MIND MAPPING SYSTEMS THINKER'S ATTITUDES FACING A SEPSIS PROBLEM

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ABSTRACT

By thinking about systems thinking, our aim was to provide other system thinkers with a mind map for the key elements of the thinking that took place.

The sepsis problem is highly complex and spans not just the biological system, but also the healthcare enterprise. Sepsis is the context in which systems thinking has been applied and examined.

Sepsis is an emergency situation that if left unrecognised and untreated in its early stage leads to multiple organ dysfunction and death. It is also the most expensive condition treated in U.S. hospitals. Stays with septicaemia (sepsis) have the highest aggregate hospital costs in comparison to all other conditions (US 2011 $20.3 billion) and these costs have more than quadrupled since 1997.

A systems thinking mind map was examined while relating the story of a systems thinker, Paul, who attempted to deal with the sepsis problem. Paul wanted to better understand sepsis in order to recognise potential leverage points for prevention, treatment and recovery.

This case study highlights the attitudes; comments on the system approach, and puts forward the cognitive concepts.

All these concepts are integrated in an overall mind map looking like a tree: the branches of the tree represent the systems thinker's attitudes; the roots of the tree represent features of systems that are commonly considered when systems' thinking.

By examining the systems thinking applied in an unfamiliar domain this has facilitated new perspectives on systems thinking and systems science.

Keywords: systems thinking, attitudes, concepts

THE NEEDS OF SYSTEMISTS

As "systemists" we need to be able to communicate the basis of systems thinking and systems science to everyday people. We also need to provide a simple compelling framework for understanding systems thinking behaviours and concepts. Such a framework should then provide a basis for expanding and improving our knowledge in systems science and practice.

It might be argued that until we have this framework, our scientific basis, we will continue to practice "alsystemy" and that this situation is comparable with transition from alchemy to chemistry when the periodic table of the elements was conceived.

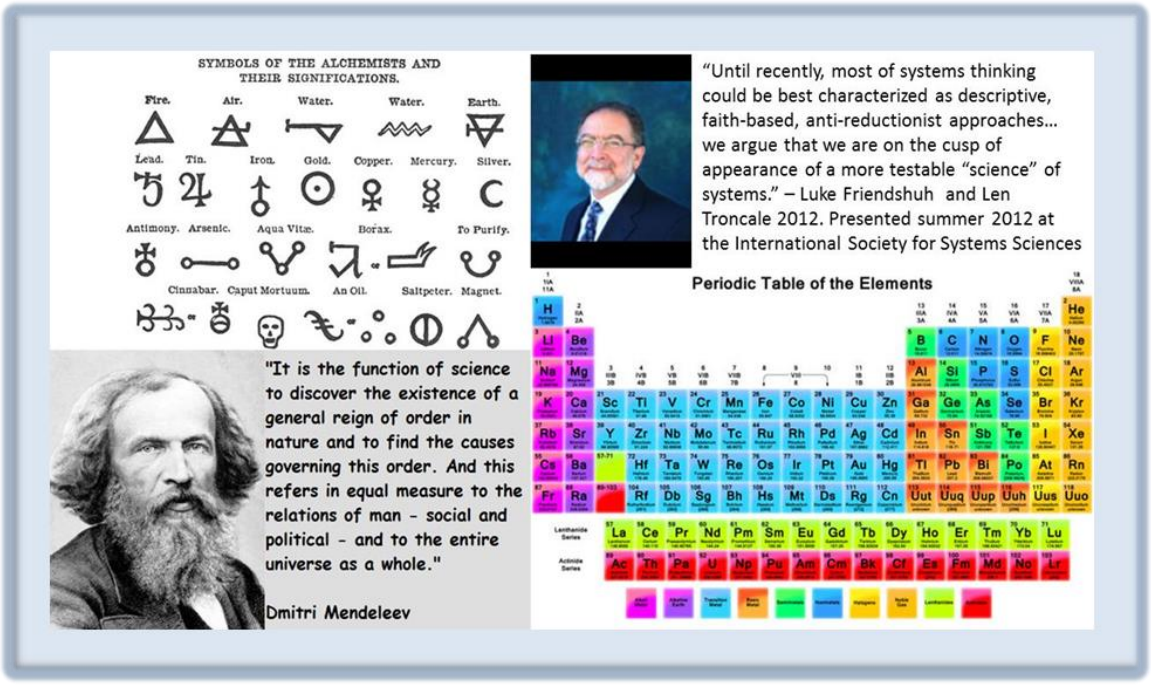

Figure 1 Building a framework for systems science

Creating the systems tree mind map

In 2012, the French INCOSE chapter requested a booklet on systems thinkers for its members. Within this Brigitte Daniel Allegro described a mind map of Systems Thinker postures and concepts which then formed the basis of training in systems thinking for the French Direction générale de l'armement (DGA). Feedback from these training sessions helped to shape, verify and validate the mind map.

In 2014, the mind map was compared with an application of systems thinking to try and understand pre-eclampsia which was presented at the INCOSE EMEASEC 2014. By combining these findings the Systems Tree was created.

Mind mapping Systems thinker's attitudes facing a sepsis problem

The systems thinker's tree is a conceptual model

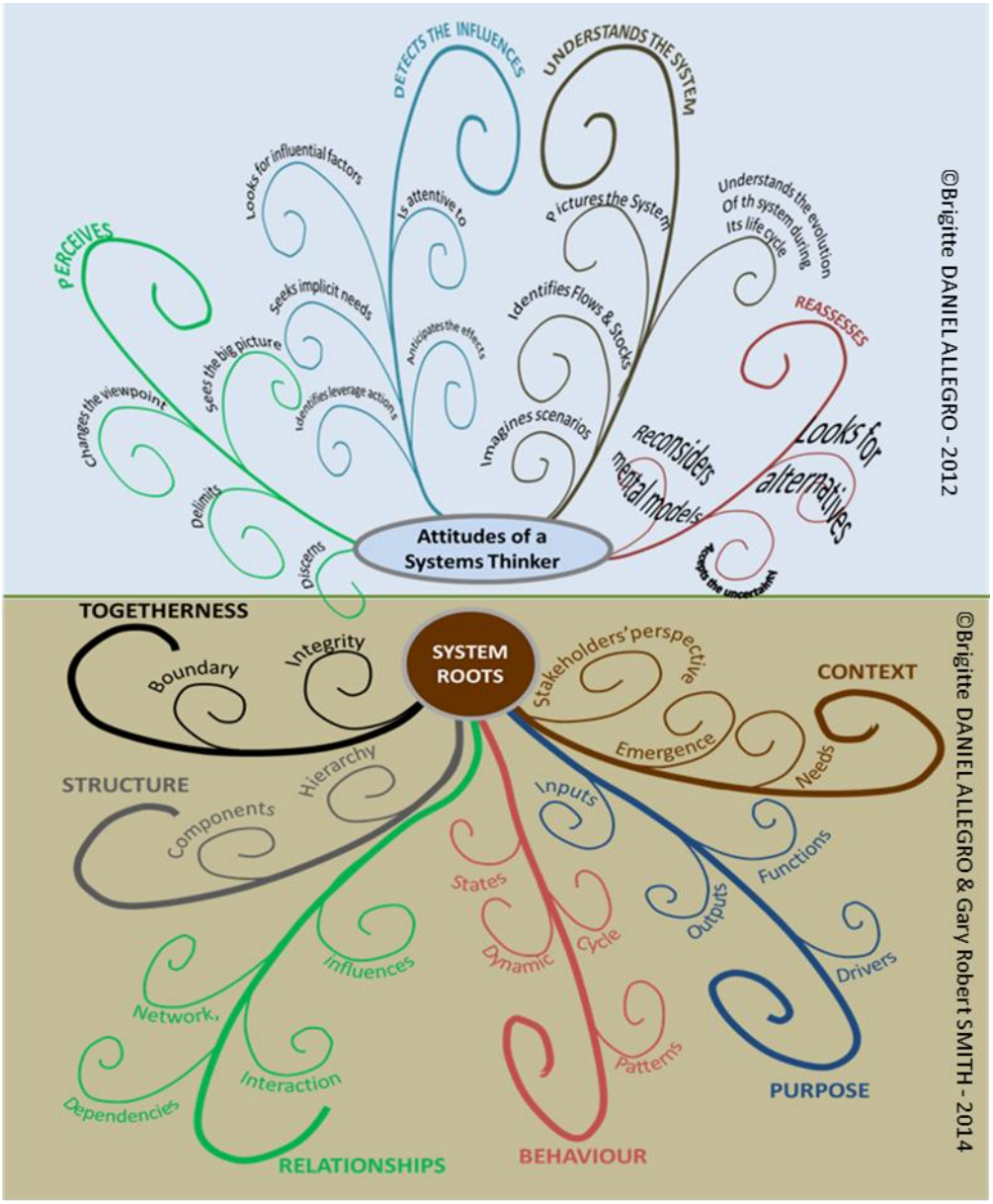

Figure 2 The Systems thinker's tree

As mentioned, the original idea for the systems thinker tree started with an analysis of system thinker attitudes as a basis for trying to teach systems thinking. This was then extended to incorporate aspects of systems that seemed to be important and useful when trying to understand complex system problems.

