Pre-48 hour MRSA

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The Institute is doing an analysis project to explore pre-48 hour MRSA (May to July 2006)

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The challenge of 'explaining' MRSA bacteraemia developed within 48hrs of admission:

- Represents 24% to 33% MRSA bacteraemia: large variation between sites in MES reports
- Several research projects have explored parts of the issue: range of factors have been identified
- By definition a cross-organisation issue. But almost all research and data is acute trust based
- Patterns suggest large % are likely to be associated with previous acute trust care
- But picture is incomplete

Our approach to giving people the understanding they need to improve MRSA rates:

To describe the problem more clearly

- Make explicit assumptions about cause and effect from literature review
- Map the MRSA processes and the way parts of the issue interrelate

To test ideas to improve rates

- Work with Trusts to find about what we could do to make a difference
- Try out / identify changes and measure the impact
- Also gather further data and evidence to fill our knowledge gaps

Where do (pre-48 hour) patients come from? Pattern of healthcare contact for patients with MRSA bacteraemia

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Headline messages from our literature review

- MRSA is mostly associated with acute Trust care, some areas higher risk
- 24 – 33% identified within 48 hours admission
  - Of these 60%+ previous stay at same hospital within 12 months
  - c.28% intensive day case attendance
  - 7-8% immediate hospital transfer
  - 6.5% admission from nursing home or residential home
  - *No mention of GP practice association*
  - Previous MRSA infection or colonisation a significant risk factor for future MRSA

Does this fit with your views / experience?

What factors are associated with MRSA bacteraemia?

Note:
Factors in bold = evidence good
Not in bold = evidence moderate
All acute Trust related

Clinical intervention risk factors

'Day case' renal, haematology, oncology care

Previous central venous catheter

Presence of indwelling catheter

History of antibiotics in last 12 months

Individual **characteristics** that make acquisition / infection more likely

Having clinical **interventions** associated with risk of MRSA infection / bacteraemia

Spending significant time in an **environment** where spread is likely and antibiotic use high

Individual characteristics: risk factors:

Cellulitis

Skin ulcers

Old age

Serious illness

Chronic illness

Spread environment risk factors:

Long stay in ITU

Long stay in an institution

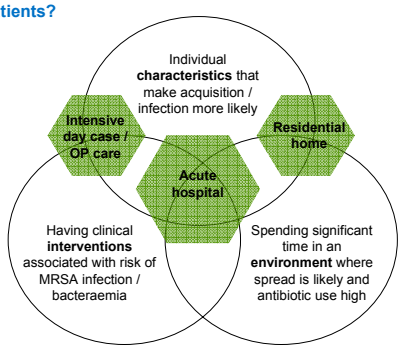
Hospital stay in last 12 months

Transfer from hospital, nursing / residential homes

Would you disagree with any of these factors?

Are there other significant factors?

Do the list of factors explain the pattern of healthcare contact for MRSA patients?



Is this (simplified) explanation accurate? Does it help?

To further understand the factors, we can map them on the process for developing MRSA

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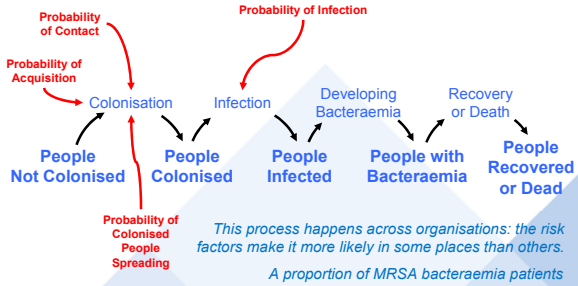

This process happens across organisations: the risk factors make it more likely in some places than others.

