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(54) **Titre : POLYPEPTIDES BACTERIENS ANTIGENIQUES COMME VACCINS**
(54) **Title: ANTIGENIC BACTERIAL POLYPEPTIDES AS VACCINES**

atgggtaaacctgtcgtagccattgtcgggagaccaaatgtaggaaaatccacaatcttt
aaccggattgcgggagaaagaatttcaatagtagaagataccctggcgtgacaagggat
cggatatacagctcggctgaatggctgaattatgatttaatttgattgatacgggcggt
attgatatcggtgatgagccgttttagcgcagattcgccagcaagctgaaatcgccatg
gatgaagcggacgtgattatttttatggtgaacggccgtgaaggcgtgacagctgctgat
gaagaagtggcgaaaatttgtaccgcacaaaaaagcctgttgttttagcggttaataaa
ctggataacacagaaatgagagcgaatatttatgatttttattcgctaggctttggcgag
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gttattgtcagcaacgtggctggaacgacaagagatgctgttgatacgtcatttacttac
aaccagcaggagtttgtcattgtcgatactgcaggtatgcgaaaaaaagggaaagtctat
gaaacgactgagaagtatagtgtactgcgggcgctaaaagcgattgaccgctcagaagtc
gtggcggttgtgctggatggcgaagaaggcattattgaacaggacaagcgtatcgccggt
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cctgcgattatcaaagctagtgaaaatcattcacttcgagttcaaacaaacgtcttaaat
gatgtcatcatggacgctgtggcaatgaatccgacaccgactcataacggttctcgtttg
aaaatttactatgcgactcaagtgtcggtaaagccgccaagcttcgttgtgtttgtaaac
gatccggaactgatgcatttttcatacgaacggtttttagaaaaccgaatcagagacgcg
ttcggttttgaggggacaccaatcaaaatatttgcaagagctagaaaa

(57) **Abrégé/Abstract:**
The invention relates to antigenic polypeptides expressed by pathogenic microbes, vaccines comprising said polypeptides; therapeutic antibodies directed to said polypeptides and methods to manufacture said polypeptides, vaccines and antibodies.

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Abstract

The invention relates to antigenic polypeptides expressed by pathogenic microbes, vaccines comprising said polypeptides; therapeutic antibodies directed to said polypeptides and methods to manufacture said polypeptides, vaccines and antibodies.

ANTIGENIC BACTERIAL POLYPEPTIDES AS VACCINES

The invention relates to antigenic polypeptides expressed by pathogenic microbes, vaccines comprising the antigenic polypeptides and therapeutic antibodies directed to the antigenic polypeptides.

BACKGROUND

A problem facing current medical development is the evolution of antibiotic resistant strains of a number of significant pathogenic microbes. An example of a pathogenic organism which has developed resistance to antibiotics is *Staphylococcus aureus. S. aureus* is a bacterium whose normal habitat is the epithelial lining of the nose in about 20-40% of normal healthy people and is also commonly found on people's skin usually without causing harm. However, in certain circumstances, particularly when skin is damaged, this germ can cause infection. This is a particular problem in hospitals where patients may have surgical procedures and/or be taking immunosuppressive drugs. These patients are much more vulnerable to infection with *S.aureus* because of the treatment they have received. Resistant strains of *S. aureus* have arisen in recent years. Methicillin resistant strains are prevalent and many of these resistant strains are also resistant to several other antibiotics. Currently there is no effective vaccination procedure for *S. aureus*.

The present invention is concerned with the identification of potential vaccine components and therapies against which the problem of directly resistant pathogen strains is avoided or reduced.

Amongst the approximately 4100 genes in the soil gram-positive bacterium *Bacillus subtilis* chromosome, 271 are indispensable ("essential") for growth and among them, 23 have undefined roles in the physiology of the organism (*gcp, obg, ppaC-yybQ-, trmU, yacA, yacM, ydiB, ydiC, yjbN, ykqC, ylaN, yloQ, ylqF, ymdA, yneS, yphC, yqeH, yqeI, yqjK, yrvO, ysxC, ytaG, ywlC*) (Kunst *et al.* 1997) . Homologs of the proteins encoded by these genes can be found in the various strains sequenced thus far of another gram-positive bacterium, the human pathogen *Staphylococcus aureus*. Amongst them, the Gcp and YneS orthologs are predicted membrane proteins (See

Appendix I), while the rest are predicted cytoplasmic proteins.(data not shown). Nonetheless, Obg has been shown to be partially bound to membranes in *B. subtilis* (Kobayashi *et al.* 2001).

