Health Issues Network – HIN

Handbook

This brief handbook aims to explain why the Health Issues Network (HIN) model was created, what are the basic concepts of f-HINe diagram and its rules, how it can be used, and what are the expected results of its use

Why is it necessary to create f-HINe diagram

1. From a static concept of diagnosis to a system evolving over time

However it occurs, making a diagnosis is always an act of classification, whereby the irreducible uniqueness of a person who lost his or her health is compressed into **an abstract container known as a "diagnosis."** Diagnoses can be related to an episode of acute illness or to the onset of a chronic condition, but they are always understood as unique, that is, without considering the possible coexistence of other health problems. Moreover, they are seen as instantaneous in time: even if a past history exists, from the time a diagnosis is done, it exists in a kind of eternal present, until it recovers - if they are acute - or become "part" of a person when it is chronic.

The diagnostic process described so far lacks:

- The **sense of time**: the clinical diagnosis intervenes as a frame in the course of a "history" often much longer in the past and that could have probabilistic future evolutions.
- The **sense of complexity**: both in the sense that the container/diagnosis could be broad and with blurred boundaries (e.g., "autism spectrum disorders") and in the sense that the simultaneous presence of other health issues can influence the probability of the evolution of the considered diagnosis (e.g., "uncomplicated acute diverticulitis in a patient with metabolic syndrome").

The epidemiology of the Italian population shows an increase in the likelihood of the same person being afflicted with more than one chronic condition. This is associated with a life expectancy at birth much longer than it was decades ago. For the physician of today and - even more - of the near future, it is therefore very important to develop the skills to:

- **manage** disease as a dynamic phenomenon, in its temporal evolution (from what does it originate? through which phases did it pass? what could its evolutions be?)
- **anticipate the mutual influences** among more than one simultaneous disease and condition. Influences are understood as changes in the probability of evolution of each disease/condition. Influences are caused by the pathophysiological processes that produce the diseases (e.g., a pro-inflammatory condition increases the likelihood of oncogenesis) and/or by the treatments (an anti-coagulant therapy increases the likelihood of bleeding)
- **hypothesize** what not yet known condition(s) may likely be associated with the known disease or disability.

2. Navigating time and reducing complexity

The best way to develop the skills listed above is, of course, clinical practice accompanied by critical reflection. However, it is possible to obtain a vicarious, valid educational experience through simulation, to represent:

- the **flow** of time, both forward and backward
- The **co-presence** and reciprocal **interactions** of multiple conditions of disability or illness, both acute and chronic.

Given the large amount of information potentially at stake, the simulation environment should allow for the following types of exercise:

- **navigate** a clinical case represented by a f-HINe diagram, moving back and forth in time and using different time scales
- **hypothesize** which clinical or pathophysiological conditions are at play
- **identify** potential interactions between conditions.