A proportion of MRSA bacteraemia patients will have it identified within 48 hours of admission to hospital

Our strategies for tackling MRSA also impact on specific parts of the process

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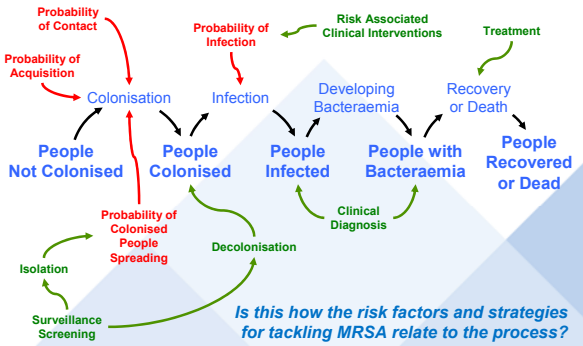

Is this how the risk factors and strategies for tackling MRSA relate to the process?

The process is more complex: this is the latest draft of our (still simplified) system diagram

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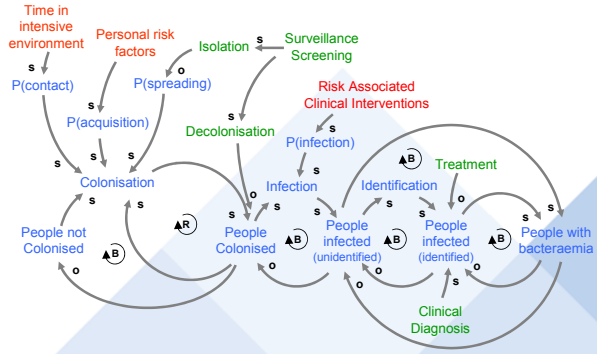

Process leading to MRSA bacteraemia

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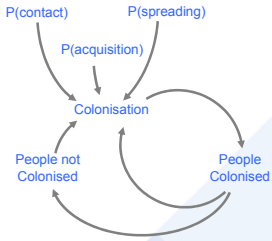

- People who are colonised make contact with people who are <u>not</u> colonised, according to a probability of contact.
- Colonised people will 'spread' MRSA according to a probability of spreading.
- <u>Not</u> colonised people will become colonised according to a probability of acquisition.
- These three probabilities are probably multiplicative in their impact on 'colonisation'.
- If the number of colonised people increases then the number of colonisations increases, and vice versa.

Process leading to MRSA bacteraemia

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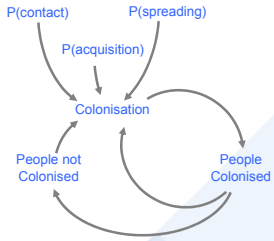

Classically 3 groups of people are described:

- Those with transient carriage, like most clinical staff
- Those with stable carriage at a low level
- "Super Spreaders" – a rare version of the above with high level carriage

Process leading to MRSA bacteraemia

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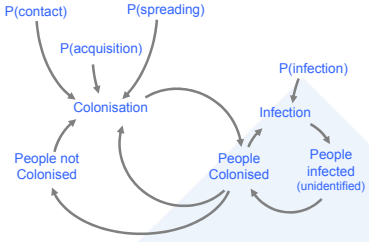

- Some colonised people become infected with MRSA, according to a probability of infection
- Initially these people are 'unidentified'
- They influence the number of people colonised and not infected

Process leading to MRSA bacteraemia

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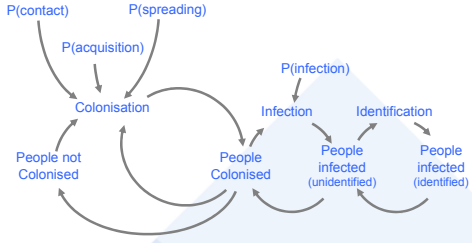

- Infected people may become 'identified'
- They influence the number of people infected and 'unidentified'
- Identification will open up possibilities for intervention

Process leading to MRSA bacteraemia

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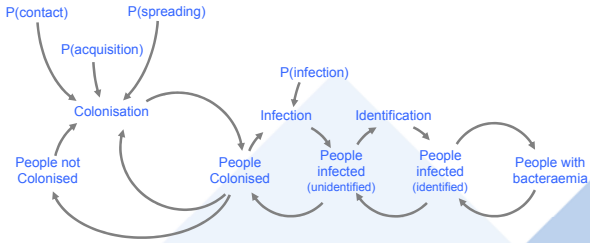

- Some identified infected people will develop a bacteraemia
- They will influence the number of people infected and without a bacteraemia
- There is evidence that the emergence of very virulent strains will influence the policies and behaviour of clinicians in reducing: spreading, contact and acquisition.