The systems thinker's tree is a "conceptual model" (in the sense of "**model of concepts**") of systems thinking. As highlighted by the above figure, it models two types of concepts, namely "**concepts of attitudes**" and "**concepts of systems**".

As the domain of application of this model is "systems thinking", we restricted the "concepts of attitudes" to those which are specific to a systems thinker. Similarly, we restricted the "concepts of systems" to those underlying systems thinker's attitudes.

The systems thinker's tree is a **mental representation** which is neither true nor false but has been found to be useful. Its concepts (the branches or the roots) have a **semantic value** and can be combined to form complete thoughts.

The practice of these concepts by a systems thinker aims at a better understanding of any situation, whether a problem to solve or an opportunity to seize.

This tree has being used for 3 years in France in the context of a continuous training in industry for systems engineers. We have used the tree twice now in the biological context (pre-eclampsia and sepsis – described as follows in this paper) and we have continued to find it fruitful (pun intended).

Quality of Systems thinking revealed by the systems thinker's attitudes

A system thinker facing a problem embodies different attitudes and uses appropriate systems concepts to solve the problem.

The application of the systems thinker's tree by a person who is attempting to understand a complex problem leads to an instantiation. It reflects on one hand the capabilities of this person in terms of *thinking* and on the other hand the capabilities to *mobilize the relevant systems concepts*.

We have also found it useful to qualify three different types of thinking that help to characterise the systems thinker's attitudes.

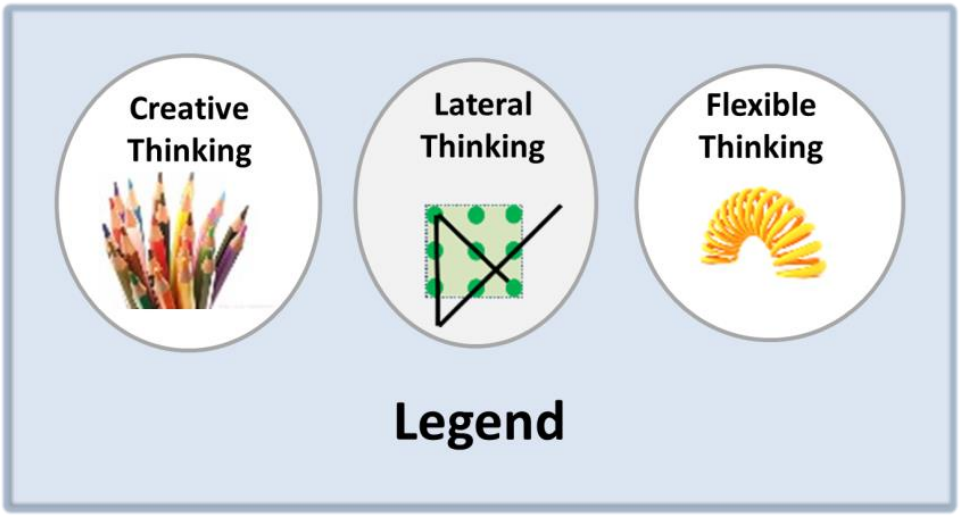

Figure 3 Icons associated to the different qualities of thinking

Mind mapping Systems thinker's attitudes facing a sepsis problem

Creative Thinking is…

… Being able to integrate and synthesize. It requires skills for developing a clear vision.

… Being able to conceptualize and verbalize. It requires skills for defining solutions and for mastering analogy, induction or abstraction. - It requires skills for qualifying observations and for measuring phenomenon.

… Being able to develop initiatives. It requires skills for seizing or recognising opportunities and for using perspectives.

… Being able to create and innovate. It requires skills for thinking out of the box without following always the same path ("the established wisdom"). It requires skills for elaborating original ideas.

Lateral Thinking is …
… Being able to step back. It requires skills for focusing (in and out) and for changing personal role.

… Being able to anticipate long term effects and to identify potential leverage actions. It requires skills for exercising intuition, for linking the facts and for taking unorthodox decisions.

Flexible Thinking
… Being able to listen and have empathy. It requires skills for listening the expectations and for answering accurately and tactfully.

… Being able to have adaptability. It requires skills for flexibility and responsiveness for adapting to changes, reorientations or shifts in mind set.

By placing the icons for these types of thinking as fruit within the branches, the following figure represents the characteristics of system thinking within the tree.

Mind mapping Systems thinker's attitudes facing a sepsis problem

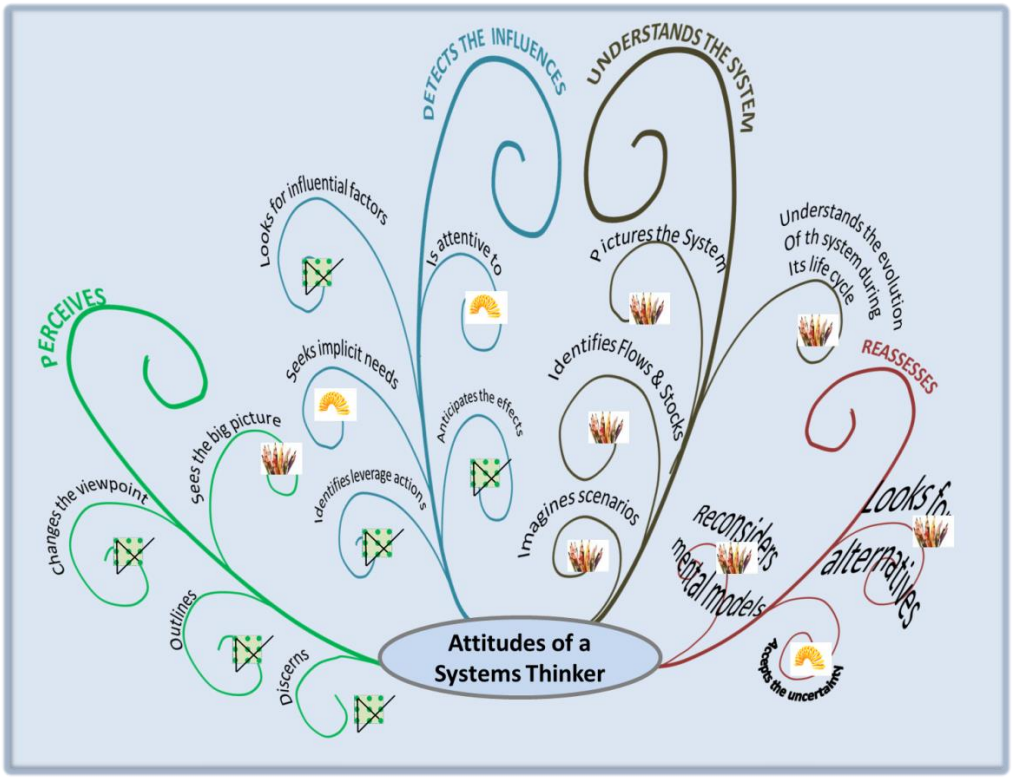

Figure 4 Quality of thinking revealed by systems thinker's attitudes

For instance, when somebody discerns elements that interacts, outlines a system and changes the viewpoint to better perceive a system, this person shows skills to step back, to focus in and to focus out, and to change the role. These are qualities of *lateral thinking*.

When somebody seeks for implicit needs or is attentive to expectations of a customer or is able to accept for some time the uncertainty of a situation, this person shows skills of listening, having empathy and adaptability. These are qualities of *flexible thinking*.

Systems' thinking reveals the unique attitudes of a Systems thinker.

The systems thinker frees their mind from the three unities rule of classical theatrical drama: time, place and action. The systems thinker dives into past events, propels into the future to understand a present day situation. The systems thinker approaches a subject in its wholeness; accepts different perspectives of diverse stakeholders within a situation and is able to play the role of any actor at any time. Exercising systems thinker attitudes leads to asking the right question at the right time in order to reassess situations. By sharpening the global understanding of a situation, the system thinker can change the world (Daniel Allegro 2013).