The inventors have isolated certain polypeptides that are essential components for growth of the pathogens *Bacillus subtilis* and *Staphylococcus aureus* and have raised antisera against these polypeptides. Antisera raised against the *Bacillus subtilis* polypeptides was found to result in extremely potent killing of *Staphylococcus aureus*. This effect could not have been predicted.

The present findings facilitate the development of vaccines and antibody therapies that mitigate some of the problems of current therapies such as antibiotic resistance.

BRIEF SUMMARY OF THE DISCLOSURE

The present invention provides antigenic polypeptides that are essential for growth of the gram-positive bacteria *Bacillus subtilis* and *Staphylococcus aureus* and which are useful in the treatment or prevention of microbial infections.

According to a first aspect of the invention there is provided an antigenic polypeptide, or part thereof, encoded by an isolated nucleic acid sequence selected from the group consisting of:

i) a nucleic acid sequence as shown in Figures 1 to 6;

ii) a nucleic acid sequence as in (i) which encodes a polypeptide expressed by a pathogenic organism;

iii) a nucleic acid sequence which hybridises to the sequence identified in (i) or (ii) above; and

iv) a nucleic acid sequence that is degenerate as a result of the genetic code to the nucleic acid sequence defined in (i), (ii) or (iii)

for use as a medicament.

In a preferred aspect of the invention the medicament is a vaccine.

The nucleic acid encoding the antigenic polypeptide of the first aspect of the invention may anneal under stringent hybridisation conditions to the nucleic acid sequence shown in Figures 1 to 6 or to its complementary strand.

Stringent hybridisation/washing conditions are well known in the art. For example, nucleic acid hybrids that are stable after washing in 0.1xSSC, 0.1% SDS at 60°C. It is well known in the art that optimal hybridisation conditions can be calculated if the sequences of the nucleic acid is known. For example, hybridisation conditions can be determined by the GC content of the nucleic acid subject to hybridisation. Please see Sambrook *et al* (1989) Molecular Cloning; A Laboratory Approach. A common formula for calculating the stringency conditions required to achieve hybridisation between nucleic acid molecules of a specified homology is:

$T_m = 81.5^0$ C + 16.6 Log [Na^+] + 0.41[% G + C] –0.63 (%formamide).

The nucleic acid encoding the antigenic polypeptide of the first aspect of the invention may comprise the sequence set out in Figures 1 to 6 or a sequence which is at least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, for example 98%, or 99%, identical to the nucleic acid sequence set out in Figures 1 to 6 at the nucleic acid residue level.

"Identity", as known in the art, is the relationship between two or more polypeptide sequences or two or more polynucleotide sequences, as determined by comparing the sequences. In the art, identity also means the degree of sequence relatedness between polypeptide or polynucleotide sequences, as the case may be, as determined by the match between strings of such sequences. Identity can be readily calculated (*Computational Molecular Biology,* Lesk, A.M. ed., Oxford University Press, New York, 1988; *Biocomputing: Informatics and Genome Projects,* Smith, D.W., ed., Academic Press, New York, 1993; *Computer Analysis of Sequence Data,* Part I, Griffin, A.M., AND Griffin, H.G., eds., Humana Press, New Jersey, 1994; *Sequence Analysis in Molecular Biology,* von Heinje, G., Academic Press, 1987; and *Sequence Analysis Primer*, Gribskov, M. and Devereux, J., eds., M Stockton Press, New York, 1991). While there exist a number of methods to measure identity between two polynucleotide or two polypeptide sequences, the term is well-known to skilled

