26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

Immune system and cyber security

Architectural parallels between biological and engineered solutions in defence and security

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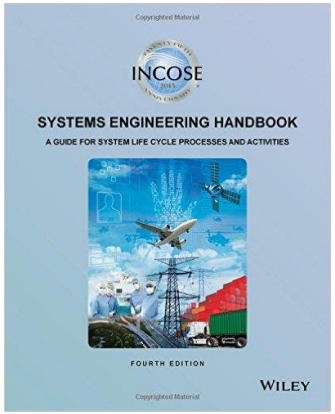
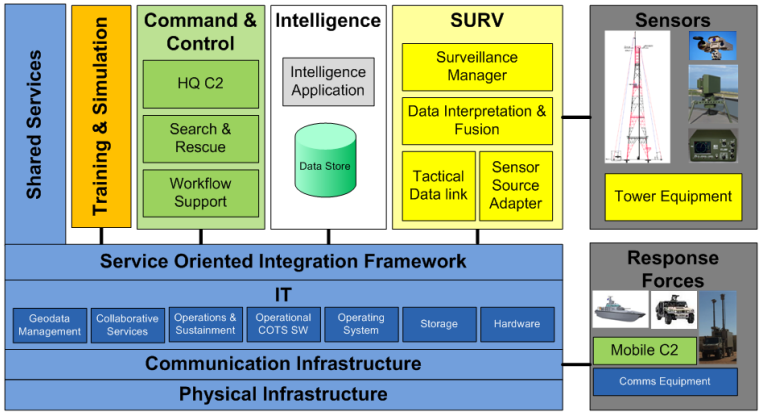
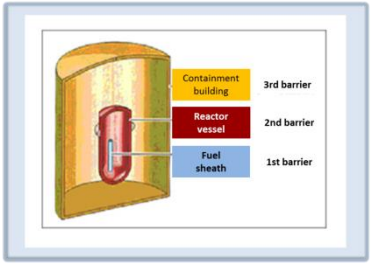
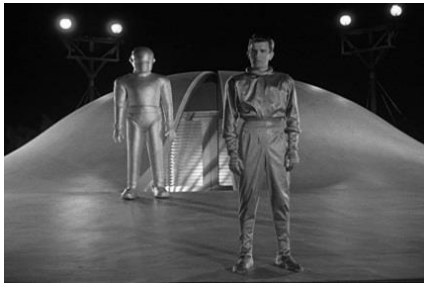
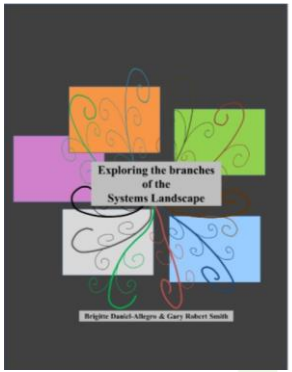
Our background

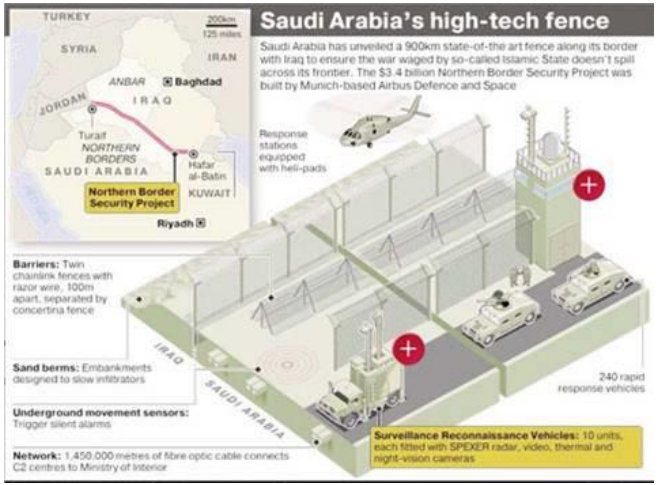






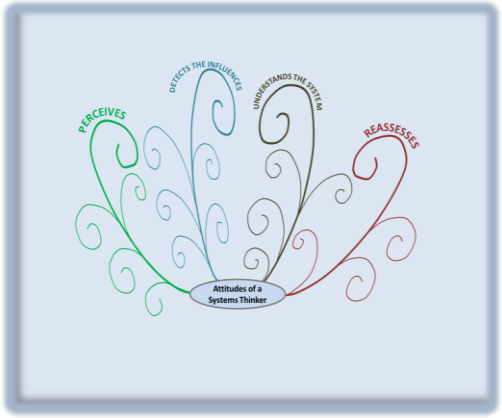






Aims of the research

to **explore** the parallels between
biological systems and engineered systems
using the *Systems Tree* – a map of systems thinking concepts



Patterns in biology, engineering in the mind of systemists

Content of the talk

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Architectural parallels between biological and engineered solutions in defence and security

1	2	3	4	5
An emerging framework for systems thinking & acting	Similarity, analogy & metaphor used in modelling	Exploring trade-off in complex distributed-autonomous-adaptive systems	Defence & Security System in the context of Influenza	Reflection on our exploration

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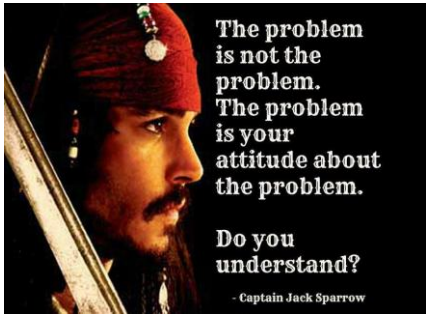
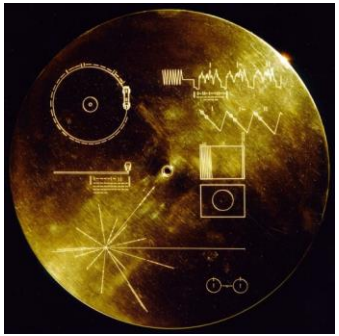
1

An emerging framework for systems thinking & acting

Systems Thinking

System Thinking *is what you have to do when you are faced with the inexplicable**
It changes *your* ***attitude about your thinking.***



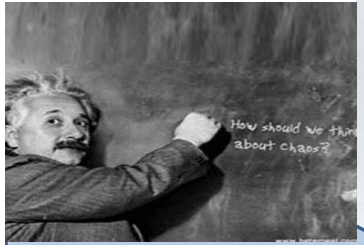


**unaccountable, unexplainable, incomprehensible, unfathomable, impenetrable, insoluble, unsolvable, baffling, puzzling, perplexing, mystifying, bewildering, mysterious, strange, weird, abstruse, enigmatic, beyond comprehension, beyond understanding…/…*

When faced with chaos and complexity

Unknown "What"
The perceiver lacks the mental models to comprehend the behaviour of these systems

New theories and concepts



Science is inadequate to predict why these systems behave as they do

Structures Patterns

Complex
Enabling constraints
Loosely coupled
probe-sense-respond
Emergent Practice

Complicated
Governing constraints
Tightly coupled
sense-analyse-respond
Good Practice

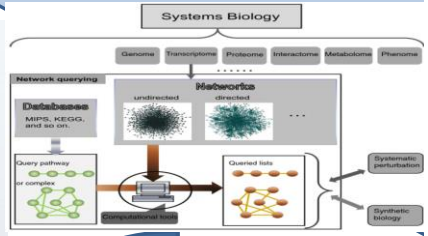
Disorder

Chaotic
Lacking constraint
De-coupled
act-sense-respond
Novel Practice

Obvious
Tightly constrained
No degrees of freedom
sense-categorise-respond
Best Practice

Leaps of faith

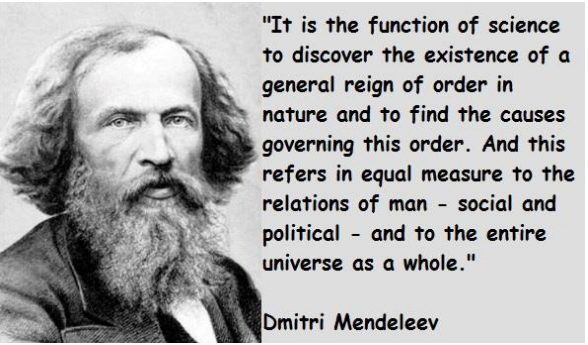
Limited "How" Analysis can be used to explain how these systems behave as they do