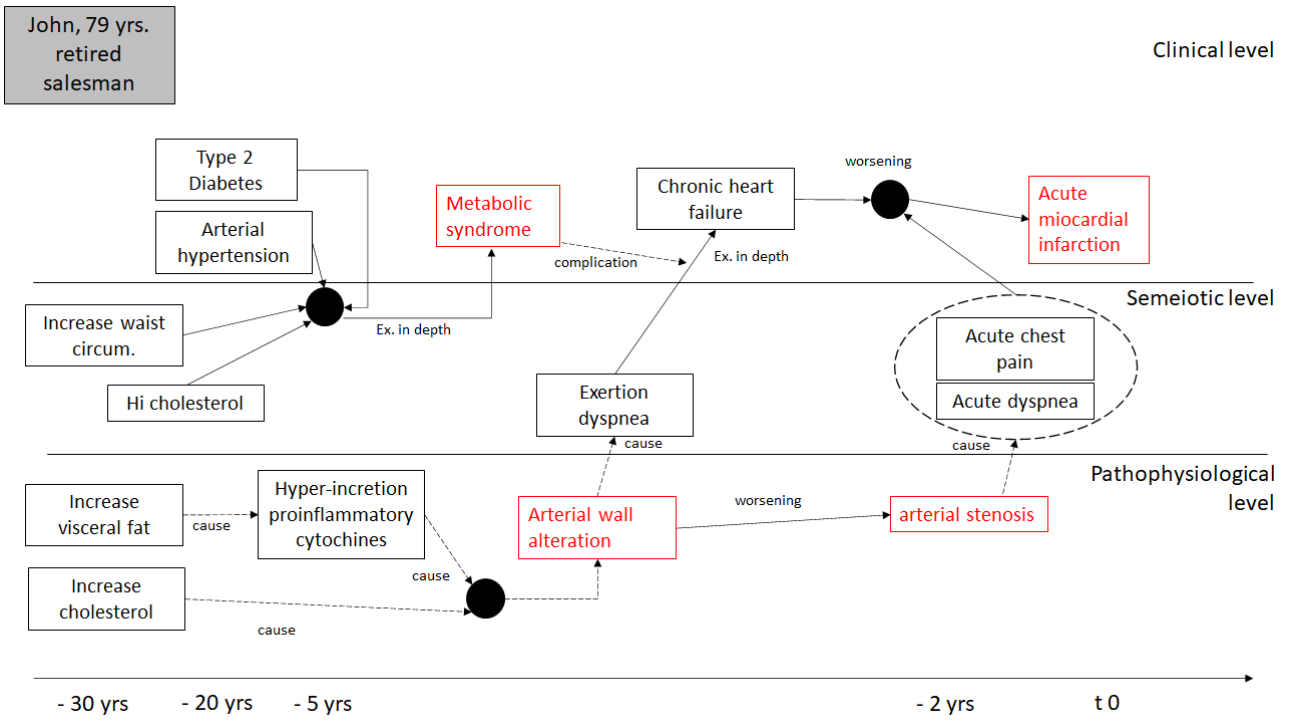
The Health Issues Network (HIN): how is it made?

The system is constituted from a series of elements, represented with a **simplified diagram** (f-HINe). The simplified diagram is translatable into a formal graph according to the formalism of the **Petri Net** (PN), a form of mathematical representation of a system. The PN is not visible to the user that acts the simulation or draws a diagram, it is generated automatically from the software fHINscene (see the section "Learning Materials") and make it possible a series of calculation, like for example the assessment of the logical correctness of a f-HINe diagram or the measure of the difference between the solution indicated by the teacher and the one proposed by the learner.
For this reason, therefore, **the diagram f-HINe has some rules**, to make it possible the translation in mathematical language.

The elements of a f-HINe diagram

A f-HINe diagram consists of three types of elements:

1. the Health Issue (HI): the rectangles
2. the evolution: the arrows (oriented edges)
3. The plan of the net: the three levels (clinical, semeiotic, patholophysiogical) and the axis of time



In this example, we represent a portion of the clinical history of a patient who developed a metabolic syndrome, a chronic heart failure and finally a myocardial infarction
Please refer to the section "Cases and exercises archive" for more examples of f-HINe diagrams.

1. The Health Issues (HIs)

A HI is any piece of information about a patient and their health.
Types of HIs are:

- a diagnosis
- a hypothesis of diagnosis
- a symptom
- a sign
- an information from a laboratory, imaging, or functional investigation
- a risk factor (familial, environmental exposure or lifestyle habit, and on)
- a pathophysiological process (inflammation, oncogenesis, hyper/ipo/dis-function, BRCA mutation, stenosis, ...)
- a socio-economic or psycho-relational condition

A HI is represented within a rectangle when referring to a fact in the patient's history. However, if the exercise requires the prediction of possible evolutions in the future, the anticipation is represented with a dashed rectangle, while the time axis will indicate the days or months or years beyond T0 (the "present" time). As we'll discuss later, this is the only condition in which two or more HIs can evolve alternatively from one HI.
The HIs are arranged in chronological order, from left to right.
Each HI is associated to a form that contains the clinical information (onset and evolution improvement-worsening, values of diagnostic tests, treatment plan, therapies and interventions, ...) related to the history of that HI, ordered chronologically. In the final version of the educational software (in production), the forms will be associated with links to the rectangles and can be recalled at the user's request.