artisans (*Sequence Analysis in Molecular Biology*, von Heinje, G., Academic Press, 1987; *Sequence Analysis Primer*, Gribskov, M. and Devereux, J., eds., M Stockton Press, New York, 1991; and Carillo, H., and Lipman, D., *SIAM J. Applied Math.*, 48: 1073 (1988). Methods commonly employed to determine identity between sequences include, but are not limited to those disclosed in Carillo, H., and Lipman, D., *SIAM J. Applied Math.*, 48: 1073 (1988). Preferred methods to determine identity are designed to give the largest match between the sequences tested. Methods to determine identity are codified in computer programs. Preferred computer program methods to determine identity between two sequences include, but are not limited to, GCG program package (Devereux, J., et al., *Nucleid Acids Research* 12(1): 387 (1984)), BLASTP, BLASTN, and FASTA (Atschul, S.F. et al., *J. Molec. Biol.* 215: 403 (1990)).

The nucleic acid encoding the antigenic polypeptide of the first aspect of the invention may comprise of fragment of a sequence according to the first aspect which is at least 30 bases long, for example, 40, 50, 60, 70, 80 or 90 bases in length.

The nucleic acid sequence encoding the antigenic polypeptide of the first aspect of the invention may be genomic DNA, cDNA or RNA, for example mRNA.

The antigenic polypeptide of the first aspect of the invention may be a cell membrane protein, for example an integral membrane protein or a cytoplasmic protein.

Preferably, the antigenic polypeptide of the first aspect of the invention is expressed by a pathogenic organism, for example, a bacterium, virus or yeast. Preferably the pathogenic organism is a bacterium. The bacterium may be a gram-positive or gram-negative bacterium, preferably a gram-positive bacterium.

The bacterium may be selected from the group consisting of:

Bacillus subtillis, Staphylococcus aureus; Staphylococcus epidermidis; Enterococcus faecalis; Mycobacterium tuberculsis; Streptococcus group B; Streptoccocus pneumoniae; Helicobacter pylori; Neisseria gonorrhea; Streptococcus group A; Borrelia burgdorferi; Coccidiodes immitis; Histoplasma sapsulatum; Neisseria

meningitidis type B; Shigella flexneri; Escherichia coli; Haemophilus influenzae; ***Listeria monocytogenes, Bacillus anthracis, Corynebacterium diptheriae, Clostridium tetani, Mycoplasma*** spp. and ***Treponema pallidum.***

Preferably the bacterium is of the genus *Staphylococcus spp.* Preferably still the bacterium is *Staphylococcus aureus.*

In a preferred embodiment of the invention, the antigenic polypeptide of the first aspect of the invention is associated with infective pathogenicity of an organism as defined herein.

In a further preferred aspect of the invention the antigenic polypeptide comprises all, or part of, the amino acid sequence shown in Figure 7 to 12.

As used herein "part of" may include a polypeptide fragment which may be at least 10, 15, 20 or 30 amino acids long.

The antigenic polypeptide of the first aspect of the invention may comprise a non-protein antigen, for example a polysaccharide antigen.

As used herein, the term "polypeptide" means, in general terms, a plurality of amino acid residues joined together by peptide bonds. It is used interchangeably and means the same as peptide, protein, oligopeptide, or oligomer. The term "polypeptide" is also intended to include fragments, analogues and derivatives of a polypeptide wherein the fragment, analogue or derivative retains essentially the same biological activity or function as a reference protein.

According to a second aspect of the invention there is provided a vector comprising a nucleic acid sequence encoding a polypeptide according to the first aspect of the invention.

The vector of the second aspect of the invention may be a plasmid, cosmid or phage. The vector may include a transcription control sequence (promoter sequence) which

mediates cell specific expression, for example, a cell specific, inducible or constitutive promoter sequence. The vector may be an expression vector adapted for prokaryotic or eukaryotic gene expression, for example, the vector may include one or more selectable markers and/or autonomous replication sequences which facilitate the maintenance of the vector in either a eukaryotic cell or prokaryotic host (Sambrook et al (1989) Molecular Cloning: A Laboratory Manual, Cold Spring Harbour Laboratory, Cold Spring Harbour, NY and references therein; Marston, F (1987) DNA Cloning Techniques: A Practical Approach Vol III IRL Press, Oxford UK; DNA Cloning: F M Ausubel et al, Current Protocols in Molecular Biology, John Wiley & Sons, Inc.(1994). Vectors which are maintained autonomously are referred to as episomal vectors.