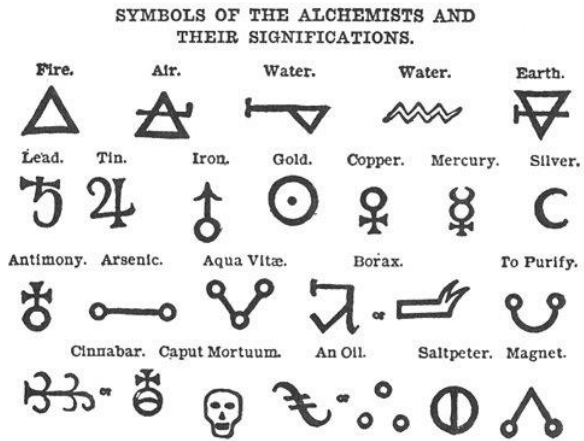


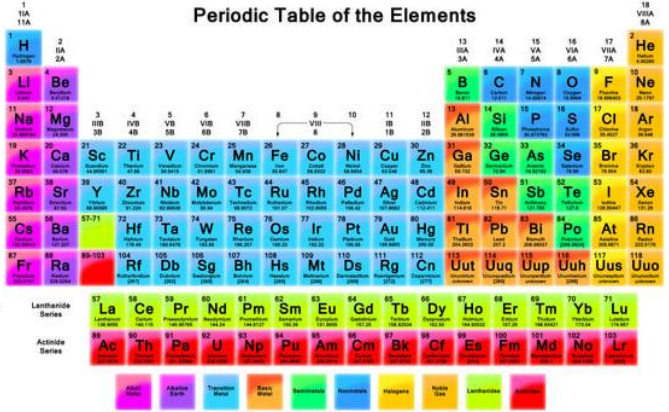
Design Application

Established common wisdom
Systems that everyone apparently understands

Without system science, we remain alsystemists

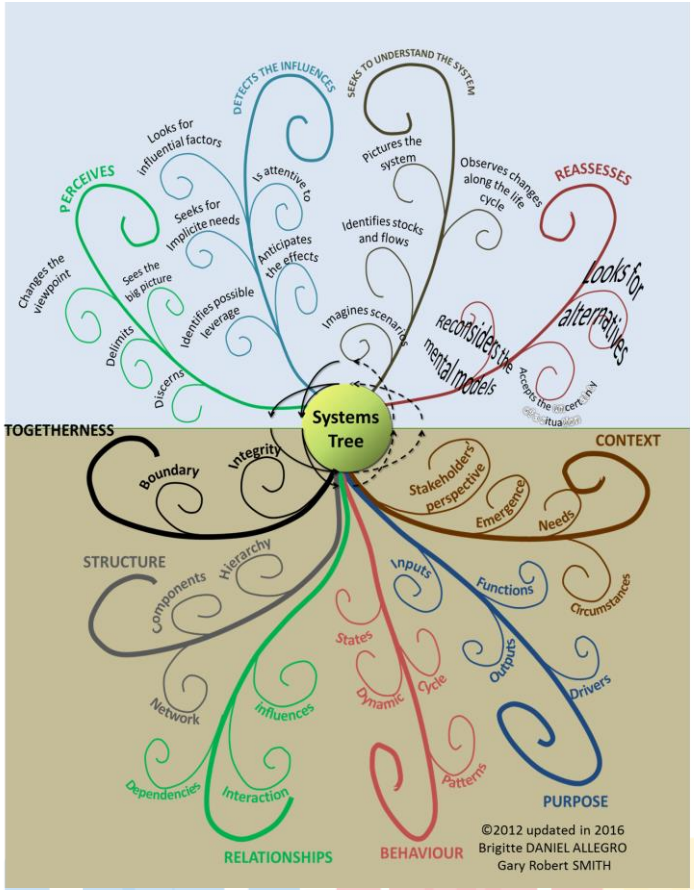






"Until recently, most of systems thinking could be best characterized as descriptive, faith-based, anti-reductionist approaches… we argue that we are on the cusp of appearance of a more testable "science" of systems." – Luke Friendshuh and Len Troncale 2012. Presented summer 2012 at the International Society for Systems Sciences

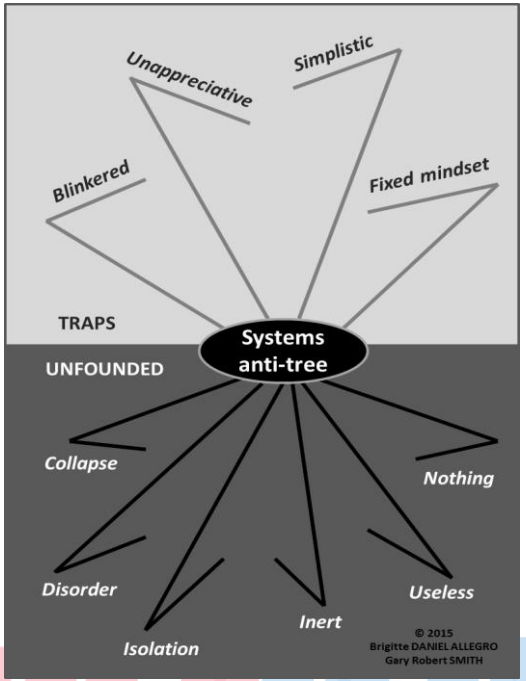
Candidate elemental framework



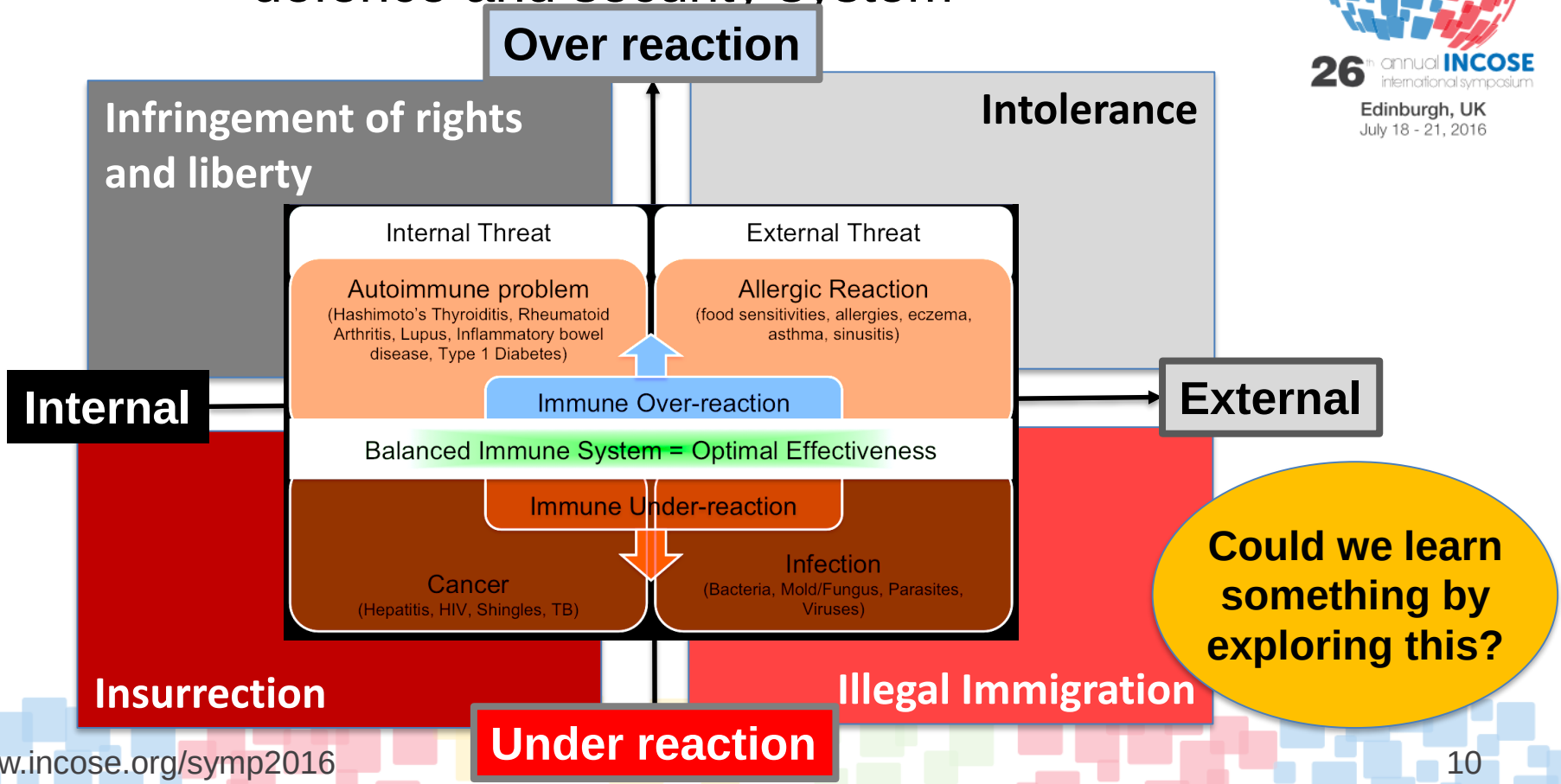
Systemists consider these **systemic mental models** **when interacting** with **any situation**

analogous to

Chemists considering **chemical elements** **when interacting** with **chemical substances**



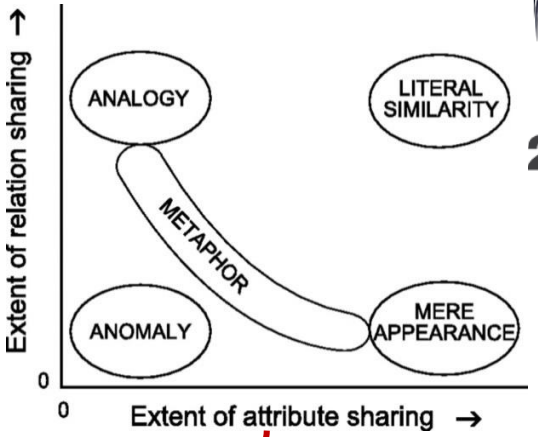
Imagine facing the challenge to build our biological defence and security system