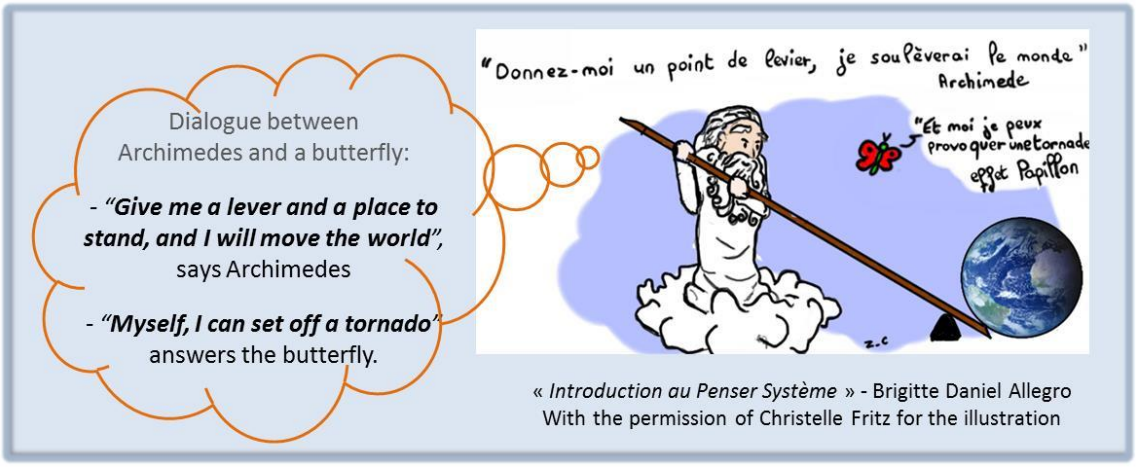

Figure 5 Changing the world with systems thinking

As systems thinkers, we advocate that it is indeed possible to solve problems for which there are currently no solutions, we just need to step outside of the box and interact in these unfamiliar domains.

AN INTRODUCTION TO THE SEPSIS PROBLEM

Sepsis is a deadly problem for which there are currently only limited solutions. Sepsis is highly complex and spans not just the biological system (which in itself is incredibly complex and beyond our current level of understanding), but also the healthcare enterprise – hospitals, funding organisations, medical instrumentation, doctors, nurses, patients etc. How can we understand the problem well enough to engineer effective therapeutics? How can we unravel the complexity of the Sepsis situation? The word "*complex*", coming from Latin "*complexus*" (meaning woven together, in an entanglement of multiple interlacing threads) is indeed appropriate to the sepsis problem.

Let us start with a really simple definition of the sepsis problem

Sepsis is a whole body inflammatory response to infection than can lead to death. We do not yet understand why inflammation, thought to a key contributor to the immune system, becomes a key feature of all complex (and not yet fully understood) disease. What we do know is that inflammation in these circumstances is immune suppressive and is a contributor to tissue, organ dysfunction and ultimately death if unresolved (Smith 2013).

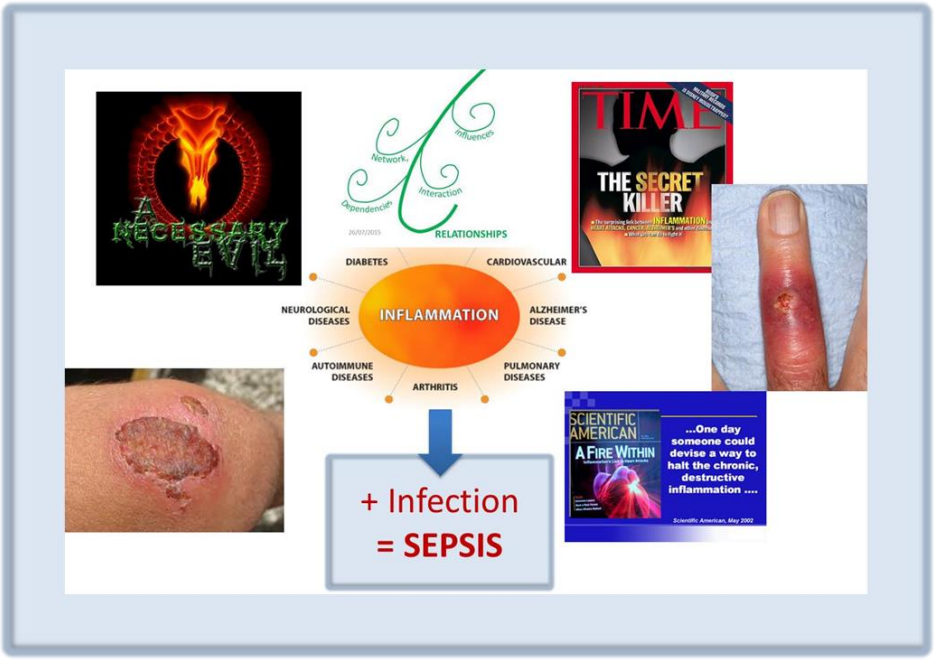

Figure 6 Inflammation – The anomaly behind the disease

In general, sepsis occurs in approximately 2% of all hospitalizations in developed countries but the rate is increasing (Martin 2012). The condition is categorised at three levels of severity which is capped by a condition known as multiple organ dysfunction (MOD).

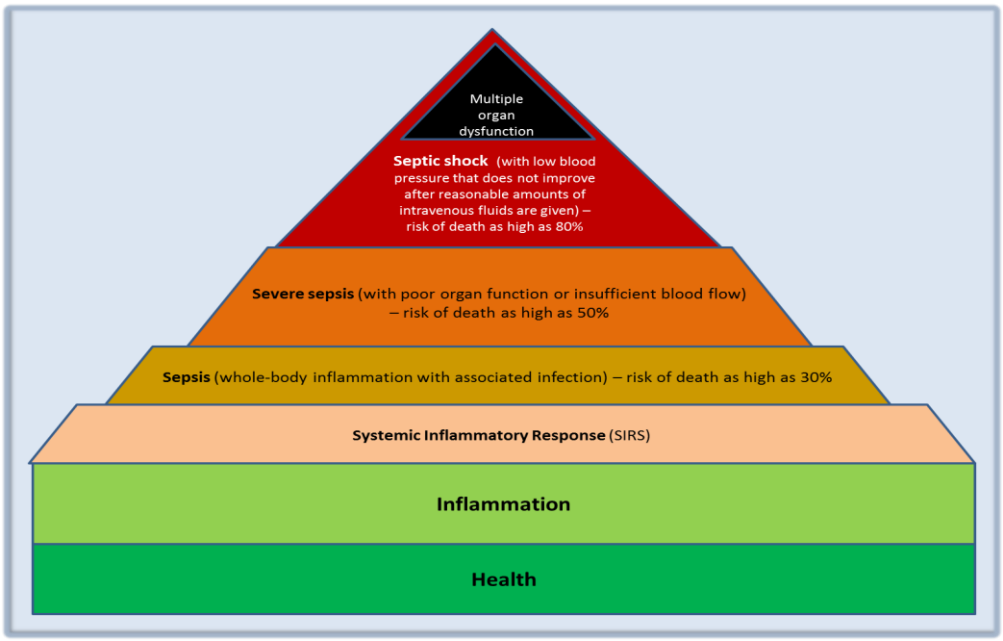

Figure 7 Three levels of sepsis severity: sepsis, severe sepsis, septic shock

Identifying sepsis and pre-requisite states helps to understand a fuzzy context

In the pyramid above, there are three other levels that underpin the sepsis states:

SIRS, because it appears to be a precondition that facilitates widespread infection of the blood;

Inflammation because local damage or infection promotes inflammation and sufficient damage, possibly across multiple sites (such as in metastatic cancer), causes SIRS;

Health, because the heathier you are, the better (efficient and effective) you are to recover from injury and the more resistant you are to infection.

Understanding that these are preconditions might reveal more about the nature of the problem and also help when considering treatment.

Martin summarises the situation with sepsis quite nicely. "Sepsis has been around since the dawn of time, having been described for more than 2000 years, although clinical definitions are recent. The consensus sepsis definitions have permitted worldwide epidemiological studies of sepsis to be conducted. We now recognize the common nature of sepsis and the consistency of its disease – particularly severe sepsis and septic shock. The incidence of sepsis, severe sepsis and septic shock continues to increase, and although Gram-positive bacterial pathogens remain the most common cause of sepsis, fungal organisms are increasing rapidly.