2. The evolutions

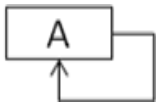
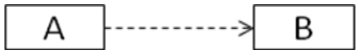
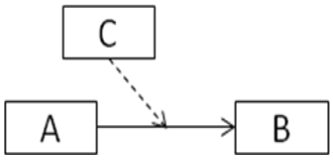
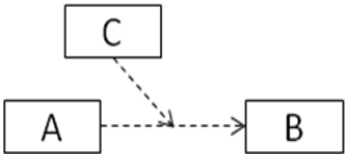
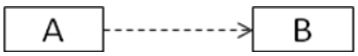
An evolution indicates how an HI transforms over time.
Evolutions are represented with continuous or dashed arrows. An evolution usually connects two HIs (continuous arrow) or - only in the case of co-presence - one HI to another evolution (dashed arrow). This last one is the case in which the HI of origin increases with its co-presence the probability of the evolution to which it is connected.
Each evolution is associated with a form that contains clinical information (clinical values at the time the evolution started, diagnostics with which the evolution was recognized, ...) related to the history of that Health Issue, chronologically ordered.
The continuous arrow represents the evolution in which the problem does not change its nature (e.g. 2nd stage renal failure that worsens in a 3rd stage); the dashed arrow represents instead the evolution in which the resulting HI is different (e.g. diabetes that complicates in diabetic nephropathy). The difference is not only nominal but substantial (and mathematical): with a continuous arrow evolution the originating HI disappears and is incorporated into the HI of arrival (the previous stage of disease in the next, the symptoms/signs that led to the diagnosis are no longer independent problems but expression of a disease), with the dashed arrow the HI of arrival stays by side with the HI of origin, which remains active.
We defined nine types of evolution

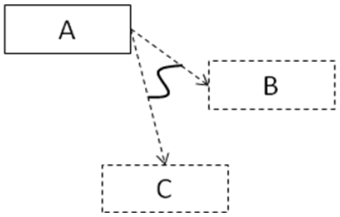
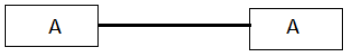
1. **examining in depth**: it corresponds to a *decision process*, whereby from one type of HI one moves to another. The most typical case is the evolution from Symptom/Sign to Diagnosis. It is represented with a continuous arrow because the evolution from symptom to diagnosis is intended as an evolution of the physician's knowledge of the problem. The symptoms/signs that led to the diagnosis are no longer independent problems but become part of the diagnosis. This is consistent with the definition of "*disease*" as a classificatory mental construct.

2. **worsening/ improvement**: a HI evolves in a worsening/improving sense, while *maintaining its nature*, so it is represented with continuous arrow.
3. **complication**: is the evolution through which a new HI is born from the dynamics of a pre-existing HI. *The HI of origin remains, the HI complication stays by side* in the appropriate temporal position. It is represented with a dashed arrow, because it results in a HI that is different from that of origin (different organ, different altered function,…).
4. **recurrence**: it is the evolution that indicates that a HI has occurred **several times**, with events independent of each other, separated by an inter-critical period. It is therefore just a way to avoid multiple repetitions of an HI over time. The arrow is continuous.
5. **co-presence**: a simple co-presence is the simultaneous presence of two or more HIs, which may or may not have a relationship with each other. The co-presence evolution indicates a relationship intended as a change in the probability that an evolution takes place. Co-presence is represented as a dashed arrow originating from the co-present HI and reaching another evolution arrow. When the evolution is worsening or complication, the co-presence can be called co-morbidity.
6. **cause**: this evolution is used to represent links between pathophysiological processes (e.g.: inflammation causes sub-intimal arterial lipid accumulation, which causes stenosis, which causes ischemia, which causes necrosis), between pathophysiological processes and symptoms/signs (e.g.: inflammation causes pain) or between a pathophysiological process and a diagnosis. This evolution is therefore used only with a pathophysiological type HI and can reach a symptom/sign or diagnosis type HI. It is dashed because the resulting HI is different in nature from the original HI.
7. **cycle**: the cycle evolution is used in two ways. In the first one, a process causes another and the latter acts with positive feedback on the former. Therefore, a recursive cycle is created, even with several elements (for example the relationship between lipid metabolism dysfunction, overweight, altered eating behaviour, sedentary motor behaviour). Another situation of recursiveness is when a chronic disease worsens, then improves, then returns to worsen. While the "recurrence" evolution (see point n. 4) represents a series of acute episodes, interspersed with a free inter-critical period, the cycle represents the oscillation between two poles of activity of a chronic disease. In the symbolism of the friendly network (f-HINe) the same symbol has been created to depict these two situations.
8. **possible complications**: this is the same evolution indicated in point n. 3, but in this case we are looking forward into the future, and we aim to represent the hypotheses of evolution. The dashed arrows are stretched between the HI of origin and the possible complication HIs, drawn as dashed rectangles. When the hypothesized complications can be mutually exclusive, we connect the two dashed arrows with a small wavy symbol, as represented at point 8 in Table 1.
9. **persistence**: persistence is not a true evolution, as the name suggests. An HI begins to exist when it appears on the diagram plane, at a point in time, and then, if it does not evolve or is not declared resolved with a healing evolution, its existence is implied to be maintained over time. However, sometimes for educational purposes it may be useful to explicitly report that an HI "persists," even though therapy has improved its manifestations. Two typical examples are diabetes and essential hypertension: the treatment can bring blood glucose and blood pressure values within the normal range, but this does not correspond to the healing of the disease conditions, the patient is still diabetic and potentially hypertensive, with good therapeutic control. Persistence is represented by a continuous bold, undirected stroke connecting two equal HIs.