Process leading to MRSA bacteraemia

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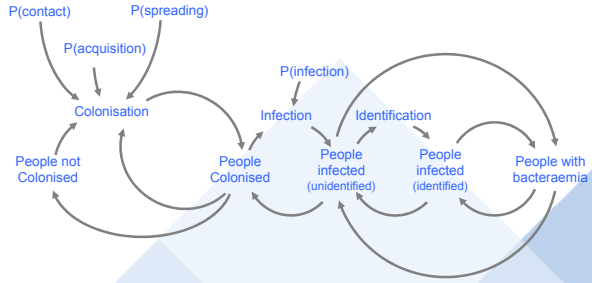

- Some people who are infected, but whose infection has not been identified will also develop a bacteraemia

Process leading to MRSA bacteraemia

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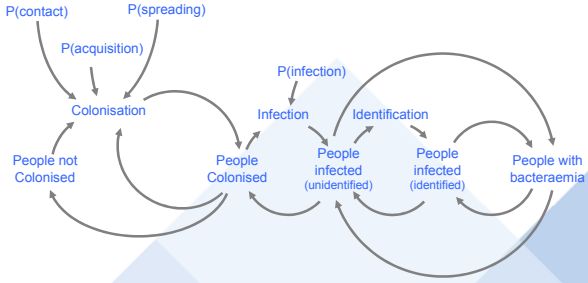

- The size of the population decreases significantly as we move from left to right

Our analysis involves describing the nature of the relationship between different elements

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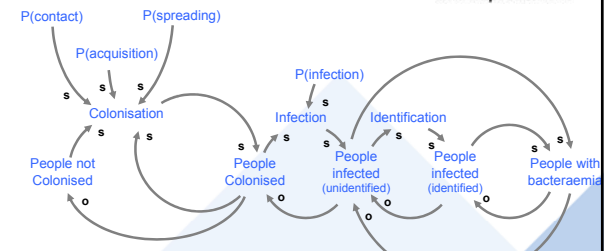

x → y (S)	If *x* increases then *y* increases	If *x* decreases then *y* decreases
x → y (O)	If *x* increases then *y* decreases	If *x* decreases then *y* increases

KEY:
S = supporting
O = opposing

An Example Identifying the relationships between variables

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KEY:
S = supporting
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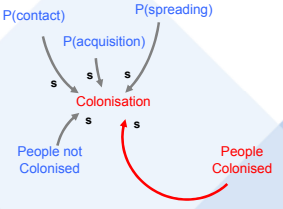
x → y (S)	If *x* increases then *y* increases	If *x* decreases then *y* decreases
x → y (O)	If *x* increases then *y* decreases	If *x* decreases then *y* increases

More people colonised … increases colonisation

OR less people colonised … decreases colonisation



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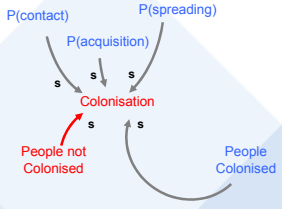
Increasing people not colonised … increases colonisations

OR decreasing people not colonised … decreases colonisation



An Example
Identifying the relationships between variables

Institute for Innovation and Improvement

KEY:
S = supporting
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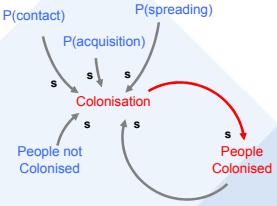
x →(S) y	If *x* increases then *y* increases	If *x* decreases then *y* decreases
x →(O) y	If *x* increases then *y* decreases	If *x* decreases then *y* increases