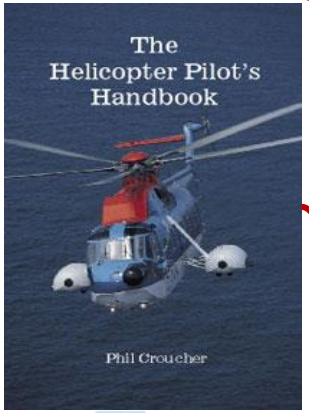


2

Similarity, analogy & metaphor used in modelling

Our method for exploring



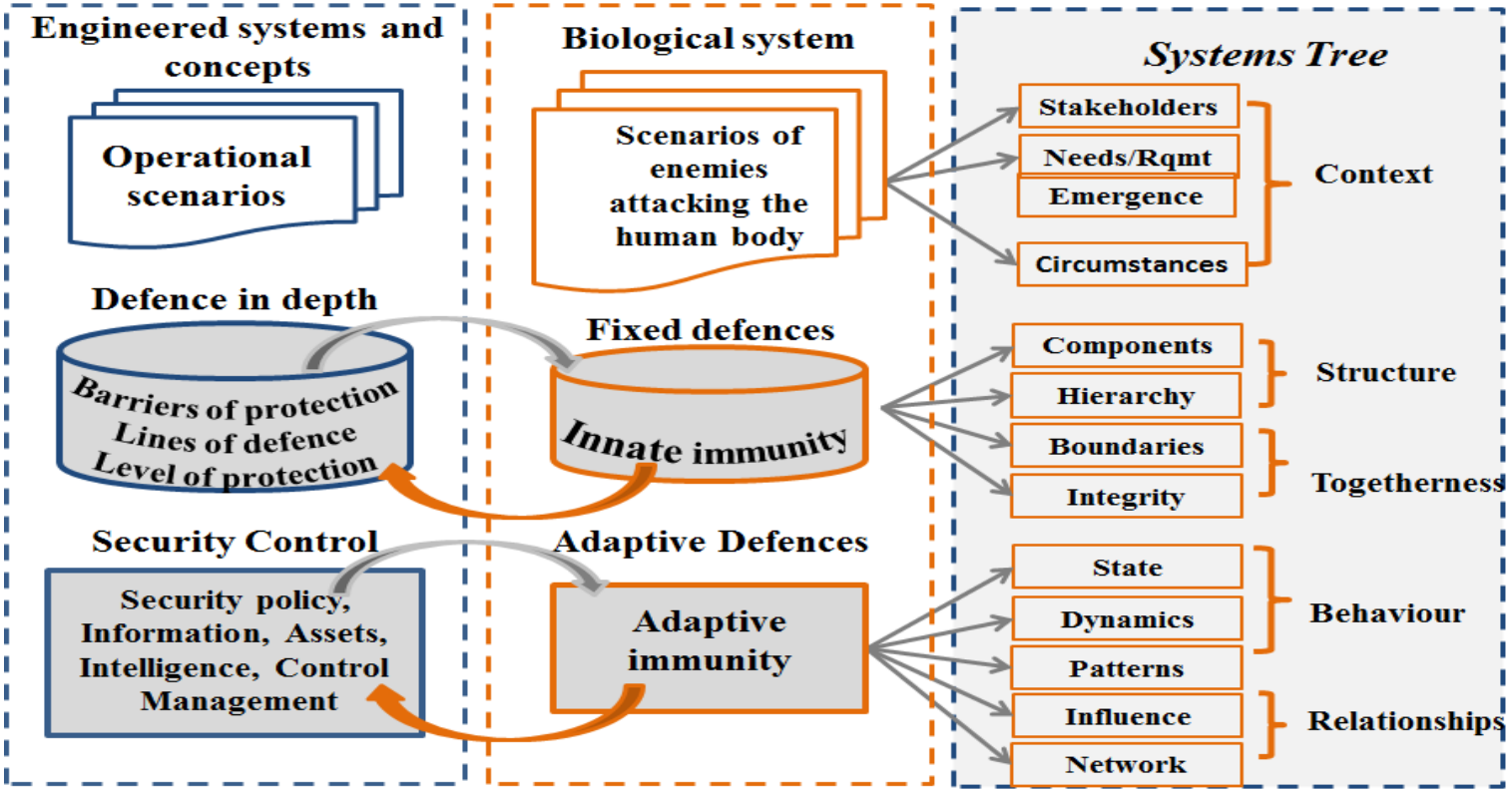


Embrace complexity and gather Data
Perceive Similarities
Try to **make sense** of it with **Analogy and Metaphor**
Formulate the big picture and **attack Anomaly**
Change viewpoint & Consider new and **additional perspectives**
Validate impressions with **experts**

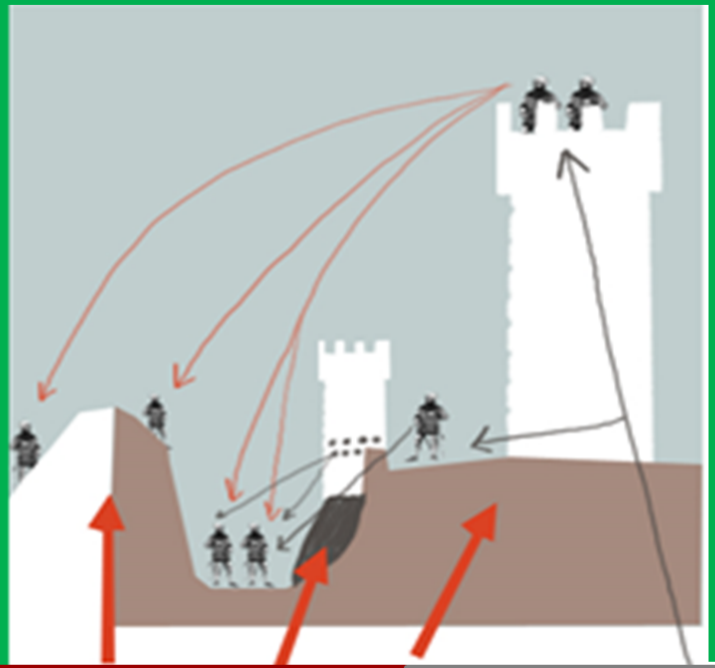
3

Exploring trade-off in complex distributed-autonomous- adaptive systems

Perceived similarities to explore



The three pilars of Defence in Depth (*& Breadth ?*)



Levels of protection

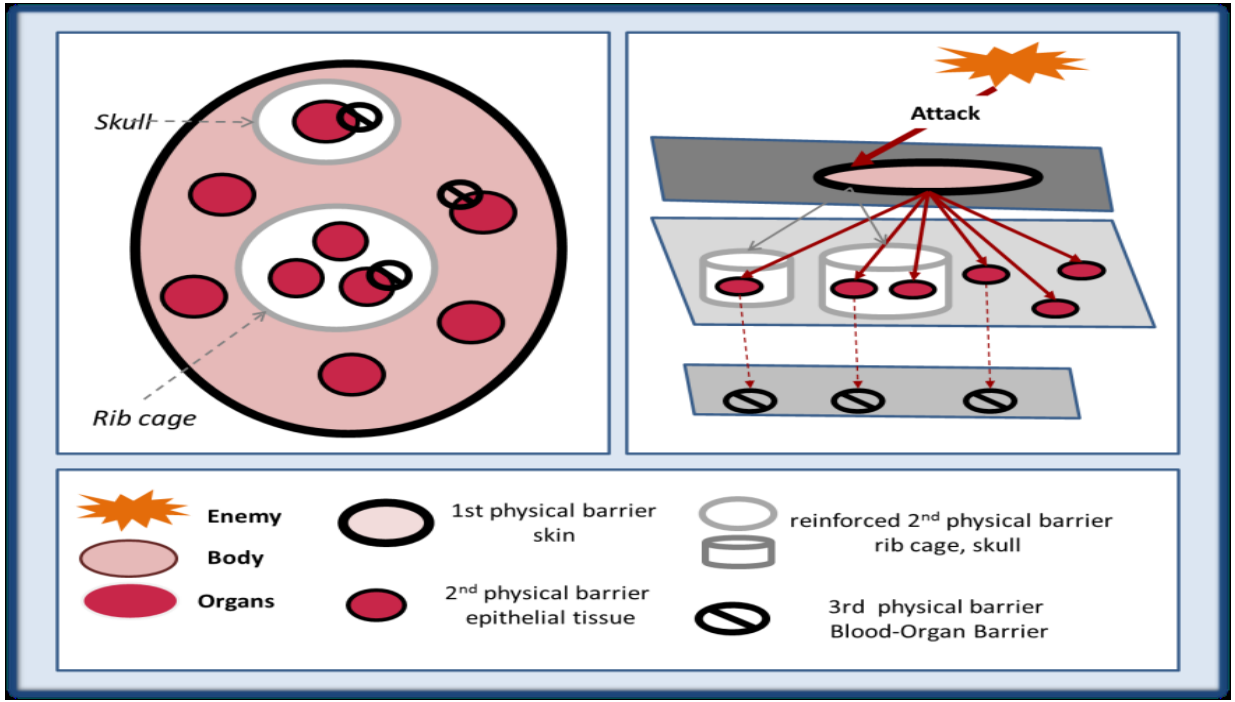
Arrangement of barriers and lines of defence according to protection goals

Should one level fail, the subsequent level comes into play.

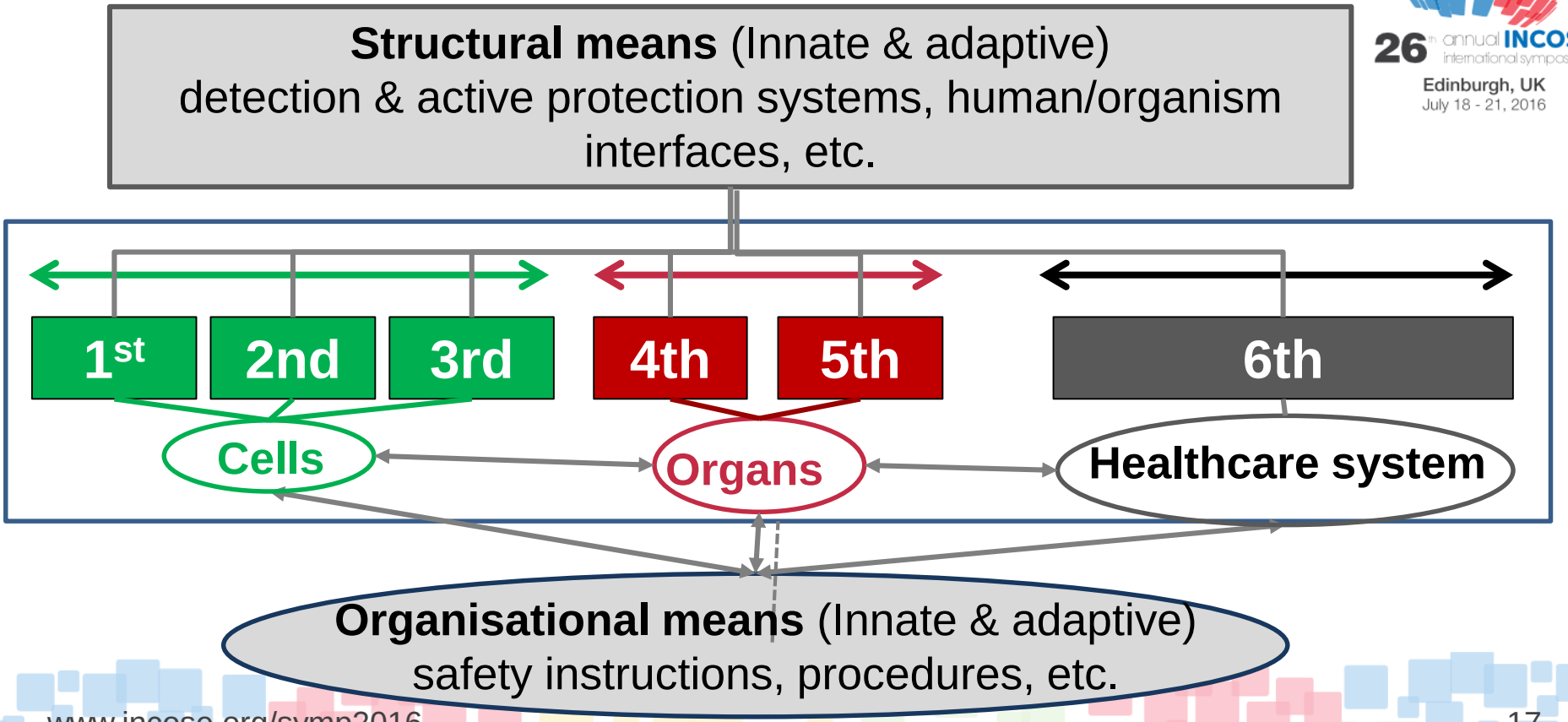
Barriers
Physical protection systems

Lines of defence
Structural & organizational means

Physical barriers of protection



Lines of Defence



Lines of defence

Concepts of Biology-1st Canadian Edition 2015, Charles Molnar and Jane Gair

Vertebrate Immunity		
Innate Immune System		Adaptive Immune System
Physical Barriers	Internal Defenses	
• Skin, hair, cilia • Mucus membranes • Mucus and chemical secretions • Digestive enzymes in mouth • Stomach acid	• Inflammatory response • Complement proteins • Phagocytic cells • Natural killer (NK) cells	• Antibodies and the humoral immune response • Cell-mediated immune response • Memory response