Table 1 summarizes all the symbols that represent evolutions.

Table 1: list of evolutions, with examples and graphic symbols

	Type of evolution	*Graphical representation*	Example
1	*Recurrence*		An asthma acute episode (A) recurres more times
2	*1. Examining in depth* *2. Worsening* *3. Improvement or healing*		1. A chest pain (A) is "examined in depth" as a miocardial inferction (B) 2. A 2nd stage renal failure (A) worsens into a 3rd stage (B) 3. An ulcerative rectocolytis (A) improves and becomes asymptomatic (B)
3	*Complication*		A type 2 diabetes (A) is complicated with a diabetic retinopathy (B)
4	Worsening *with co-presence*		A type 2 diabetes (A) worsens (B) in co-presence of a pneumonia (C)
5	*Complication with co-presence*		A diverticular disease (A) is complicated with a hemorrage (B) in co-presence of a persistent atrial fibrillation (C)
6	*Cause*		A neoplastic spread (A) causes neuropathic pain(B)
7	*Cycle:* *1. oscillation worseningin – improvement* *2. positive feedback*		1. a multiple sclerosis alternates worsening (A) and improvement (B) 2. following a muscular stretch, pain (A) causes antalgic contracture (B), which in turn causes pain

8	*Mutually exclusive complications*		Obesity (A) can be complicated with lombalgia without radicolopathy (b) or with radicular radiation (C)
9	*Persistence*		A type 2 diabetes (A) persists from x years (the details of lab tests and medication are in the associated forms)

3. The network plane

The third element is the Cartesian plan on which the f-HINe network lies. Its most important property is the horizontal time axis.
The axis must report the time scale (years, in the example above) and represents the times in a preferably relative way, as in the example, to avoid the recognizability of real cases from dates. The "present moment" (time T0) can be placed at the end of the scale or in the centre or even on the left if the teacher proposes an exercise of anticipation of the possible evolutions. In this case the HIs of the "future" will be represented with dashed rectangles.
The scale is not necessarily proportional to time and can also change temporal units from a certain point onwards, thus moving from evolutions in the scale of years to evolutions in thescale of days. In this case, the axis is interrupted by a dashed line, which warns the user of the jump in temporal units.
The vertical axis of the plan can have no meaning, or be used to segment the network according to two perspectives: of clinical proximity (the swimlanes) or of meaning (the levels).

a. The "lanes"