Increasing colonisation … increases people colonised

OR reducing colonisation … decreases people colonised



An Example
Identifying the relationships between variables

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KEY:
S = supporting
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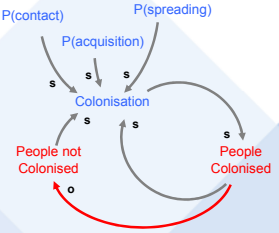
x →(S) y	If *x* increases then *y* increases	If *x* decreases then *y* decreases
x →(O) y	If *x* increases then *y* decreases	If *x* decreases then *y* increases

Increasing people colonised … decreases people not colonised

OR

reducing people colonised … increases people not colonised



One reason to do this analysis is to uncover patterns that may not be obvious

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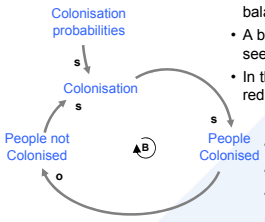
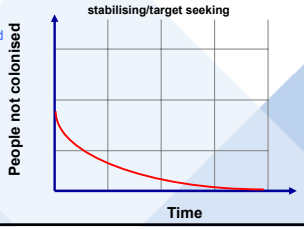


Balancing Loop

- A loop with an odd number of O's is defined as a balancing loop
- A balancing loop in isolation will generate target seeking behaviour
- In this example 'people at risk of contact' would reduce to zero as people become colonised



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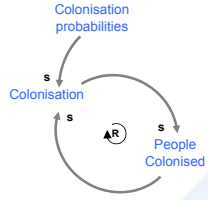
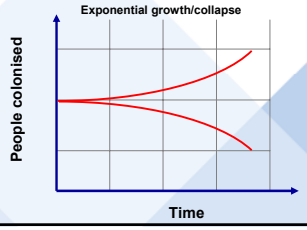


Reinforcing Loop

- A loop without any O's is defined as a reinforcing loop
- A reinforcing loop in isolation will generate exponential growth or collapse
- In this example 'people colonised' would grow or collapse exponentially



Can inferences about cause and effect be made in a complex dynamic system like this?

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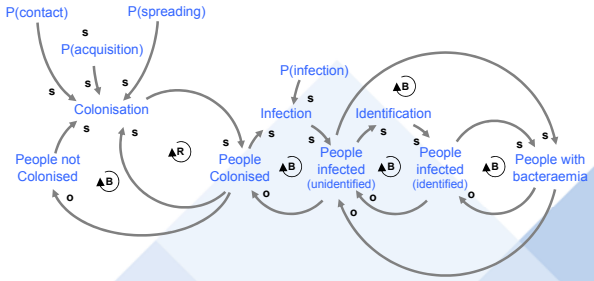
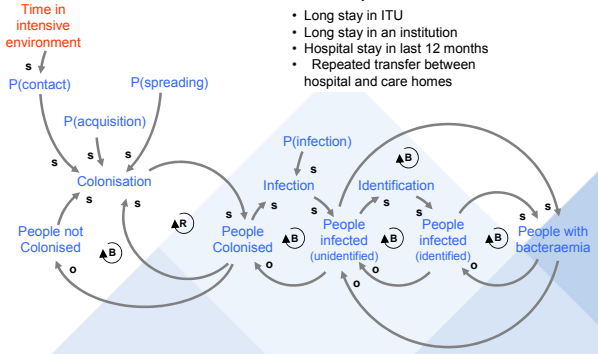


- An intervention on a single variable will have a dynamically complex impact on the whole system
- New strains may develop and transmission parameters may change over time

Colonisation Risk Factors

The research suggests that the probability of contact is associated with time spent in certain environments. Groups of people with this risk may have these characteristics:

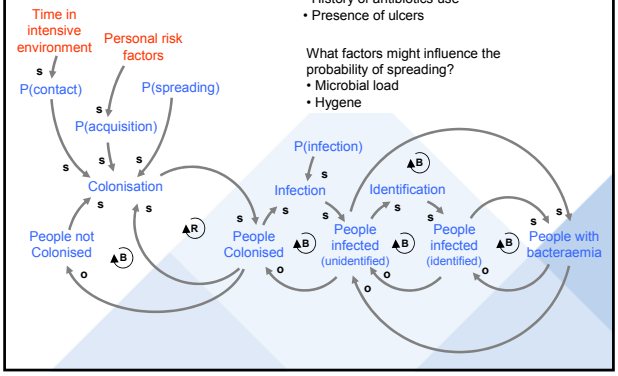
- Long stay in ITU
- Long stay in an institution
- Hospital stay in last 12 months
- Repeated transfer between hospital and care homes