Promoter is an art recognised term and may include enhancer elements which are *cis* acting nucleic acid sequences often found 5' to the transcription initiation site of a gene (enhancers can also be found 3' to a gene sequence or even located in intronic sequences and is therefore position independent). Enhancer activity is responsive to *trans* acting transcription factors (polypeptides) which have been shown to bind specifically to enhancer elements. The binding/activity of transcription factors (please see Eukaryotic Transcription Factors, by David S Latchman, Academic Press Ltd, San Diego) is responsive to a number of environmental cues which include intermediary metabolites (eg glucose, lipids), environmental effectors (eg light, heat,).

Promoter elements also include so called TATA box and RNA polymerase initiation selection (RIS) sequences which function to select a site of transcription initiation. These sequences also bind polypeptides which function, *inter alia*, to facilitate transcription initiation selection by RNA polymerase.

The vector of the second aspect of the invention may include a transcription termination or polyadenylation sequences. This may also include an internal ribosome entry sites (IRES). The vector may include a nucleic acid sequence that is arranged in a bicistronic or multi-cistronic expression cassette.

According to a third aspect of the invention there is provided a method for the production of a recombinant antigenic polypeptide according to any previous aspect of the invention comprising:

(i) providing a cell transformed/transfected with a vector according to the second aspect of the invention;

(ii) growing said cell in conditions suitable for the production of said polypeptides; and

(iii) purifying said polypeptide from said cell, or its growth environment.

In a preferred aspect of the method of the third aspect, the vector encodes, and thus said recombinant polypeptide is provided with, a secretion signal to facilitate purification of said polypeptide.

According to a fourth aspect of the invention there is provided a cell or cell-line transformed or transfected with the vector according to the second aspect of the invention.

In a preferred embodiment of the invention said cell is a prokaryotic cell, for example, yeast or a bacterium such as *E.coli*. Alternatively said cell is a eukaryotic cell, for example a fungal, insect, amphibian, mammalian, for example, COS, CHO cells, Bowes Melanoma and other suitable human cells, or plant cell.

According to a fifth aspect of the invention there is provided a vaccine comprising at least one antigenic polypeptide, or part thereof, according to the first aspect of the invention. Preferably said vaccine further comprises a carrier and/or adjuvant.

As used herein "part thereof" may include a fragment or subunit of the antigenic polypeptide wherein the fragment or subunit is sufficient to induce an antigenic response in a recipient.

The vaccine according to the fifth aspect may be a subunit vaccine in which the immunogenic part of the vaccine is a fragment or subunit of the antigenic polypeptide according to the first aspect of the invention.

The terms adjuvant and carrier are construed in the following manner. Some polypeptide or peptide antigens contain B-cell epitopes but no T cell epitopes. Immune responses can be greatly enhanced by the inclusion of a T cell epitope in the polypeptide/peptide or by the conjugation of the polypeptide/peptide to an immunogenic carrier protein such as key hole limpet haemocyanin or tetanus toxoid which contain multiple T cell epitopes. The conjugate is taken up by antigen presenting cells, processed and presented by human leukocyte antigens (HLA's) class II molecules. This allows T cell help to be given by T cell's specific for carrier derived epitopes to the B cell which is specific for the original antigenic polypeptide/peptide. This can lead to increase in antibody production, secretion and isotype switching.

An adjuvant is a substance or procedure which augments specific immune responses to antigens by modulating the activity of immune cells. Examples of adjuvants include, by example only, agonsitic antibodies to co-stimulatory molecules, Freunds adjuvant, muramyl dipeptides, liposomes. An adjuvant is therefore an immunomodulator. A carrier is an immunogenic molecule which, when bound to a second molecule augments immune responses to the latter.

