellipses	*f* All trees take bath in mornings
f The earth is a tree	*f* Smith is a tree
---	---
t Earth moves in an ellipse	*f* Smith takes bath in morning

Only the premises and conclusion can be true or false. The truth or falsehood of the implication does not concern the logical derivation as such, but the status of the consequence being true or false. The implication is rated valid or invalid. The important thing that is pointed out by the implication, is that it is invalid if A and non-B occur at the same time (cf. def.). This is what we use in the falsification (modus tollens).

Semmelweis again: Viennese hospital in the 1840s. Abnormal occurrence of maternity fever. Hypothesis: The priest, who goes through the ward to give the dying women the last sacrament, unintentionally deprives the other women their courage. Experiment: Let the priest go another way. Expected consequence: Termination of abnormal incidence of maternity fever. Factual consequence: Unchanged incidence of maternity fever. In other

words: The hypothesis has been falsified. The expected consequence did not happen. The falsity of the conclusion leads to the falsity of the premises.

The hypothesis: If the priest is the cause of an abnormal incidence of maternity fever, then the abnormal incidence of maternity fever ceases if the priest goes another way.

p => q	If the priest goes another way, then the abnormal occurrence of maternity fever ceases
p	The priest goes another way
----	----------
~ q	The incidence of maternity fever is unchanged
----	----------
~ p	The priest is not the cause of abnormal occurrence of maternity fever

The 'true' cause of the frequent maternity fever has since been shown to be a bacterial infection, which was due to the doctors' lack of hand washing between patient visits - but can we confirm this hypothesis definitively?

The hypothesis: If bacterial infection via the doctors' hands is the cause of an abnormal incidence of maternity fever, then the abnormal incidence of maternity fever ceases if the doctors wash their hands between each patient visit.

p => q	If doctors wash their hands between each hospital visit, the abnormal coming of maternity fever deceases
p	The doctors wash their hands
--	----------
q	The incidence of maternity fever is normalized
--	----------
?	Bacterial infection via doctors' hands is a possible cause of abnormal occurrence of maternity fever. It is permissible to assume lack of hand washing as the reason. The hypothesis is fortified, but it is not confirmed

It is not hereby proved that the hypothesis is true, but since it has not been shown to be false either, we are allowed to assume it to be true for the time being. But it should be tested further, we lack for example to detect the presence of the same type of bacteria on the hands of doctors and in the dying patients. But no matter how many tests, the hypothesis cannot be verified definitively, but can at best be corroborated:

If the consequence of the hypothesis is false, we can conclude that the hypothesis is false or partially false. If the consequence of the hypothesis is true, we cannot conclude anything about the truth of the hypothesis, but only that it has at least until now resisted falsification and is thus corroborated. In other words, there is a logical asymmetry between the consequences of refutation and of affirmation.