Colonisation Risk Factors

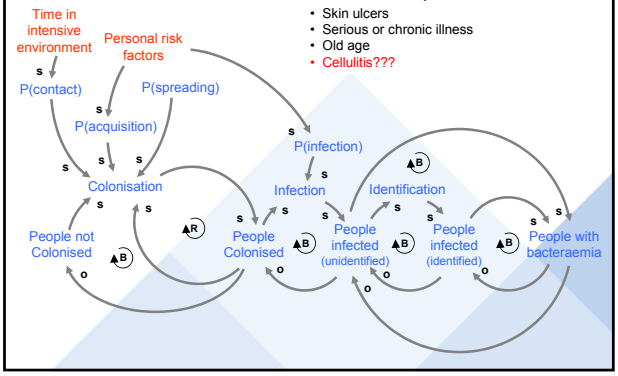
The research suggests that factors influencing the probability of acquisition given contact are:
- History of antibiotics use
- Presence of ulcers

What factors might influence the probability of spreading?
- Microbial load
- Hygene



Infection Risk Factors

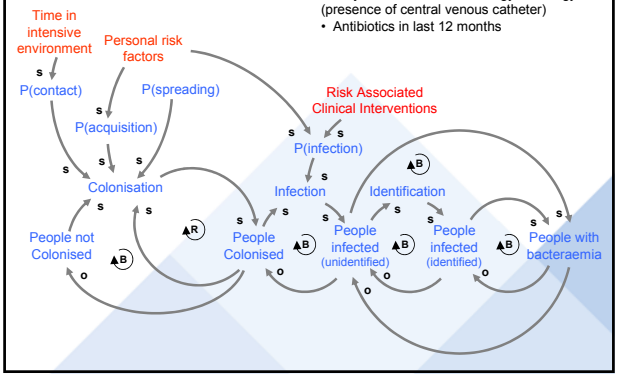
The research suggests that people with these characteristics are *directly* at risk of infection
- Skin ulcers
- Serious or chronic illness
- Old age
- Cellulitis???



Infection Risk Factors

… and that clinical interventions can increase the risk of infection

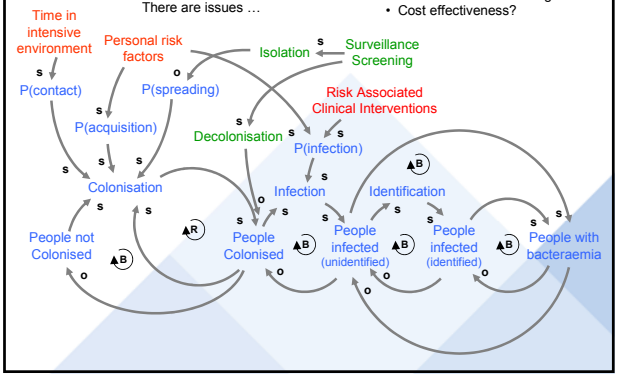
- Presence of indwelling catheter
- 'Day case' renal, haematology, oncology (presence of central venous catheter)
- Antibiotics in last 12 months



Interventions to reduce spreading and colonisation

Surveillance screening for colonised bacteria is an option. There are issues …

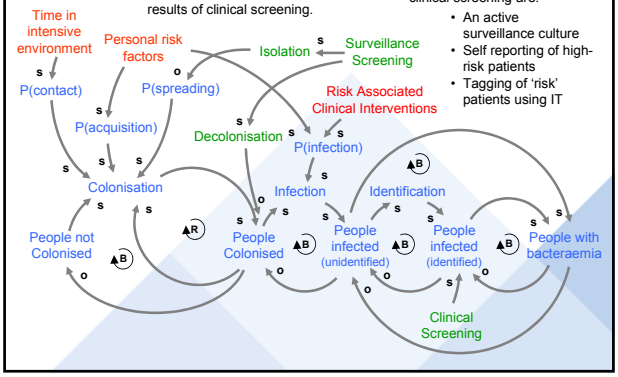
- General or selective screening?
- ITU – universal screening?
- Cost effectiveness?