First line | Second line | Third line

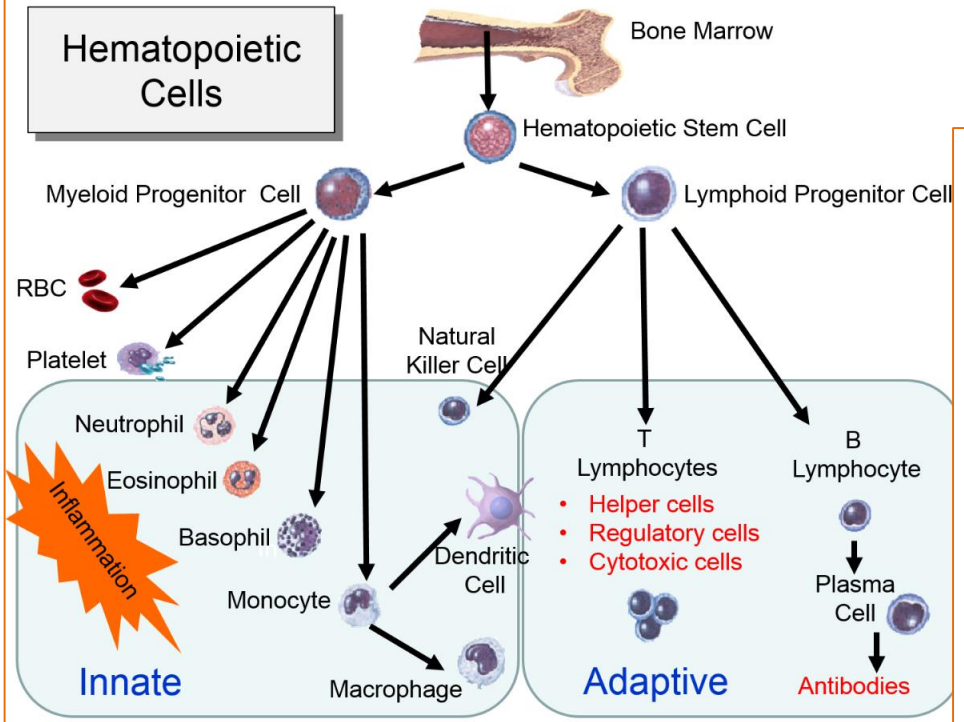
When you identify a new concept… typically someone else has most likely already had the same thought

DSS response forces

The various cells in the **Innate immune** system are analogous **to civil servants**. *Fire fighters, waste disposal, healthcare, police.*

Macrophages & Dendritic Cells in particular **provide intelligence to the Adaptive Immune** System.

During incidents **neutrophil**s **are usually the first on the scene.**

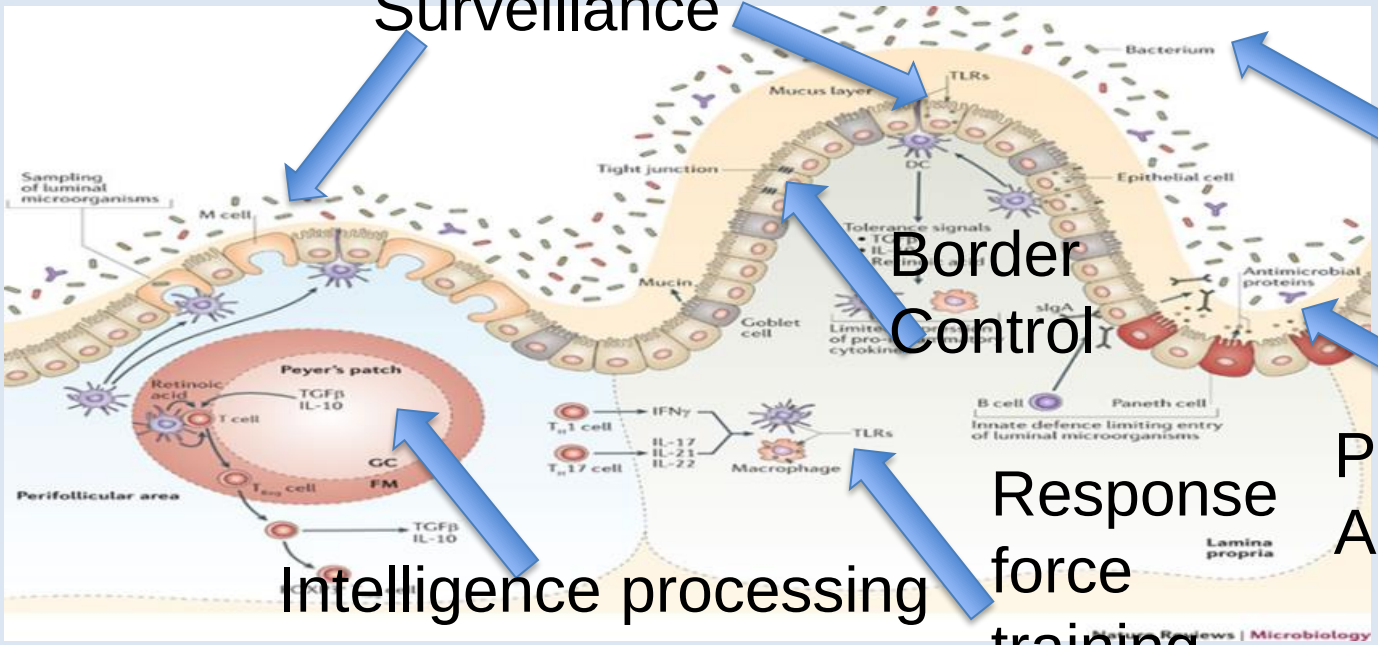


The **Adaptive Immune** system works on **acquired intelligence**

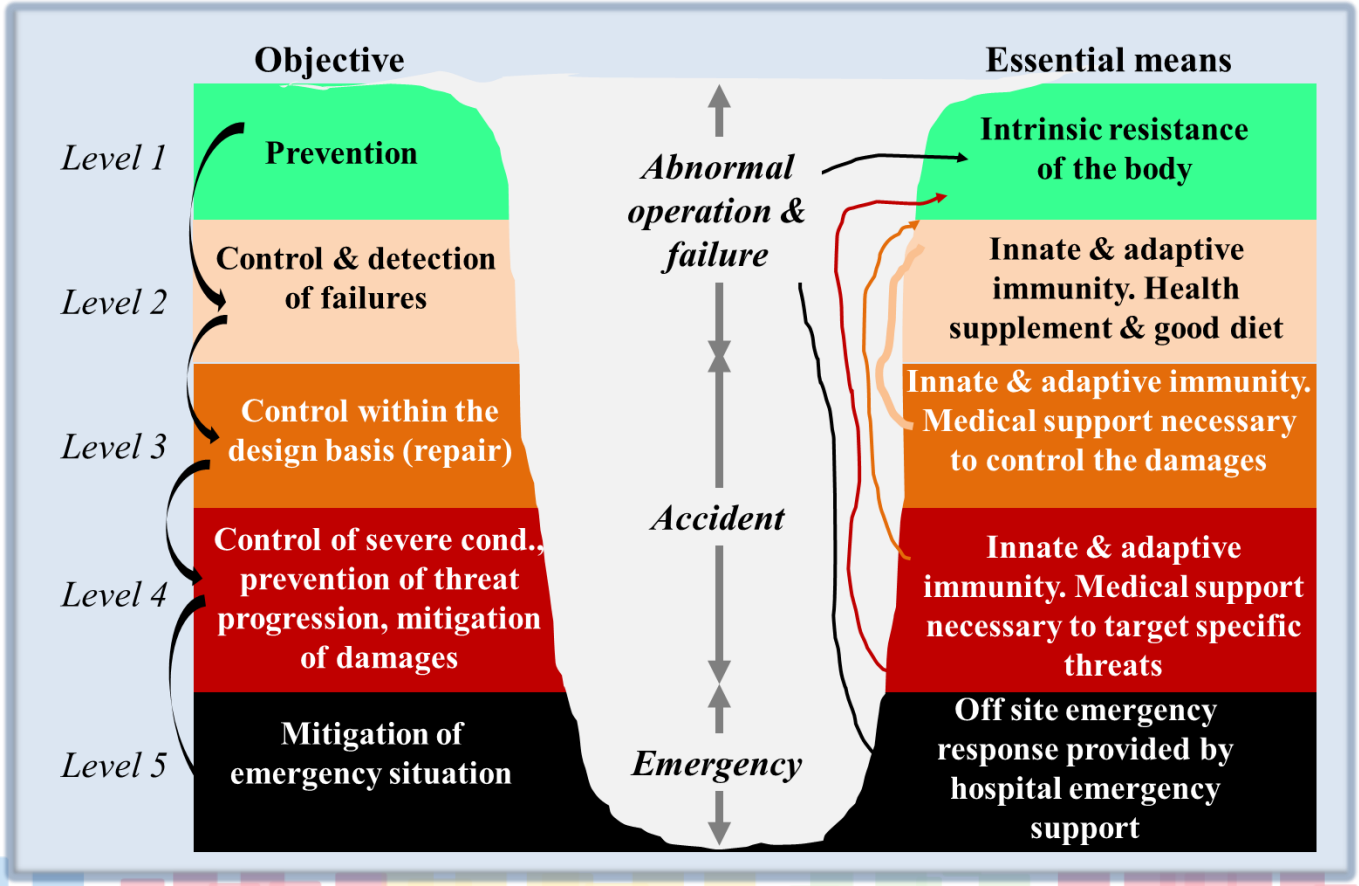
T cells mature in the Thymus, a **training & proving** area *in **friend/foe detection***, where only the top 2% of the candidates pass.