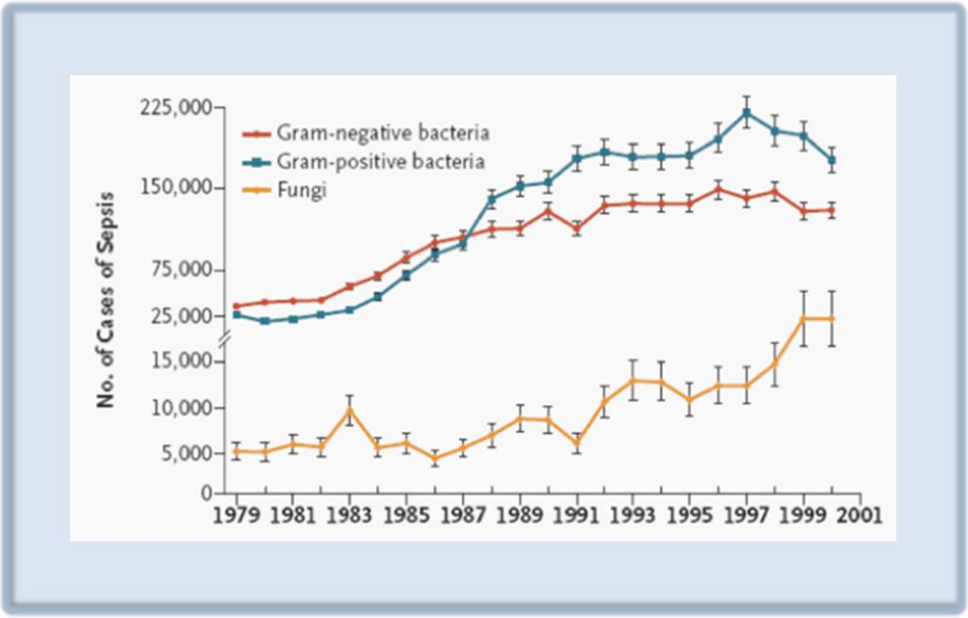

Figure 8 Epidemiology of sepsis in the US from 1979 to 2000. (Martin et al. 2003)

We have made progress over the past half-century in identifying and treating patients with sepsis, and decreasing fatality rates reflect this progress. However, owing to the increasing incidence of sepsis (**about 9% per year in developed world**), the number of people who die each year continues to increase. The mortality with sepsis, particularly related to treating organ dysfunction, remains a priority to clinicians worldwide (**around 50 % of severe sepsis patients will require intensive care services**) and is deserving of greater public health attention."

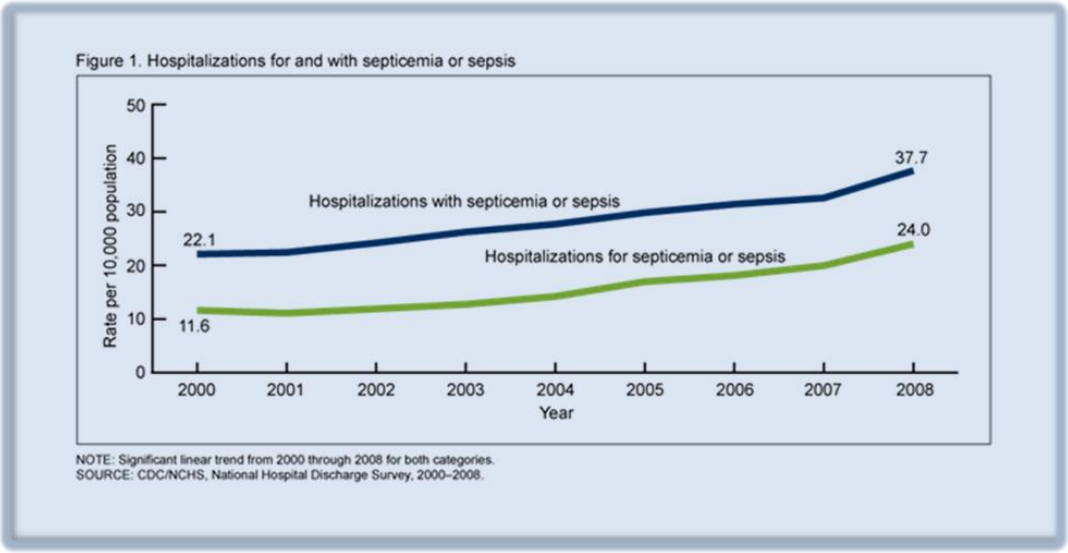

Figure 9 Hospitalizations for and with septicemia or sepsis

Why it does seem urgent to act?

The trend in sepsis rates becomes even more concerning when you overlay a chart for the years 2000-2008 (David 2012) with the previous publication. It is tempting to speculate to what degree the rapid growth in sepsis incidence is influenced by a continuing trend in escalation of fungal infections. Invasive candidiasis being attributed as the cause of sepsis in about 5% of all cases of sepsis in intensive care unit patients (Delaloye and Calandra 2014).

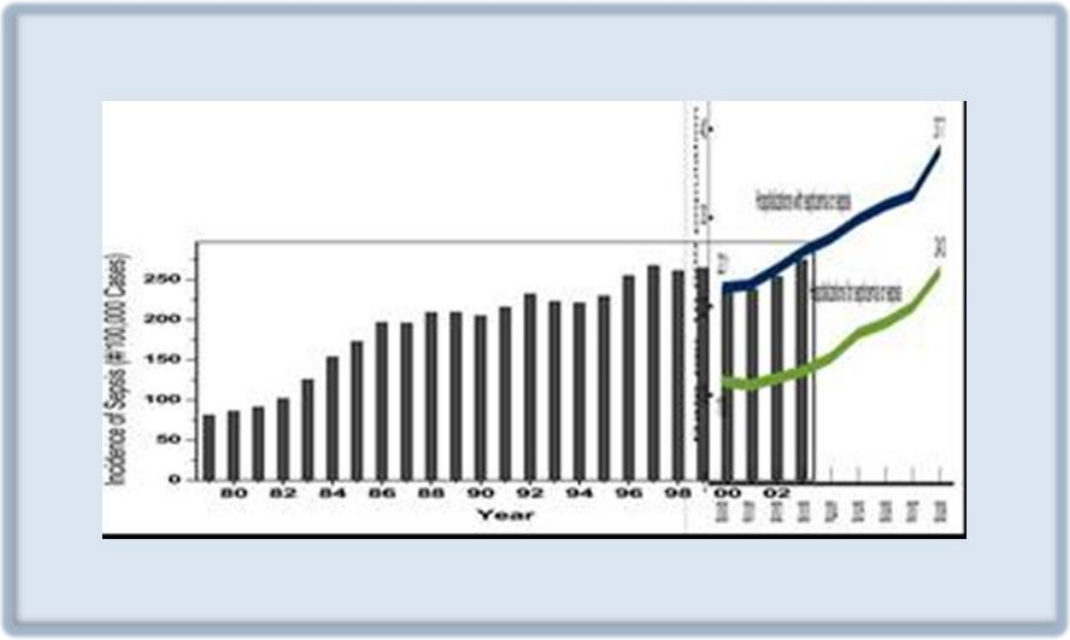

Figure 10 Trends in sepsis incidence

SEPSIS AND SYSTEMS THINKING

Paul, is a hypothetic doctor (and systems thinker), who attempts to deal with the sepsis problem. Imagine yourself in the position of Paul who wants to better understand sepsis in order to recognise potential leverage points for prevention, treatment and recovery. By placing ourselves in Paul's position we can identify with his thinking and system approach.

Paul, who works in emergency situations, has an established way of treating the problem of sepsis but he is sincerely motivated to find ways of dealing with it. He knows the critical importance of the relationships between time, treatment and patient outcome (Paul displays the capability to look for influential factors). He has lost some patients who were not identified early enough despite the best efforts of staff and the hospital system. What he would really like to do is find ways of improving the probability of survival and recovery, in particular for those that have already progressed to severe sepsis. At this stage the benefit of antibiotics are significantly reduced and he wants to better understand the problem so that he could find better solutions (Paul displays the capability to look for alternatives, other options).