Interventions to identify infection

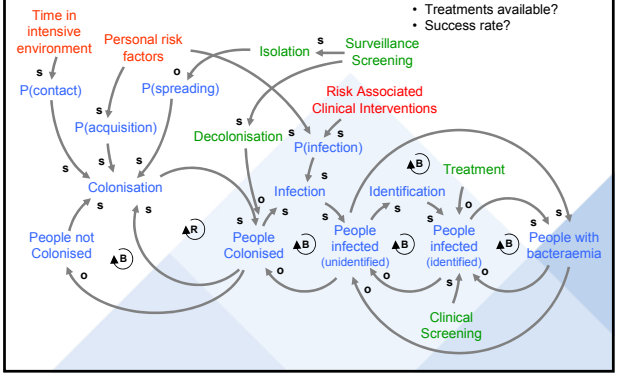
There are issues over how to use the results of clinical screening.

Clinical screening can be used to identify infection. Processes that support clinical screening are:
- An active surveillance culture
- Self reporting of high-risk patients
- Tagging of 'risk' patients using IT



Interventions to treat infected people

Research has provided little information on:
- Treatments available?
- Success rate?



Three Distinct Stages
Contact and colonisation … Infection … Bacteraemia

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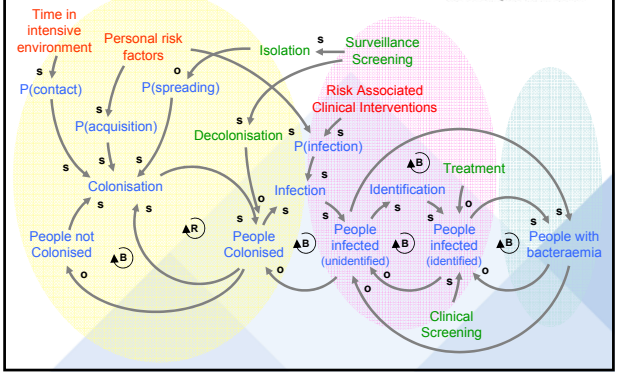

Reporting MRSA bacteraemia – a fourth stage

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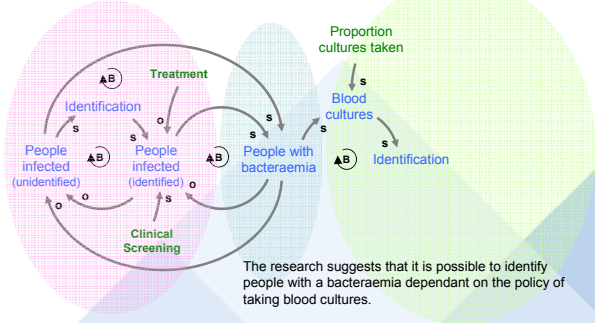

The research suggests that it is possible to identify people with a bacteraemia dependant on the policy of taking blood cultures.

Reporting MRSA bacteraemia – a fourth stage

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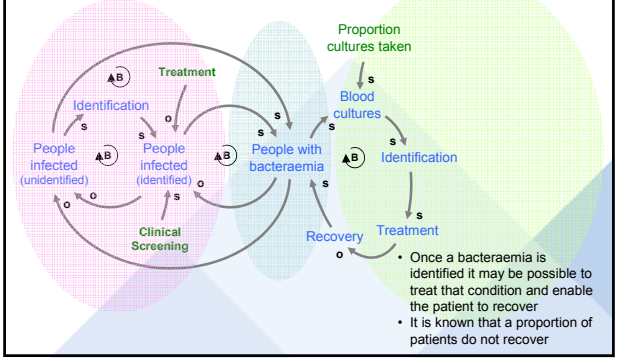