B cell activity is antibody mediated. They are **supported in threat recognition** by **T cells.**

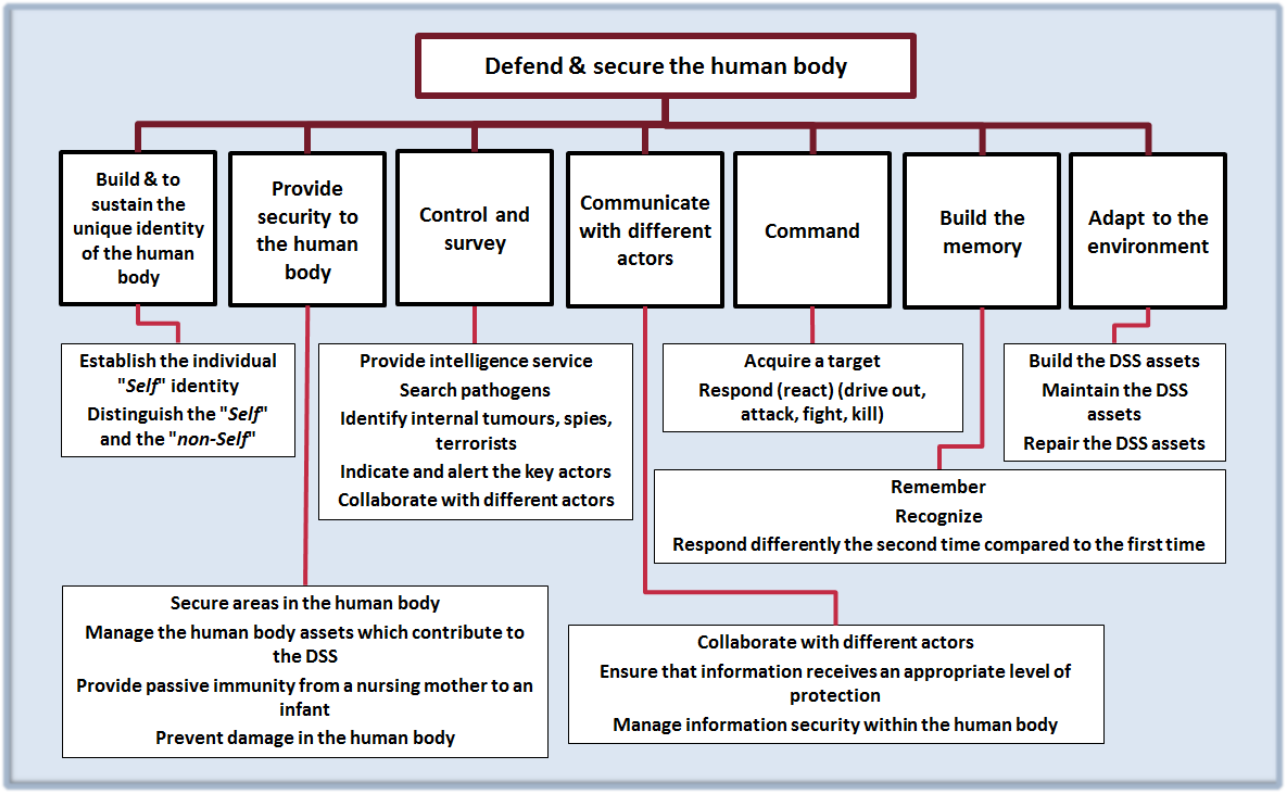
Operational Overview - Border Protection



Levels of protections



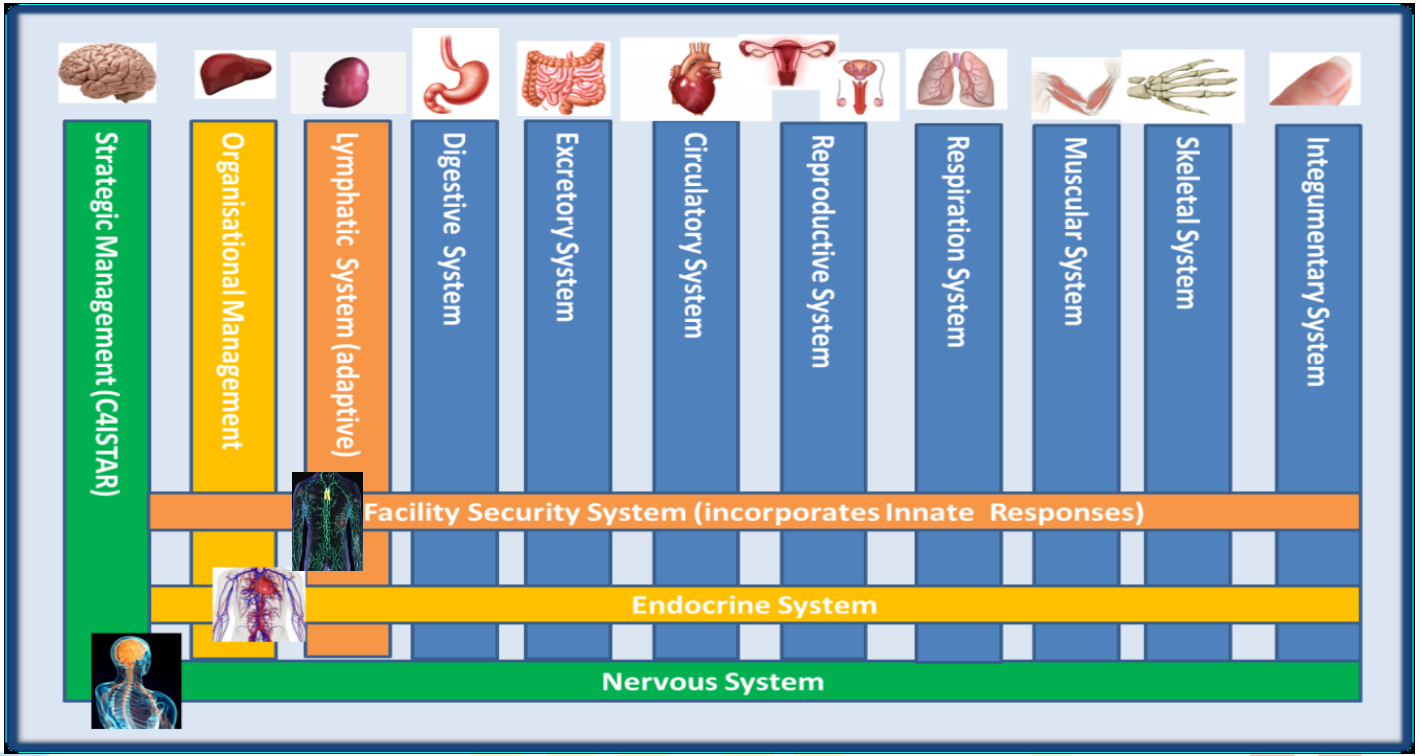
The Defence and Security System functions…



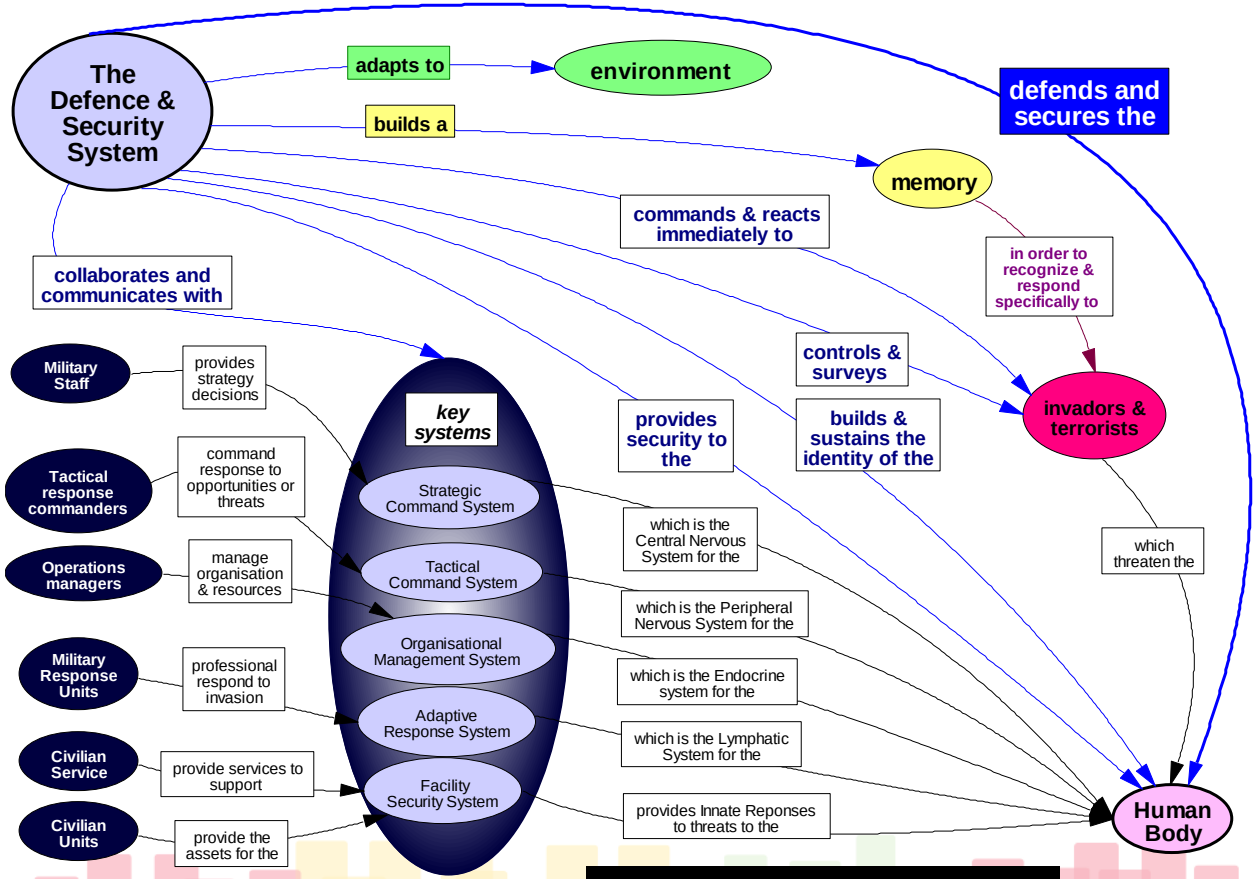
The Defence and Security System architecture

	Facility Security Systems (Includes Innate Responses)					Response systems (Lymphatic system / Adaptive Security Systems)							Endocrine system (Organisational Management Systems)				Peripheral Nervous System (T… Systems)		
	Perimeter Defence Systems			Interior Defence Systems		Primary lymphoid organs		Secondary lymphoid organs					Axis of the Endrocrine System				Autonomus		Som
	Epithelia Tissues, Skull , vertebral column and Ribs	Mucosa and other Excretions from Epithetial Tissue	Commensal Biological Support	Civilian Service Support (Complement System)	Civilian Units (Myeloid progenitor cells)	Bone Marrow (Matures B Cells)	Thymus (Matures T Cells)	Lymph Nodes (Include Tonsils, Peyer's patches)	Lymph Vessels (Includes Ducts)	Spleen	Appendix	Military Response Units (NK, B and T Cells)	Gonad (HPG) (Sex)	Adrenal (HPA) (Stress)	Thyroid (HPT) (Infection)	Stomach (HPS) (Hunger)	Parasympathetic (Rest or Digest)	Sympathetic (Fight or Flight)	Som (Volu Mover
Functions provided by the systems																			
	X				X							X							
To provide different physical barriers of protection	X																		
To provide chemical barriers of protection		X																	
To provide biological barriers of protection (commensal			X																
To provide a protective coating for the mucous surfaces	X																		
To recruit agents of immune response				X	X			X	X	X		X		X	X			X	
												X							