In yet a further aspect of the invention there is provided a method to immunise an animal against a pathogenic microbe comprising administering to said animal at least one polypeptide, or part thereof, according to the first aspect of the invention. Preferably, the polypeptide is in the form of a vaccine according to the fifth aspect of the invention.

In a preferred method of the invention the animal is human.

Preferably the antigenic polypeptide of the first aspect, or the vaccine of the fifth aspect, of the invention can be delivered by direct injection either intravenously, intramuscularly, subcutaneously. Further still, the vaccine or antigenic polypeptide, may be taken orally. The polypeptide or vaccine may be administered in a pharmaceutically acceptable carrier, such as the various aqueous and lipid media, such

as sterile saline, utilized for preparing injectables to be administered intramuscularly and subcutaneously. Conventional suspending and dispersing agents can be employed. Other means of administration, such as implants, for example a sustained low dose releasing bio-observable pellet, will be apparent to the skilled artisan.

The vaccine may be against the bacterial species *Staphylococcus aureus S. epidermidis*, *Streptococcus pneumoniae*, *Streptococcus pyogenes*, and *B. anthracis*, *Listeria monocytogenes.*

It will also be apparent that vaccines or antigenic polypeptides are effective at preventing or alleviating conditions in animals other than humans, for example and not by way of limitation, family pets (e.g. domestic animals such as cats and dogs), livestock (e.g. cattle, sheep, pigs) and horses.

A further aspect of the invention provides a pharmaceutical composition comprising an effective amount of at least one of the polypeptides of the invention, or a vaccine of the invention. These polypeptides may also include a pharmaceutically acceptable carrier or diluent.

According to a further aspect of the invention there is provided an antibody, or at least an effective binding part thereof, which binds at least one antigenic polypeptide, or part thereof, according to the invention.

As antibodies can be modified in a number of ways, the term "antibody" should be construed as covering any binding member or substance having a binding domain with the required specificity for the antigenic polypeptide. Thus, this term covers antibody fragments, derivatives, functional equivalents and homologues of antibodies, including any polypeptide comprising an immunoglobulin binding domain, whether natural or wholly or partially synthetic. Chimeric molecules comprising an immunoglobulin binding domain, or equivalent, fused to another polypeptide are therefore included. Cloning and expression of chimeric antibodies are described in EP-A-0120694 and EP-A-0125023.

In a preferred aspect of the invention said antibody is a polyclonal or monoclonal antibody.

In a further preferred aspect of the invention said antibody is a chimeric antibody produced by recombinant methods to contain the variable region of said antibody with an invariant or constant region of a human antibody.

In a further preferred aspect of the invention, said antibody is humanised by recombinant methods to combine the complimentarity determining regions of said antibody with both the constant (C) regions and the framework regions from the variable (V) regions of a human antibody.

Preferably said antibody is provided with a marker including a conventional label or tag, for example a radioactive and/or fluorescent and/or epitope label or tag.

Preferably said humanised monoclonal antibody to said polypeptide is produced as a fusion polypeptide in an expression vector suitably adapted for transfection or transformation of prokaryotic or eukaryotic cells.

Antibodies, also known as immunoglobulins, are protein molecules which have specificity for foreign molecules (antigens). Immunoglobulins (Ig) are a class of structurally related proteins consisting of two pairs of polypeptide chains, one pair of light (L) (low molecular weight) chain (κ or λ), and one pair of heavy (H) chains (γ, α, μ, δ and ε), all four linked together by disulphide bonds. Both H and L chains have regions that contribute to the binding of antigen and that are highly variable from one Ig molecule to another. In addition, H and L chains contain regions that are non-variable or constant.

The L chains consist of two domains. The carboxy-terminal domain is essentially identical among L chains of a given type and is referred to as the "constant" (C) region. The amino terminal domain varies from L chain to L chain and contributes to the binding site of the antibody. Because of its variability, it is referred to as the "variable" (V) region.