- Once a bacteraemia is identified it may be possible to treat that condition and enable the patient to recover
- It is known that a proportion of patients do not recover

Reporting MRSA bacteraemia – a fourth stage

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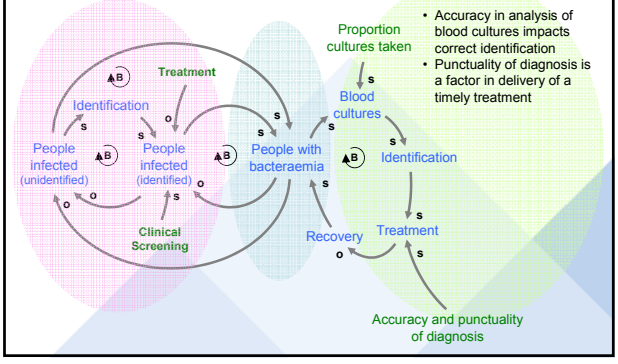

- Accuracy in analysis of blood cultures impacts correct identification
- Punctuality of diagnosis is a factor in delivery of a timely treatment

Reporting MRSA bacteraemia – a fourth stage

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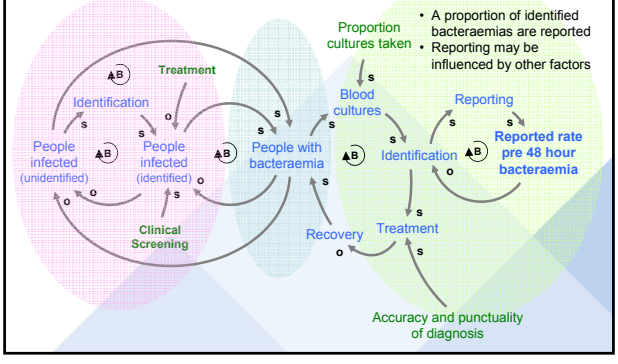

- A proportion of identified bacteraemias are reported
- Reporting may be influenced by other factors

Reporting MRSA bacteraemia – a fourth stage

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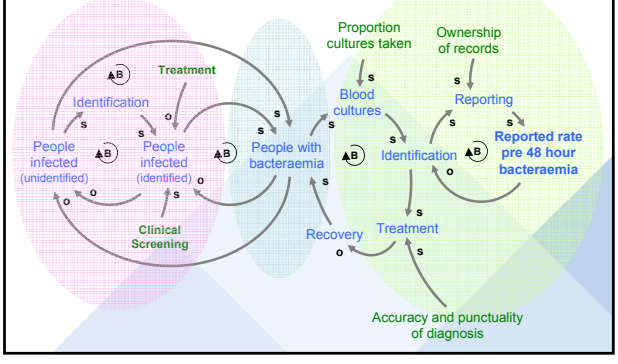
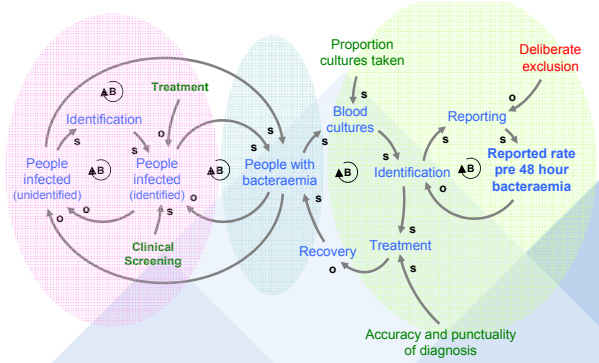
There is a suggestion that, as patients move across organisational boundaries, ownership of patient records and so *who* should report bacteraemias, becomes an issue.



Reporting MRSA bacteraemia – a fourth stage

There is also a hypothesis that there is an element of deliberate exclusion of identified bacteraemias from reported bacteraemias.



Research Questions

- What numbers are going to flow through this system over the next 5 – 10 years?
- How much impact can we have on MRSA?
- How long will it take?
- Should we target sub-populations?
- What will be the unintended side effects of interventions?
- Should we bring together scientific evidence and public discourse & debate to answer these questions?