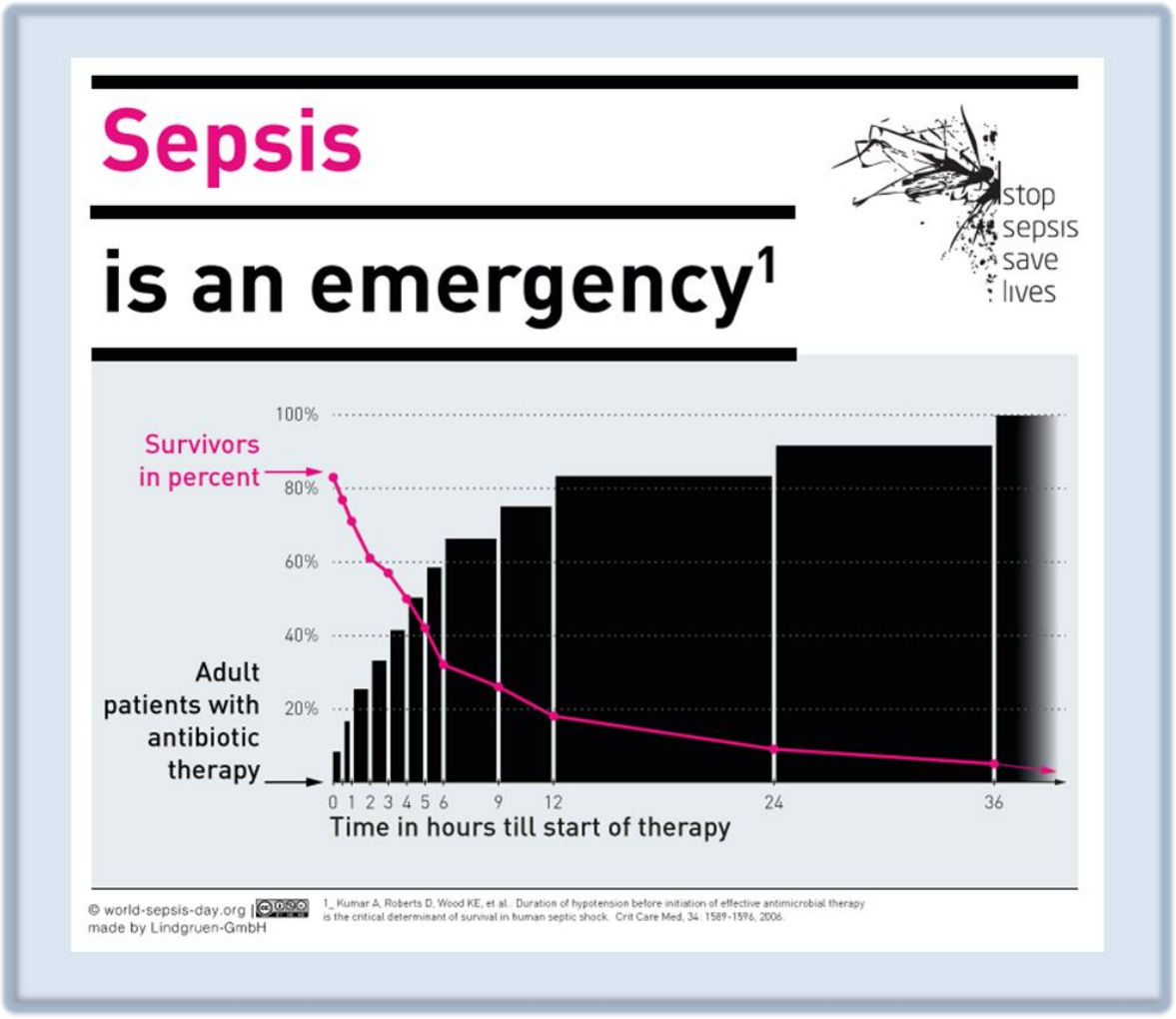

Figure 11 Sepsis is an emergency situation

Analysing the cause and effects – "Health" is degraded.
Paul was aware of the indirect effect on patients who survived from a first sepsis episode. (Paul displays the capability to be attentive to the life of the sepsis survivors).

Paul collected data and found that the sepsis survivors were seriously affected by long term effects. Post-sepsis syndrome is a condition that affects up to 50% of sepsis survivors. These leave "recovered" patients with physical and/or long-term effects, such as:

- Insomnia, difficulty getting to sleep or staying asleep;
- Nightmares, vivid hallucinations and panic attacks;
- Disabling muscle and joint pains;
- Extreme fatigue;

- Poor concentration;
- Decrease mental (cognitive) functioning;
- Loss of self-esteem and self-belief.

Around 20% of sepsis survivors are also diagnosed with Post Traumatic Stress Disorder.

Within 30 days from release as a result of sepsis, they are around 40% likely to be readmitted to hospital.

Over a two year period, they were also around 10 times more likely to be readmitted to hospital suffering from an infection.

In order to have a big picture of survivors and of healthcare system during a short term period (within 30 days) as well as a long term period (2 years after the sepsis), Paul started to draw *systemigrams.* A *systemigram* is a diagram which "depicts a complex system in a relatively simple manner" (Boardman and Sauser 2013) .