In general, there is no criterion for ordering the different HIs along the vertical axis. As mentioned, the key feature is that HIs are ordered over the time, thus along the horizontal axis. However, in certain cases, the HIs have their own clinical proximity, because they are problems related to the same function/system/organ or because they are one the complication of another. In these cases, it is a useful graphical trick to create lanes that keep "neurological problems", "cardiovascular problems" and so on close together. The fHINscene software allows the HI rectangles to be coloured in different ways to represent the lanes.

b. The "levels"

Another way to segment the network plan is to create a clinical level, a semeiotic level, and a pathophysiologic level.
In the first level the HIs of diagnostic type or diagnostic hypothesis will be ordered along the time, in the second one the symptoms, signs, diagnostic findings, in the third one the pathophysiological processes.
In this case also, the segmentation has the sole purpose of facilitating the reading of the diagram and has no particular consequences on the formal level. It is not even mandatory to use all three levels, but if you do, it is suggested to place the semeiotic level in an intermediate position between the

clinical level (top) and the pathophysiological level (bottom). This corresponds to a mental order whereby pathophysiologic alterations and risk factors cause the damage to structures/functions, including mental structures/functions. These damages are expressed as symptoms/signs/alterations. The aggregation of semeiotic findings is interpreted as disease in the diagnostic level.
Recall that "cause" evolution can only be used in the pathophysiological level or between the pathophysiological and semeiotic or clinical levels. Finally, we are studying the possibility of creating a "communicative-relational" level, to represent HI that introduce psychological elements or those related to the doctor-patient relationship.

Grammatical rules

We summarize here some fundamental rules, which in the experience gained with the first experiments are often misunderstood.

Evolutions that "seem" the same but are different

Worsening and complication: a worsening is the same disease that advances in stage, class or activity index. Examples are diabetes in which HbA1c increases, diverticular disease that becomes symptomatic, or defined as complicated by abscess or stenosis. If there were an open perforation, peritonitis would conversely be an "evolution into a complication" because it affects a different organ (the peritoneum).
A complication is a health problem that arises as a pathophysiological evolution of a disease but affects a different organ or function. For example, a "diabetic foot" or retinopathy are complications of diabetes.

Relapse and cycle: there is a difference between "relapse" (e.g., asthmatic crisis, with healthy inter-critical period) and the pendular "worsening-improving" dynamic (e.g., different phases of activity of a chronic inflammatory bowel disease). While in the latter case the manifestations of the disease never completely disappear (mild alteration of bowel habits, histopathology showing the landmarks of the disease even if asymptomatic), in the former each new manifestation of the disease is independent of the previous/next and separated by an asymptomatic period.

Cause and complication: the evolution "cause" is used ONLY to link a pathophysiological event with a symptom or HI diagnosis. When a pathophysiologic event is caused by the therapy of a disease (e.g., taking anticoagulants for atrial fibrillation), one connects with "complication" the HI diagnosis to a pathophysiologic condition (decreased coagulation) and the pathophysiologic HI with the clinical manifestation (e.g., melena) or diagnosis (hemorrhagic gastritis).

Persistence: it is a "false" evolution. It is indicated by a thick continuous line and serves only as a "placeholder", to remind us that - for example - a hypertensive patient under chronic treatment with good blood pressure control is NOT healed of the disease. Its use is discretionary, depending on the purposes that the designer of the training exercise sets.

Ramifications of evolutions

A fundamental rule, necessary for coherence with the mathematical model underlying the diagrams (Petri Nets), is that a HI can be reached by ONLY ONE evolution. When there are several possibilities to reach a HI as an evolution of another, it is necessary to use the small black circle, on which several arrows from several HIs converge and from which only one arrow will come out. In the example above, the history of chronic heart failure and the symptoms (chest pain and dyspnea) converged and reached the HI acute myocardial infarction.

The exercises

Different kind of exercises are possible with a f-HINe diagram:

1. Read a complete f-HINe diagram and
    a. to write the corresponding story in free text
    b. to answer questions explicating the knowledge implied by the answer:
        - from which problem(s) did the HI x evolve?
        - what evolution(s) did HI x have?
        - what interaction(s) did HI x have with other HIs?
2. Complete an incomplete f-HINe diagram, adding health problems and/or evolutions left unaddressed.
3. Draw a full f-HINe digram from the text of a clinical history.