From *Qualitative* to *Quantitative* Modelling

Why Simulation is Essential

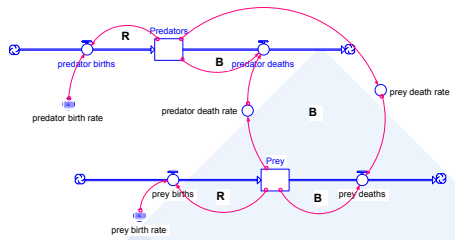
- In the qualitative model the elements of the system remain *vaguely* defined
- We can only speculate about what patterns of behaviour the systems will produce
- A quantitative simulation model will enable people learning about the problem to:
  - Synthesise known data relevant to the problem and test the sensitivity of unknown or 'best guess' data
  - Be precise about variables, processes and policies in the system
  - Show how the model's structures produce known performance of the system in the 'real world'
  - Explore how behaviour will change when different aspects of the structure are altered
  - Unveil points of leverage that might otherwise be ignored
  - Engage teams in experimenting with the consequences of their thinking

The 'map' of our hypotheses can be tested using numbers

- This process has elicited and mapped different people's mental models of the problem
- The method has yielded a qualitative model showing causal relationships
- … leading to an initial hypothesis about the structure of the system responsible for historic levels of pre-48 hour bacteraemia
- However the qualitative model omits important aspects of the problem
  - Initial conditions; e.g. the numbers of the people in the different groups
  - Parameters; e.g. the probability of contact or acquisition
  - Accumulations and rates; e.g. how the population of people spreading MRSA changes over time or the rate at which infected people develop bacteraemia
  - Processes; e.g. the processes by which people become colonised and decolonised
  - Information flows; e.g. reporting of outcomes of screening or blood culture analysis
  - Policies; e.g. how that information is used to influence the system
  - Time delays; e.g. time taken to report information and time for a person to develop a bacteraemia.

Simulation Modelling - Stocks and flows – An Example

Predator Prey Model



In this simple example we model the births, deaths and populations of two species.
Predator death rate is dependent on prey population and vice versa.
Determining the behaviour of this simple system over time is impossible without specifying the initial conditions and parameters.
Simulating the performance of the system over time would be extremely difficult without the aid of a computer.

Simulation Modelling

Stocks and flows

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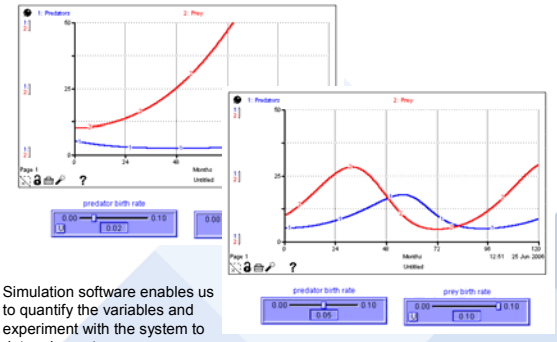

Simulation software enables us to quantify the variables and experiment with the system to determine outcomes.

Further analysis and data work can help to explore immediate actions and longer term issues

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The DoH assumes[1] for a hospital acquired bacteraemia :

- An average additional cost of around £4,300
- An additional length of stay of 11.3 days

Quantitative modelling can enable an enquiry to explore :

- The operational and financial consequences different interventions on the system
- The impact of a community acquired outbreak of MRSA

1. Plowman et al; 'The Socioeconomic Burden of HAI'.

Why is this worth doing?

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- Helps describe 'the whole' of a complex problem visually
- Discussing the specific factors helps generate new ideas and insights
- Cause and effect is not straightforward or linear
- This approach helps you understand how MRSA rates are likely to change when you make specific interventions: so you can assess how to have the biggest, sustainable impact
- We can explore 'in theory' what is likely to be happening across organisations, even when the hard data is mostly from acute Trusts
- At present, this describes qualitatively what people think is happening
- It may be possible to develop this into a quantified model

System Dynamics Bibliography

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A short bibliography relevant to epidemiology.

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