Defence and Security spans our systems of systems – Reconsidering our previous model

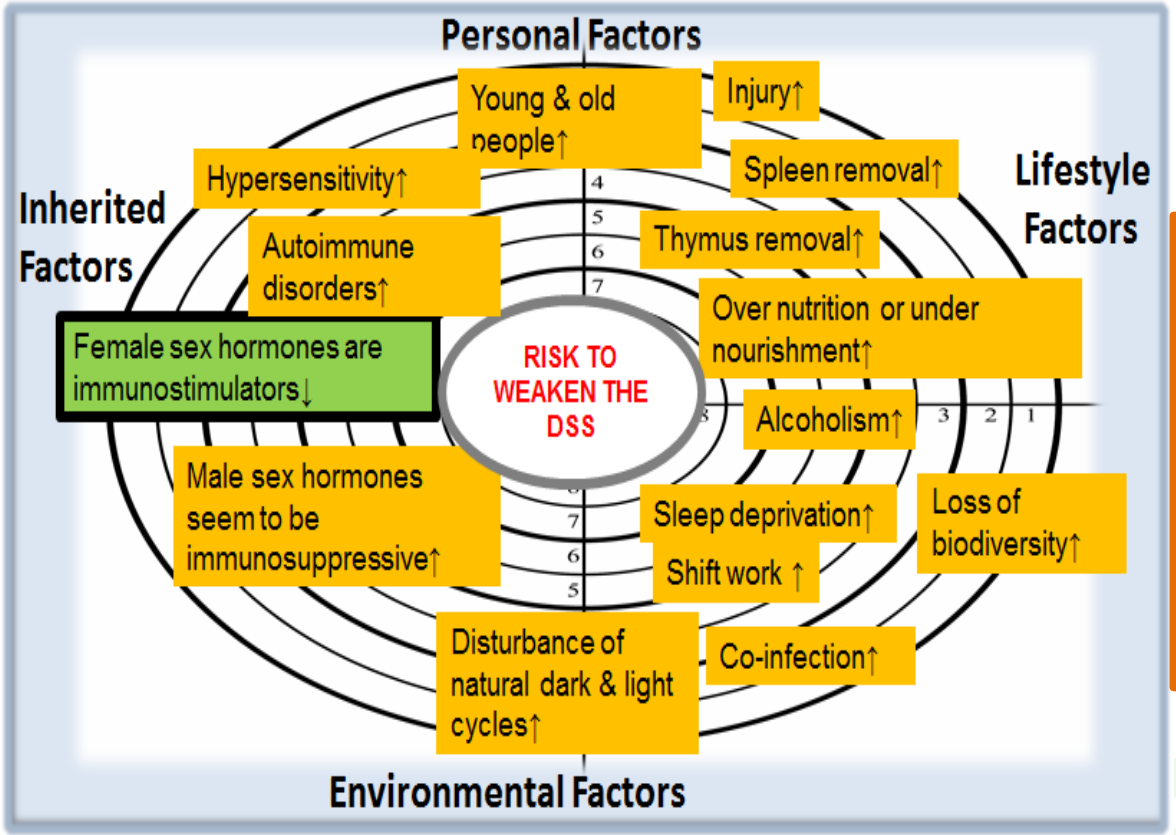


DSS functions, actors & roles



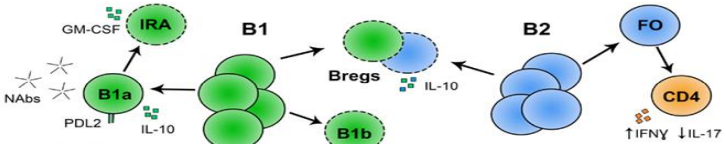
DSS functions, actors and roles

Many factors can throw our defence and security off balance

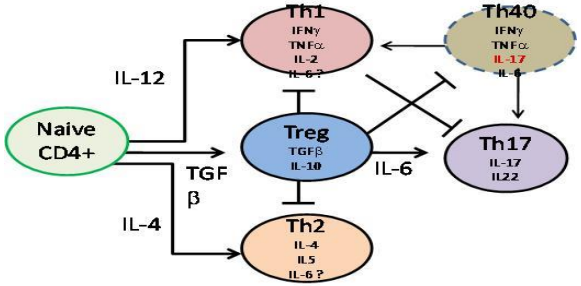


Understanding *these* ***influences*** *might give us some insight into* ***how our DSS functions*** *and the* ***compromises it takes***

Old thinking used to be that Immune Cell phenotype *(observable characteristics)* once set was fixed…

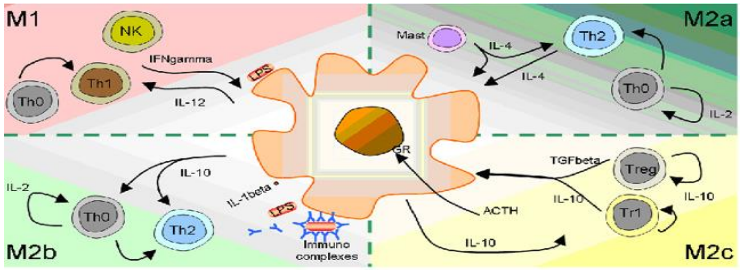


B cell subsets in atherosclerosis, Heather Perry et al. 2012



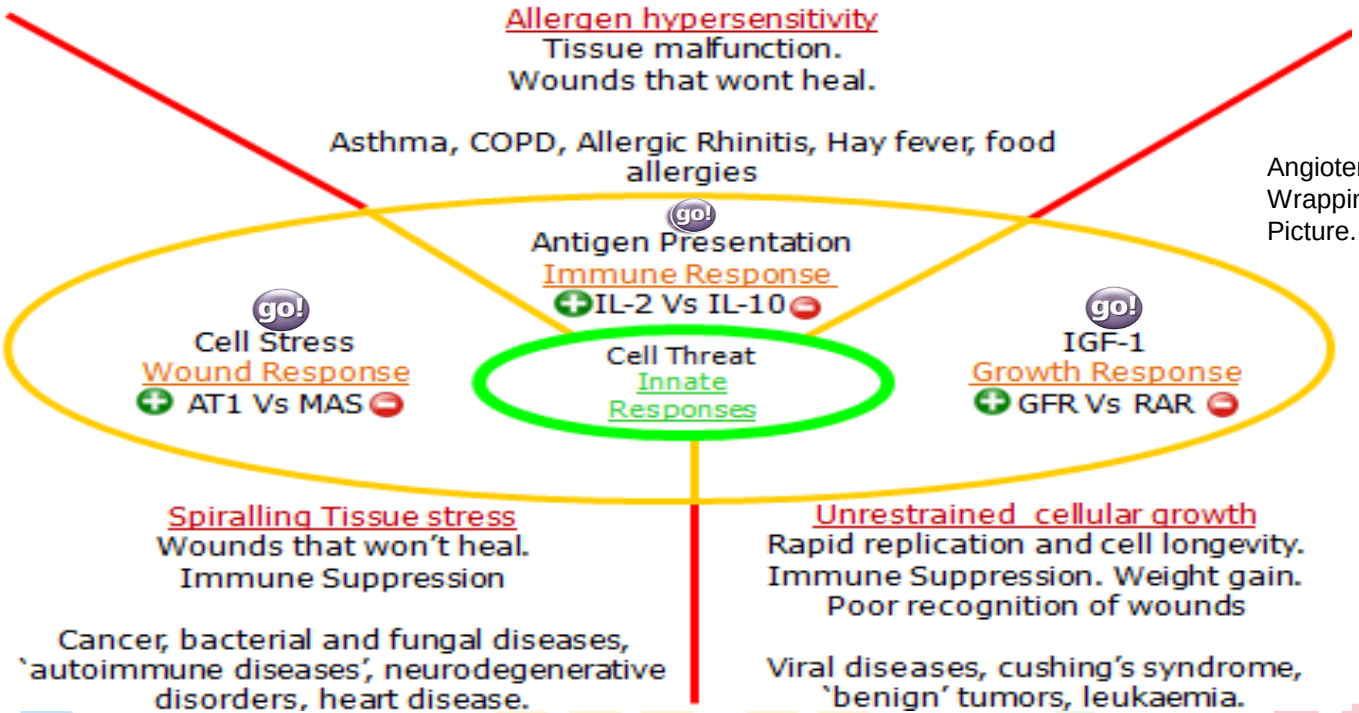
The Role of T Cells in Type 1 Diabetes. By David Wagner 2011.

Macrophage activation and polarization - Fernando Oneissi Martinez et al. 2008



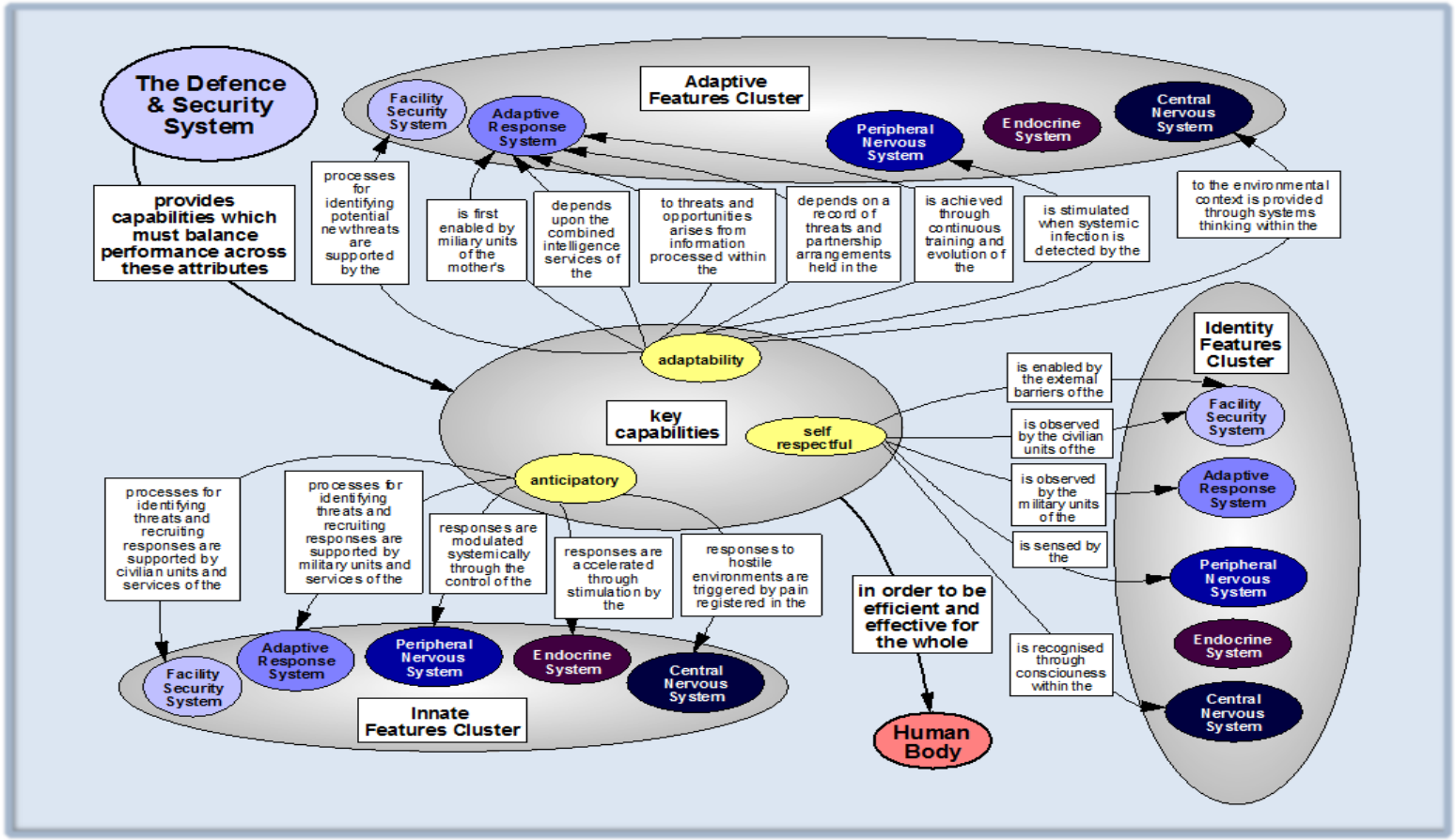
…but this has changed, especially in the last 5 years…