The H chains of Ig molecules are of several classes, α, μ, σ, α, and γ (of which there are several sub-classes). An assembled Ig molecule consisting of one or more units of two identical H and L chains, derives its name from the H chain that it possesses. Thus, there are five Ig isotypes: IgA, IgM, IgD, IgE and IgG (with four sub-classes based on the differences in the H chains, i.e., IgG1, IgG2, IgG3 and IgG4). Further detail regarding antibody structure and their various functions can be found in, Using Antibodies: A laboratory manual, Cold Spring Harbour Laboratory Press.

Chimeric antibodies are recombinant antibodies in which all of the V-regions of a mouse or rat antibody are combined with human antibody C-regions. Humanised antibodies are recombinant hybrid antibodies which fuse the complimentarity determining regions from a rodent antibody V-region with the framework regions from the human antibody V-regions. The C-regions from the human antibody are also used. The complimentarity determining regions (CDRs) are the regions within the N-terminal domain of both the heavy and light chain of the antibody to where the majority of the variation of the V-region is restricted. These regions form loops at the surface of the antibody molecule. These loops provide the binding surface between the antibody and antigen.

Antibodies from non-human animals provoke an immune response to the foreign antibody and its removal from the circulation. Both chimeric and humanised antibodies have reduced antigenicity when injected to a human subject because there is a reduced amount of rodent (i.e. foreign) antibody within the recombinant hybrid antibody, while the human antibody regions do not illicit an immune response. This results in a weaker immune response and a decrease in the clearance of the antibody. This is clearly desirable when using therapeutic antibodies in the treatment of human diseases. Humanised antibodies are designed to have less "foreign" antibody regions and are therefore thought to be less immunogenic than chimeric antibodies.

In a further preferred embodiment of the invention said antibodies are antibodies whose activity is mediated by complement for example, the activity of the antibody may be activated by complement.

In another aspect of the invention there is provided a vector comprising a nucleic acid sequence encoding the humanised or chimeric antibodies according to the invention.

In a yet further aspect of the invention, there is provided a cell or cell line which comprises the vector encoding the humanised or chimeric antibody according to the invention. The cell or cell line may be transformed or transfected with the vector encoding the humanised or chimeric antibody according to the invention.

In a yet further aspect of the invention there is provided a hybridoma cell line which produces a monoclonal antibody as hereinbefore described.

In a further aspect of the invention there is provided a method of producing monoclonal antibodies according to the invention using hybridoma cell lines according to the invention.

In a yet further aspect of the invention there is provided a method for the production of the humanised or chimeric antibody according to the invention comprising :

(i) providing a cell transformed or transfected with a vector which comprises a nucleic acid molecule encoding the humanised or chimeric antibody according to the invention;

(ii) growing said cell in conditions suitable for the production of said antibody; and

purifying said antibody from said cell, or its growth environment.

In a further aspect of the invention there is provided a method for preparing a hybridoma cell-line according to the invention comprising the steps of:

i) immunising an immunocompetent mammal with an immunogen comprising at least one polypeptide having an amino acid sequence as represented in Figure s 7 to 12, or fragments thereof;

ii) fusing lymphocytes of the immunised immunocompetent mammal with mycloma cells to form hybridoma cells;

iii) screening monoclonal antibodies produced by the hybridoma cells of step (ii) for binding activity to the amino acid sequences of (i);

iv) culturing the hybridoma cells to proliferate and/or to secrete said monoclonal antibody; and

v) recovering the monoclonal antibody from the culture supernatant.

The immunocompetent mammal may be a mouse, rat or rabbit.

The production of monoclonal antibodies using hybridoma cells is well-known in the art. The methods used to produce monoclonal antibodies are disclosed by Kohler and Milstein in Nature 256, 495-497 (1975) and also by Donillard and Hoffman, "Basic Facts about Hybridomas" in Compendium of Immunology V.II ed. by Schwartz, 1981.

In a further aspect of the invention there is provided the use of an antigenic polypeptide according to the first aspect of the invention in the manufacture of a medicament for the treatment or prophylaxis of a microbial infection or a microbe related disorder.