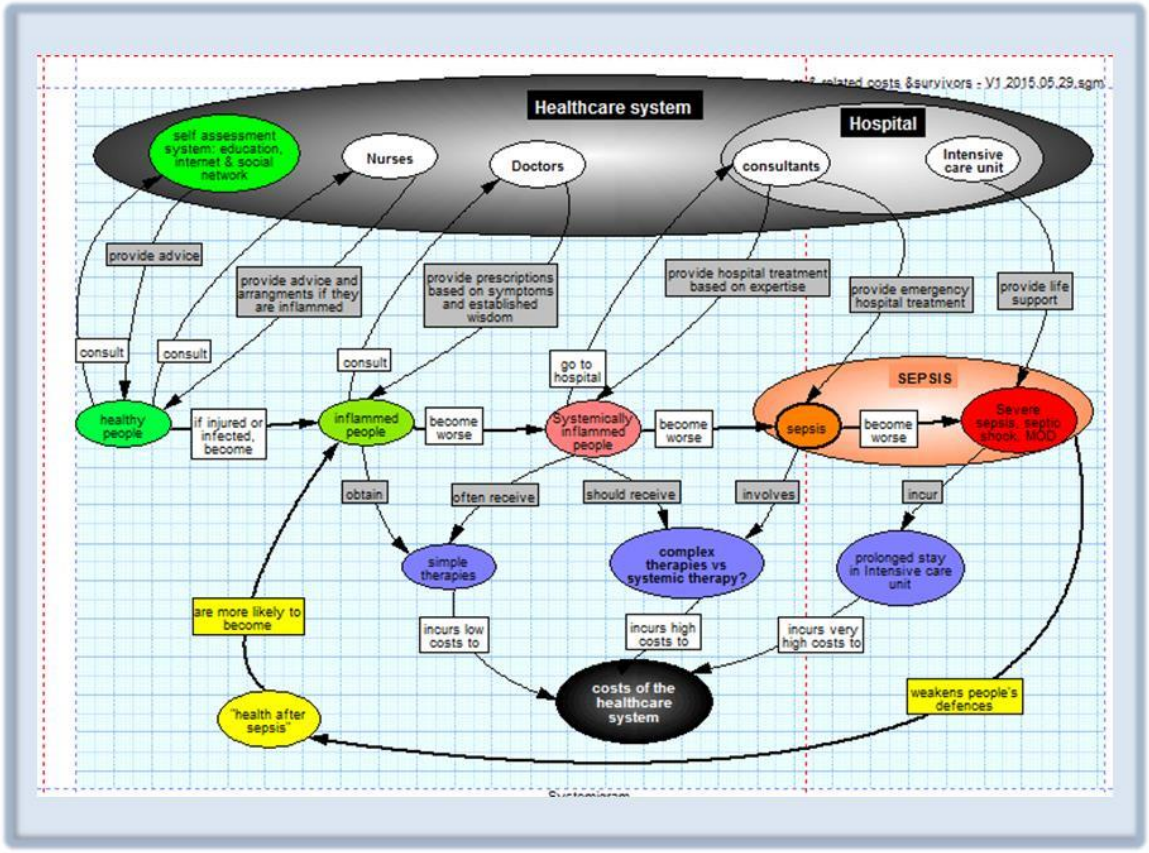

Figure 12 The progression of sepsis within the healthcare enterprise

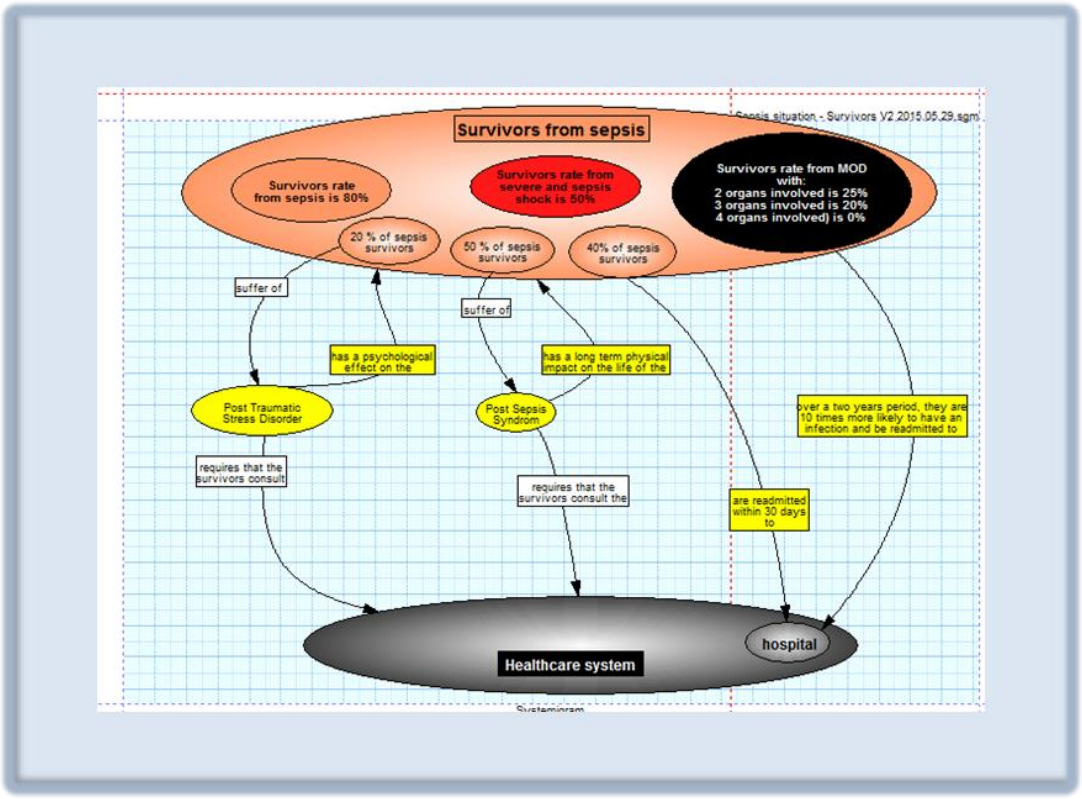

Figure 13 Sepsis situation system & Survivors of sepsis

Using *systemigrams*, Paul identified flows of survivors from sepsis in relationship with the healthcare system and he identified the accumulation of these survivors, (namely stocks), in the healthcare system (Paul displays the capability to detect influences).

He realised with this diagram how substantial effort is required by the global healthcare system and not just immediately but long term and cumulative of time. (Paul displays the capability to picture the system).

With these *systemigrams* Paul was able to start to understand why an improvement in sepsis survival also has a negative emergent consequence of increasing the rate and cost of sepsis. Survivors of sepsis have weakened defences and increase the pool of those who are susceptible. (Paul displays the capability to see the big picture).

Known Risk Factors

Paul knew several of the risk factors related to the incidence of sepsis, but from examining the literature found many more (Paul displays the capability to look for influential factors).

Some of these risks, "inherited" factors can be taken into account as they might offer clues as to the mechanisms underlying sepsis. Many of the others are as a consequence of

intervention for other medical problems. Paul thought that they should be taken into consideration in the long term health plan for the patient.

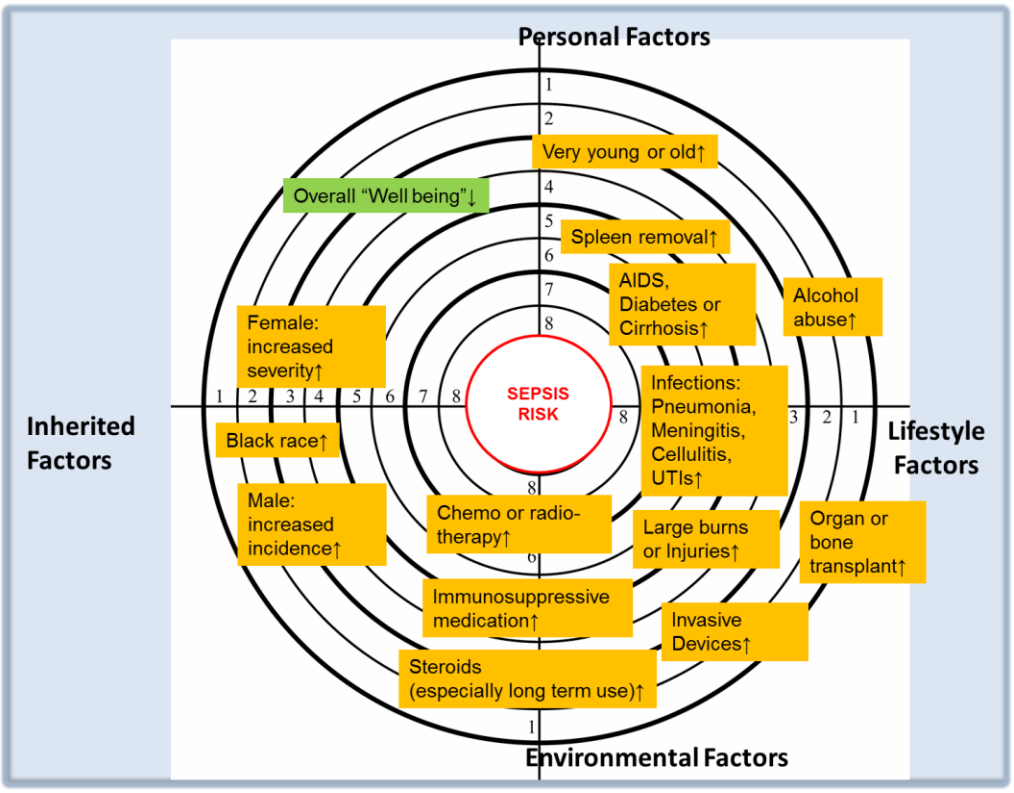

Figure 14 The risk factors of incidence and severity of sepsis.

His problem was that some patients developed severe sepsis; even those treated under the best of circumstances (Paul pictures the system). He and his colleagues have very limited options to treat septic shock or multiple organ dysfunction.

Treating the patient - The situation system and coupling diagram with decision making

Paul considered the "SEPSIS problem" to solve as a situation system, hereinafter referred to as "General sepsis situation system". Indeed, three elements become interrelated, namely a "patient", the "healthcare system" and an "infection" in a "General sepsis situation system" (Paul showed skills to conceptualize and verbalize).

In order to respond to a "General sepsis situation system", Paul captured in a "Respondent system to sepsis" the established strategy and the associated protocols based on the established wisdom.

The strategy consisted of:

- Quelling the infection;
- Sustaining the vital organs;

- Preventing or avoiding a drop in blood pressure.

He conceptualised a "*systems coupling diagram*" - a useful concept he discovered in the book "a Journey through the Systems Landscape" (Lawson 2010) - which is portrayed in the following figure.