But compromise across capabilities comes at a cost that is exploitable



Angiotensin and Systems Thinking: Wrapping Your Mind Around the Big Picture. Gary R Smith. Ochsner J. 2013

The DSS is a complex adaptive system

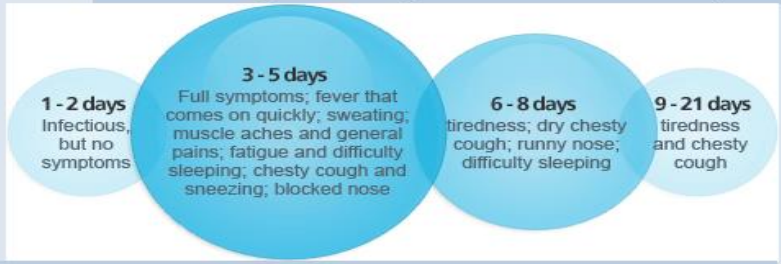


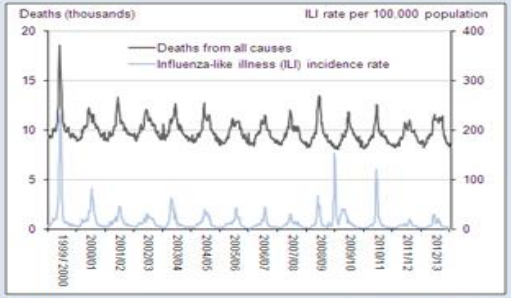
4

Defence & Security System in the context of Influenza

DSS Scenario – Influenza – a viral challenge

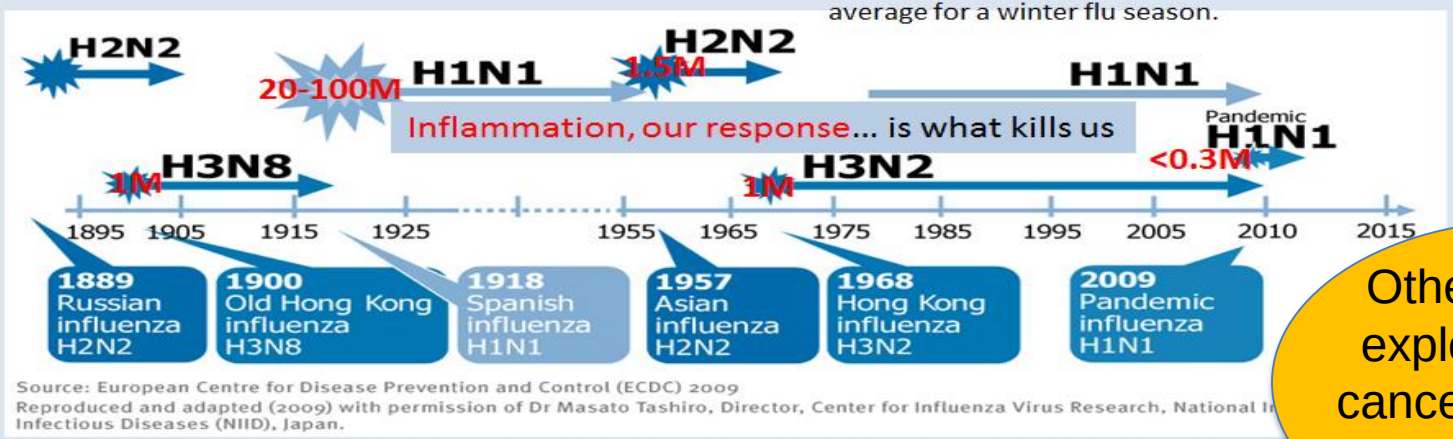
Viruses hijack living cells is order to replicate





Viral mutation is frequent, with new annual outbreaks

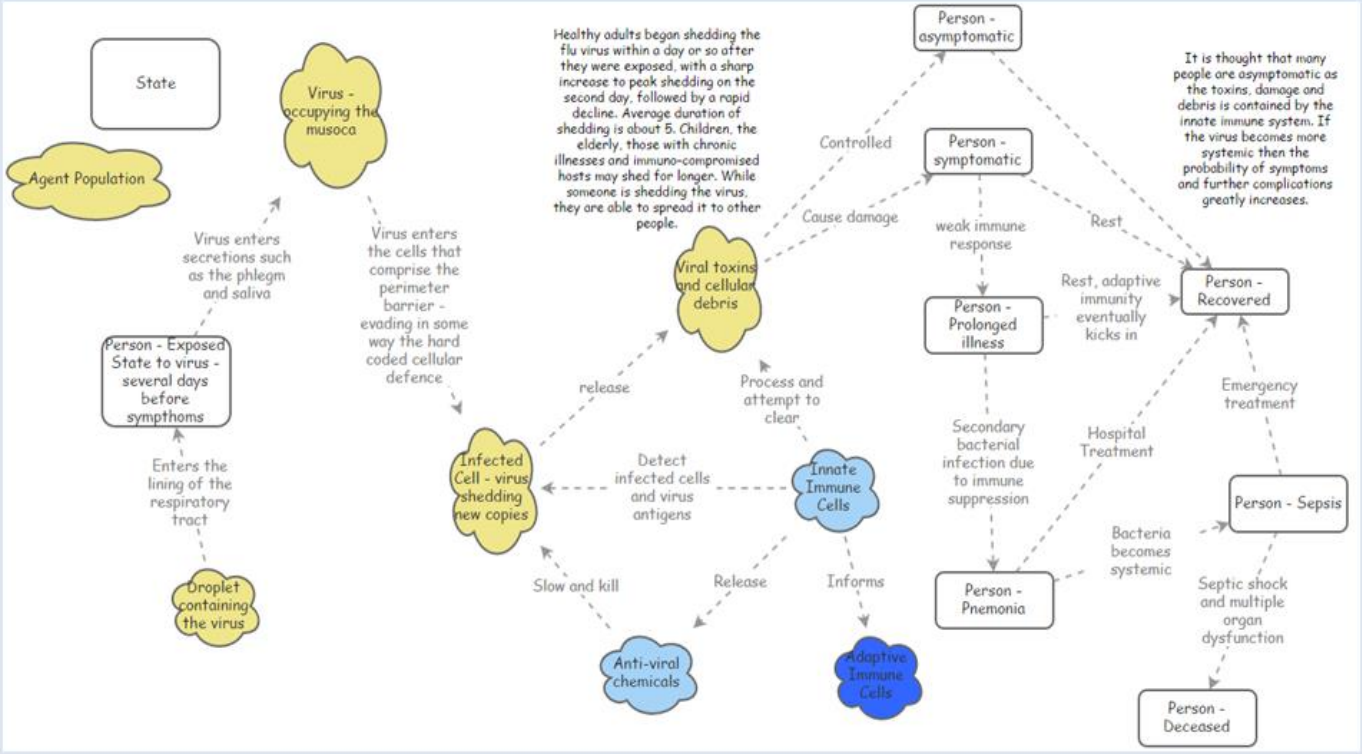
The last big UK flu outbreak occurred in 1999/2000, when 22,000 people died, which is 10 times the average for a winter flu season.