Preferably, the microbial infection is a bacterial infection caused by a bacterial pathogen derived from a bacterial species selected from the group consisting of: *Staphylococcus spp e.g, Staphylococcus aureus, Staphylococcus pyrogenes, Staphylococcus epidermidis; Enterococcus spp e.g. Enterococcus faecalis; Lysteria spp; Pseudomonas spp, Mycobacterium spp e.g Mycobacterium tuberculsis; Enterobacter spp; Campylobacter spp, Salmonella spp; Streptococcus spp e.g Streptococcus group A or B, Streptoccocus pneumoniae; Helicobacter spp e.g Helicobacter pylori; Neisseria spp e.g. Neisseria gonorrhea, Neisseria meningitidis; Borrelia burgdorferi spp; Shigella spp e.g. Shigella flexneri; Escherichia coli spp; Haemophilus spp e.g. Haemophilus influenzae, Chlamydia spp e.g. Chlamydia trachomatis, Chlamydia pneumoniae, Chlamydia psittaci; Francisella tularensis; Bacillus spp e.g. Bacillus anthracis; Clostridia spp e.g. Clostridium botulinum; Yersinia spp e.g. Yersinia pestis; Treponema spp; Burkholderia spp; e.g. Burkholderia mallei and B pseudomallei.*

The bacteria related disorder may be a *Staphylococcus aureus*-associated disorder. A *Staphylococcus aureus*-associated disorder may include, for example, septicaemia; tuberculosis; bacteria-associated food poisoning; blood infections; peritonitis; endocarditis; osteomyelitis; sepsis; skin disorders, meningitis; pneumonia; stomach ulcers; gonorrhoea; strep throat; streptococcal-associated toxic shock; necrotizing fasciitis; impetigo; histoplasmosis; Lyme disease; gastro-enteritis; dysentery; shigellosis

In a further aspect of the invention there is provided the use of antibodies according to the invention in the manufacture of a medicament for the treatment of a microbial infection.

In a further aspect of the invention there is provided a method of treating a patient comprising administering to the patient an antigenic polypeptide according to the first aspect of the invention, or a vaccine according to the fifth aspect of the invention, or an antibody according to the invention.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", means "including but not limited to", and is not intended to (and does not) exclude other moieties, additives, components, integers or steps.

Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

An embodiment of the invention will now be described by example only and with reference to the following materials, methods and figures:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the DNA sequence of the yphC polypeptide from *Bacillus subtilis*;

Figure 2 shows the DNA sequence of the ysxC polypeptide from *Bacillus subtilis*;

Figure 3 shows the DNA sequence of the ywlC polypeptide from *Bacillus subtilis*;

Figure 4 shows the DNA sequence of the yneS ortholog peptide 731 from *Staphylococcus aureus*;

Figure 5 shows the DNA sequence of the yneS ortholog peptide 733 from *Staphylococcus aureus*;

Figure 6 shows (a) the DNA sequence encoding the gcp region putatively exposed outside of the membrane; and (b) the full DNA sequence of the gcp ortholog polypeptide, both from *Staphylococcus aureus*;

Figures 7 to 11 show the amino acid sequences corresponding to the DNA sequences shown in Figures 1 to 5 respectively;

Figure 12 (a) and (b) show the amino acid sequences corresponding to the DNA sequences shown in Figure 6 (a) and (b) respectively;

Figures 13 and 14 show hydropathy plots of the membrane proteins yneS and gcp. The calculation of the hydropathy plots of the proteins stated above and the corresponding graphic representation to predict the transmembrane topology model was determined according to the ConPredII Method;

Figure 15 Graphs showing that heat treatment of sera from a human patient (□), from a non-immunized rabbit (○) or from sera raised against the *A. thaliana* cyclophilin protein (△) did not induce death of *S. aureus* SJF741. No killing of *S. aureus* SJF741 was observed either when using native sera from a patient convalescent from *S. aureus* infection (■) (Panel A) and from a non-immunized rabbit (●) (Panel B). When native sera raised against the *A. thaliana* cyclophilin protein (▲) (Panel C), against the *B. subtilis* proteins Obg (▼) and YdiB (✚) (Panel D) and against the *S. aureus* protein SA1387 (◆) (Panel E) a minor decrease in the number of *S. aureus* SJF741 during the first 6 hours was observed, which was followed by subsequent recovery.