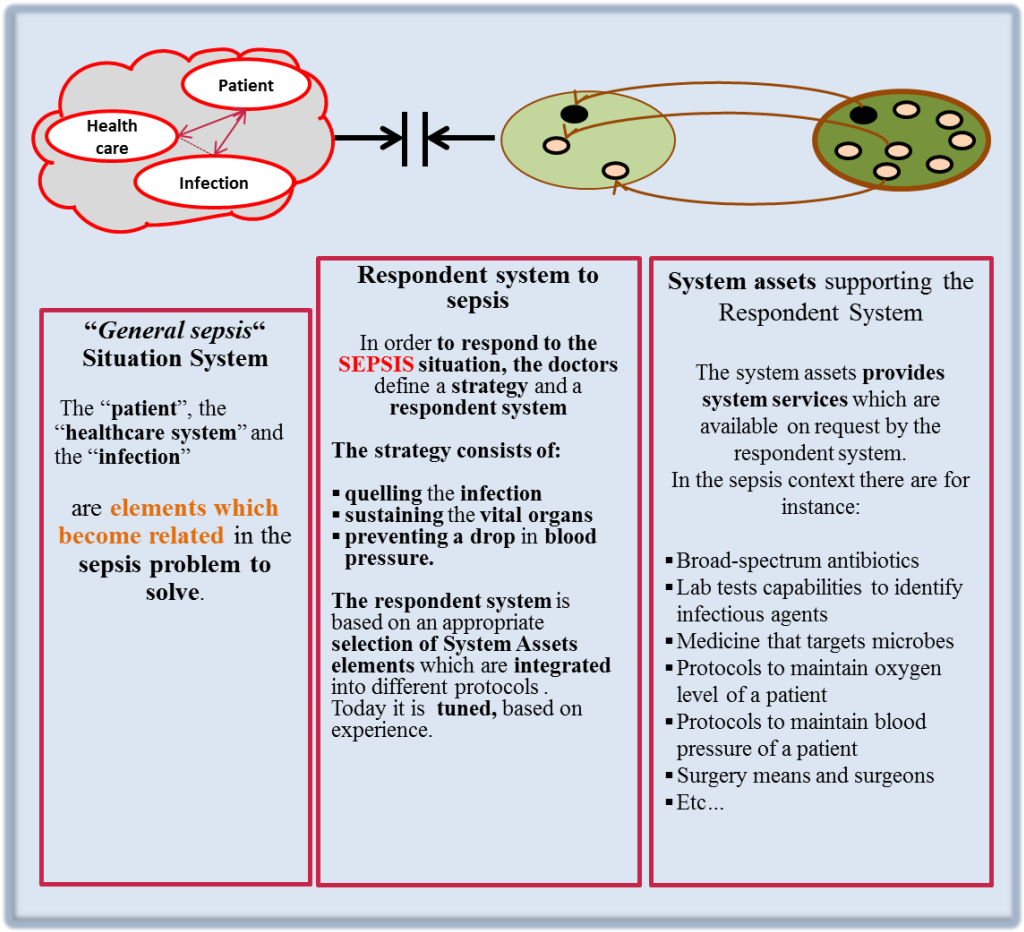

Figure 15 "General sepsis situation system" coupling diagram

The "Respondent system to sepsis" was based on an appropriate selection of "Healthcare system assets" elements which were integrated into different treatment protocols (Ombudsman 2013). A team, typically led by a consultant level medical doctor was responsible of the "Respondent system to sepsis" (Paul displays the capability to create an abstraction of a real problem in order to better understand it).

In this "General sepsis situation system", the "Coupling Element" was essential because it captured and monitored the evolution of the situation based on the evolution of the patient as well as the evolution of the sepsis severity and the course of the infection.

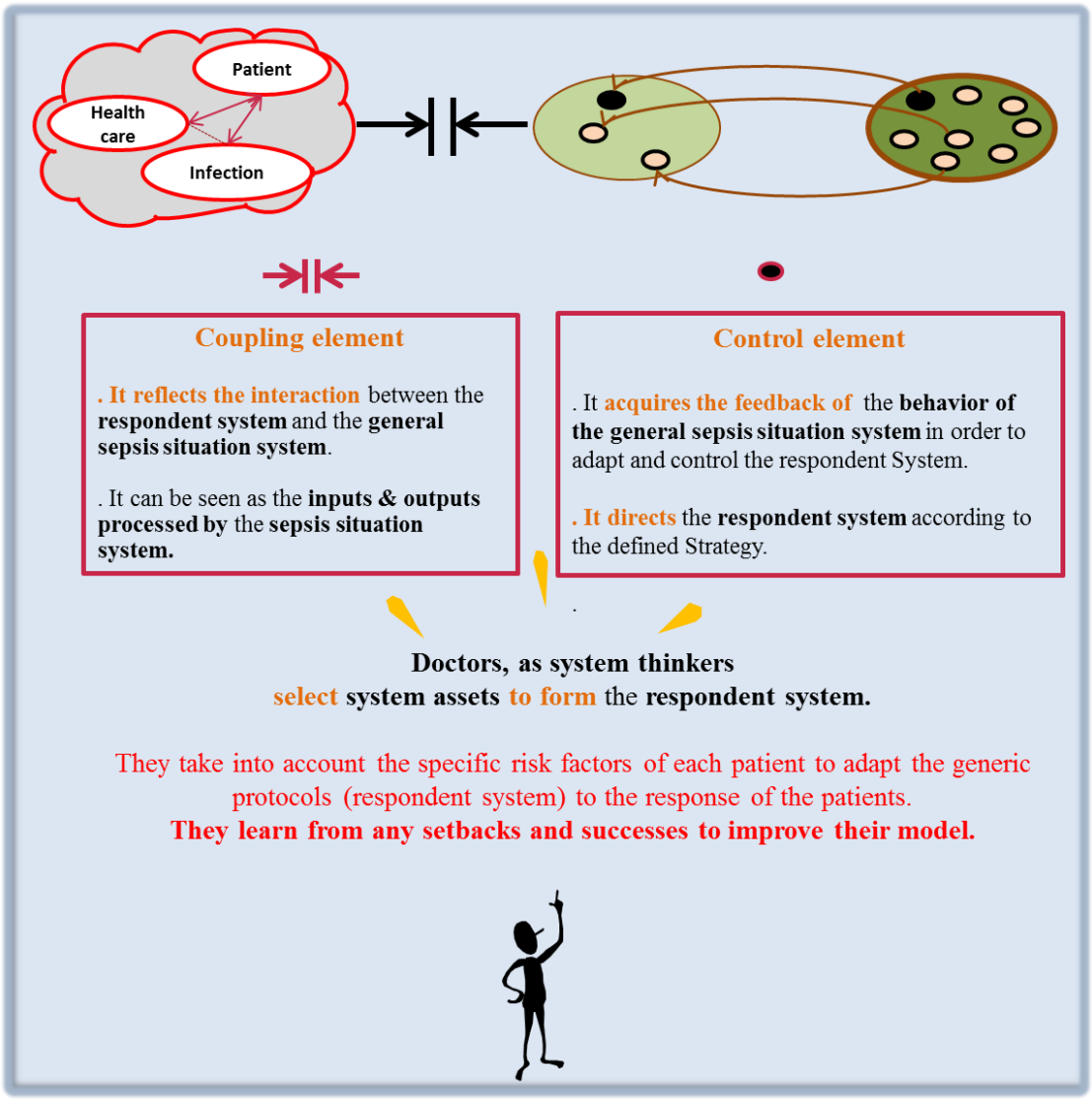

Figure 6 "General sepsis situation system" - Coupling and control elements

Paul found that the "General sepsis situation system" coupling diagram was useful but he knew that the dynamic of the situation was crucial for the patient. The particular issue was to be able to contain sepsis and to avoid an evolution towards a "severe sepsis" or a "septic shock", as there is no reliable treatment.

His thoughts highlight the fact that the as-is "Respondent system to sepsis" was inadequate as it did not address the prevention of a degradation. (Paul showed skills to step back, to point out the uncertainty of the situation, capabilities to think out of the box and to reconsider the mental models).

Managing state transitions using systems thinking

The physical features and symptoms of the patient in the different sepsis states helped Paul a little to understand what was happening from a biological perspective but it was not sufficient to understand how the condition progressed.

Some key question remained. Were there any pre-conditions or any events which were favourable to an evolution of the sepsis to one state to other ones?

Paul drew a sketch in order to integrate in one picture the qualification of each state and the events generating a transition from one state to another one (Paul displays the capability of synthesis and integration).

Then Paul extended the *as-is three levels of sepsis severity* to *multiple organ dysfunction* (*MOD*) on one side and to the pre-conditions which could lead to sepsis on the other side, namely from *health* to *inflammation* and *systemic inflammatory response* (*SIRS*) (Paul focuses in and out to discern elements and relationships in the big picture).