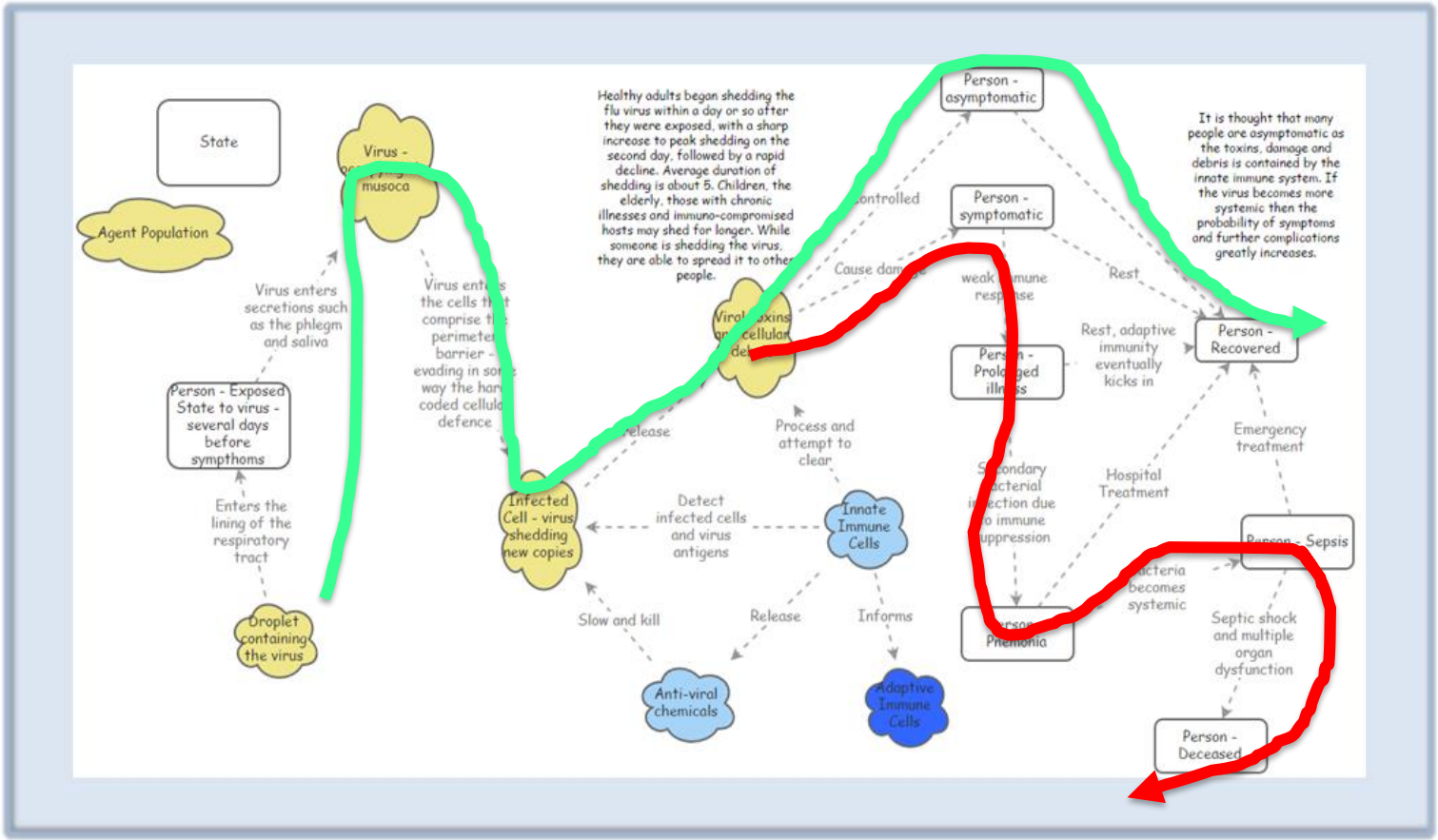
Source: European Centre for Disease Prevention and Control (ECDC) 2009
Reproduced and adapted (2009) with permission of Dr Masato Tashiro, Director, Center for Influenza Virus Research, National I
Infectious Diseases (NIID), Japan.

Other scenarios explored include cancer, sepsis and pre-eclampsia

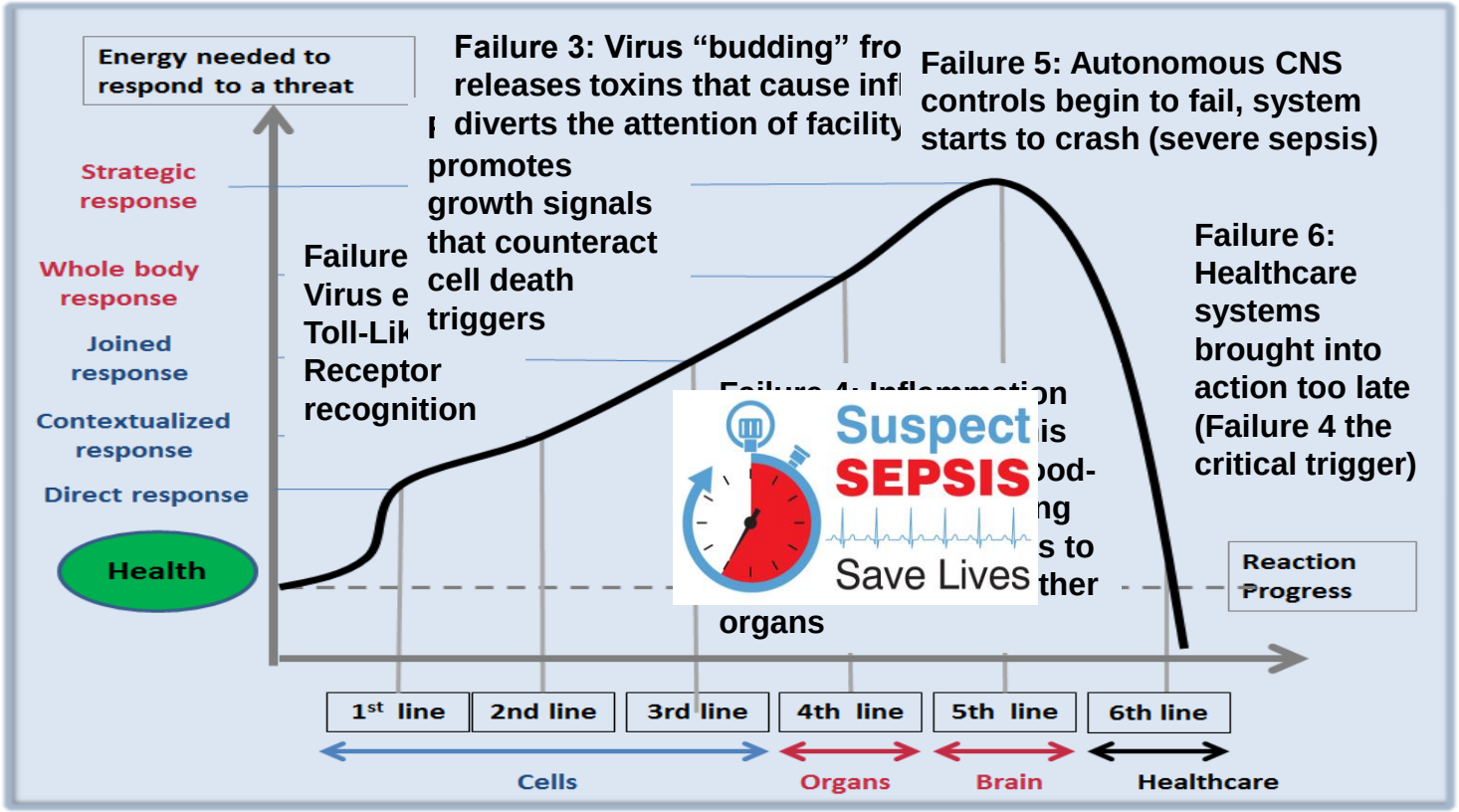
Agent / State Interactions for Influenza progression



Agent / State Interactions for Influenza progression



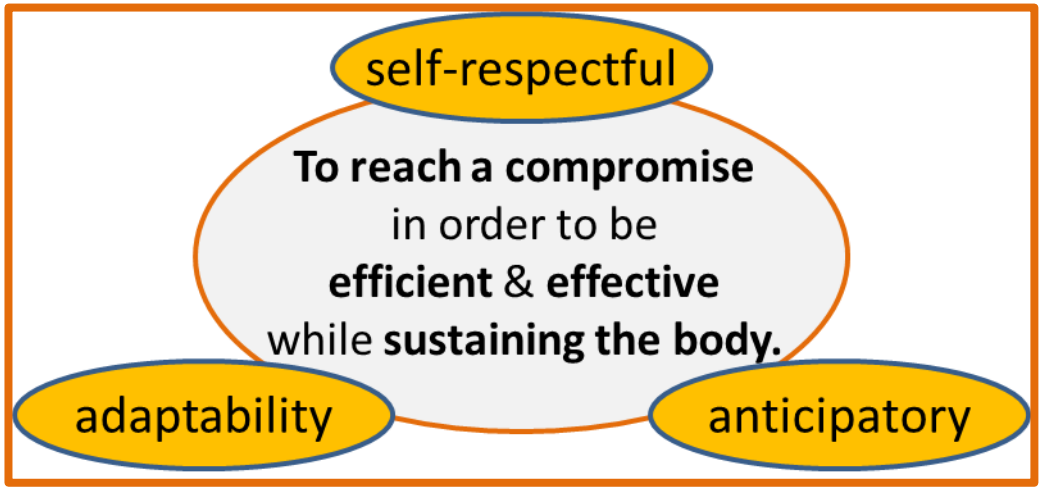
Failures of the DSS leading to death



5

Reflections on the exploration

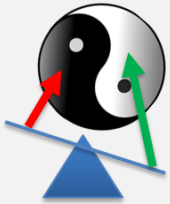
Reflections on the exploration – DSS Capabilities



To balance without resting divergent polarities

7/24/365

Attack
non-specific response
quick reaction



limit damage
specific response only when needed
thoughtful response based on memory

Reflections on the exploration

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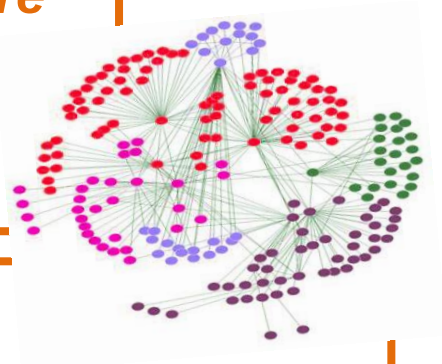
What could be a **benefit for industry to learn more about this DSS**?

- This ***full autonomous distributed system could inspire researches in authority sharing***
- ***A trade-off across attack, repair, learning and cost could also inspire investigations in industry.***



Fields of investigation for us for the next months

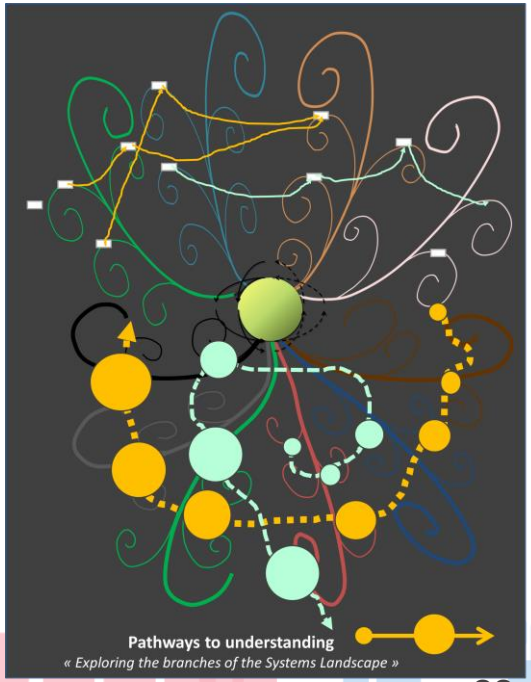
What are the different **DSS information networks interconnected** in a response to a threat taking into account **the topology** of the human body.

Reflections on the exploration

How System Thinking could help to solve the current dilemma of vaccine

A big picture of
stock and flows combined with
end-to-end dynamics combined with
a quotation of expressed need and risks factors

could help for understanding this difficult dilemma that young parents are confronted with as well as elderly people.



Thank you for your attention