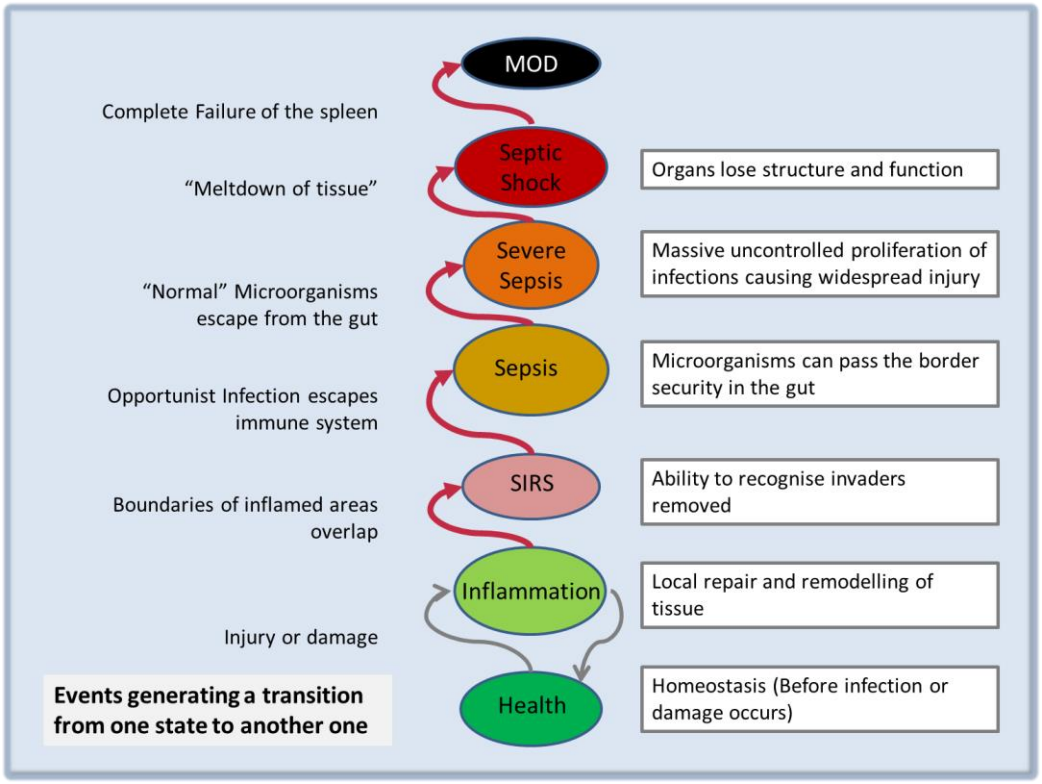

Figure 17 Candidate mechanisms for sepsis states progression

Paul decided then to share his personal view with peers (Paul displays the capability of developing initiatives).

As a result, he got into contact with other doctors, nurses, and searchers who had also been applying "lateral thinking" about sepsis. He was surprised when he discovered how

this simple diagram generated so fruitful discussions. Consequently they decided to work together on potential leverage points for sepsis prevention, treatment and recovery.

CONCLUSION

How the systems thinker's tree has been applied by Paul for sepsis problem?

During Paul's story, we have inserted comments such as "(Paul displays the capability to look for influential factors)". These comments came directly from the systems thinker's tree.

From Paul's perspective, we can imagine that he intuitively navigated from one branch of the tree to another one with the intention to get a better insight of the problem. By doing that, he showed his personal skills and demonstrated how he can combine different qualities of thinking (*lateral, creative and flexible thinking*). The fruits of the tree demonstrate his applied systems thinking capabilities to this problem. What we envisage is if systems thinkers keep in mind the model of the systems thinker's tree then they would be better equipped to explore the problem in a productive (fruitful) way.

Paul's particular tree

At the end of the story, we were able to instantiate the complete model, Paul's tree, while Paul was thinking of the sepsis problem. It is portrayed in the following figure. The areas illuminated (yellow) being the attitudes and concepts that Paul paid particular attention to.

Mind mapping Systems thinker's attitudes facing a sepsis problem

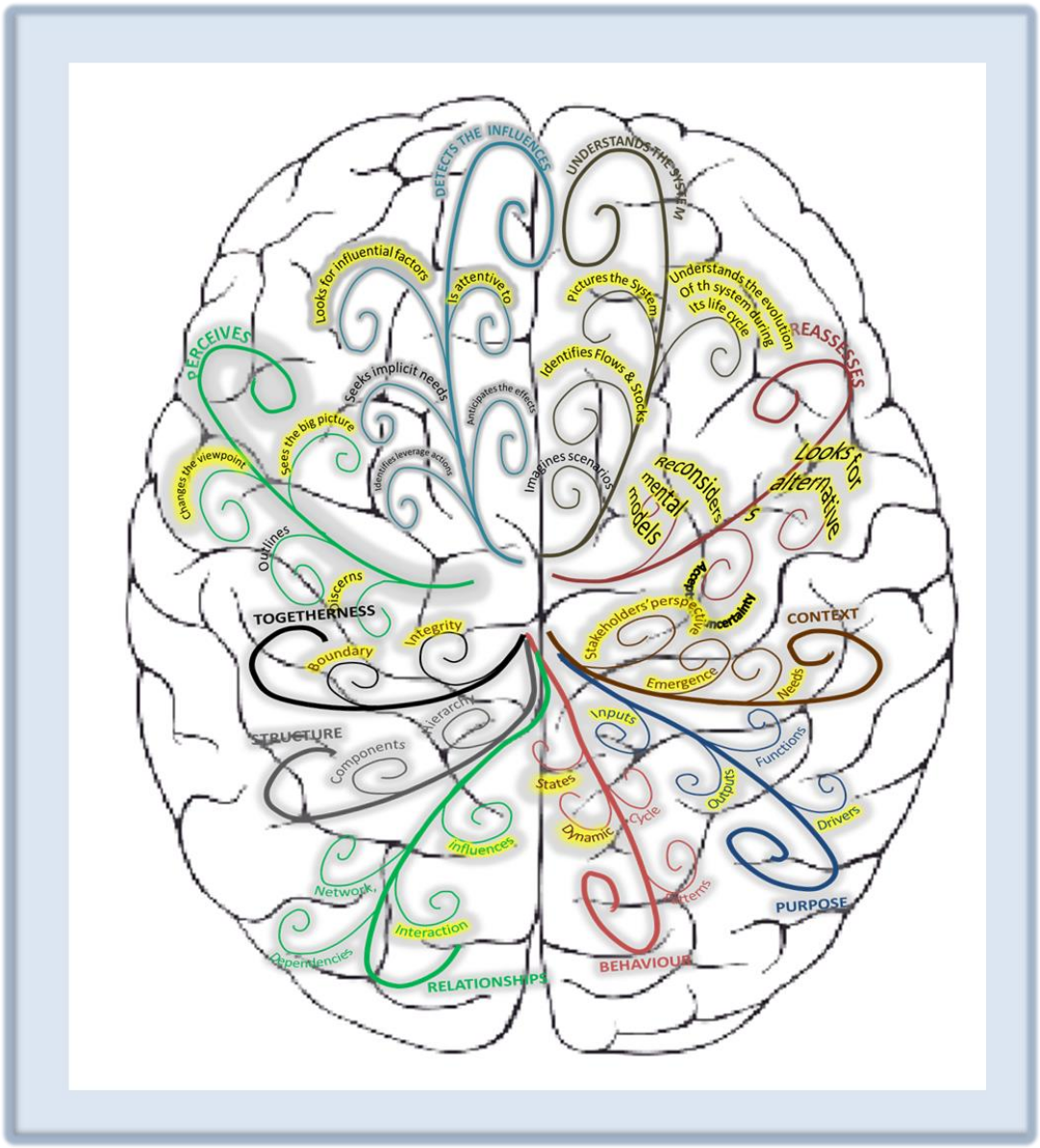

Figure 18 Paul's tree, when he is thinking of his sepsis problem

What Paul also found out for the sepsis problem with systems thinking

- The reason why the antibiotics are important in sepsis, why they have detrimental or limited effects in severe sepsis and septic shock.
- The important role of the spleen in managing the overall organism security.
- There are two emerging strategies: artificial spleens and blood filtration. Understanding the problem better could improve the timing and focus of these new treatments.

- By better understanding the key role of the gut barrier we may find ways of enhancing the security protection (empty the gut or find ways of improving the barrier for instance using "faecal microbiota transplantation").
- Paul discovered that other people were already developing ideas and treatments for sepsis that he did not know about. He broadened his perspective, which let to re-evaluation of his knowledge and belief's and a new paradigm for sepsis.

Take home messages

Systems' thinking is what needs to be done when you are faced with a complex problem that you have not faced before. Knowledge of the attitudes of the systems thinker can lessen some of the mental barriers to this productive mode of thinking.

By examining systems thinking applied in an unfamiliar domain, we feel this has facilitated useful new perspectives on systems thinking and systems science. Once you have a simple (but not overly simple) framework it is possible to improve your understanding of systems.

Systems thinking across this complex subject would also appear to offer potential concepts that could be explored for more effective and efficient healthcare management in the sepsis situation. We hope that this provides encouragement for all systems thinkers to look beyond their current experience.

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