Figure 16 Graphs showing that native sera raised against the *B. subtilis* proteins YsxC (●), YphC (■), and YwlC (▲) (Panels **A** and **B**) killed *S. aureus* SJF471 dramatically, a 5 log decrease within 2 to 4 hours. A similar effect was observed when using native sera raised against the S. aureus peptides YneS-731 (▼) and YneS 733 (◆) and the S. aureus protein Gcp (✚) (Panels **C-E**). In contrast, heat treating the sera raised against the *B. subtilis* YsxC protein (○) or the *S. aureus* peptides YneS-731 (▽) and YneS-733 (◇) (Panels **A, C, D**) abolished the killing abilities of these sera, which were able to kill S. aureus SJF741 in the native form (not heat-treated), as indicated above. Hence, the killing abilities of the sera are due to a heat labile component, which is inactivated in the heat treated sample. No experiments using heat treated sera raised against the *B. subtilis* proteins YphC (■) and YwlC (▲) or against the *S. aureus* gcp protein (✚) are shown in this figure, and the experiments with the corresponding native sera (Panels **B** and **E**), as indicated above, illustrate the *S. aureus* killing capability of these sera.

EXAMPLES

MATERIALS AND METHODS

Strains

The chromosomal DNA used for PCR amplification of the gene sequences of interest were *B. subtilis subsp. subtilis str.* 168, *S. aureus* NCTC 8325, *S. aureus* N315 and *S. aureus* COL (See Table I for information regarding the location of the DNA sequences). An erythromycin resistant *sodA::lacZ* transcriptional fusion derivative of *S. aureus* SH1000 (*S. aureus* SJF741), was the strain used in the assays (Horsburgh *et al.* 2002).

Table I

DNA, protein and peptide sequences used as antigens

The gene and protein sequences of the genes mentioned can be found at:
B. subtilis subsp. subtilis str. 168

S. aureus 8325. (this is a non-annotated sequence; equivalent annotated sequences of *S. aureus* containing the genes of interest can be found below): Iandolo *et al*, 2002; Novick, 1967; University of Oklahoma Norman Campus, Advanced Center for GenomeTechnology

Other *S. aureus* strains:

S. aureus subsp aureus str. N315: Kuroda, 2001;

S. aureus strain subsp. *aureus* COL: The Center for Genomic Research

NOTE: Different strains of S. aureus have different locus names for the same genes due to phage insertions within the sequence. In this document, the locus names used for the S. aureus genes correspond to those in the S. aureus N315 sequence.

Antigen preparation

The genes encoding selected proteins from *Bacillus subtilis* 168 (Obg, YdiB, YphC (Fig 1), YsxC (Fig 2), YwlC (Fig 3), and *S. aureus* N315 (SA1387, Gcp/SA1854 (Fig 6)) were amplified by PCR. The resulting products were cloned in plasmid pETBlue-1, and the genes overexpressed in Escherichia coli Tuner™(DE3) pLacI Competent Cells (Novagen) according to the manufacturers instructions. The overexpressed proteins were purified in a 3-step scheme based on anion exchange, hydrophobic and gel filtration chromatography. The level of protein overexpression was confirmed by SDS-PAGE, and the purity had an average of 90%. In addition, selected peptides within the *S. aureus* N315 protein SA1187 (YneS-731 (Fig 4) and YneS-733 (Fig 5)) were synthesized on a Milligen 9050 Peptide Synthesizer using F-moc chemistry. The F-moc amino acids (Novobiochem/Merck) were activated immediately before coupling using equimolar amounts of HCTU or HBTU in the presence of a 10% molar excess of HOBt. In both cases, a cysteine was incorporated at the C-terminus of the peptide to enable linkage to carrier protein by assembling the peptide on Fmoc-L-Cys(Trt)-PEG-PS resin (Applied Biosystems). Peptides were purified using a C18 Vydac column (22x250 mm) using gradients of acetonitrile in 0.1% TFA. Peptides were verified by Mass Spectrometry. The purified peptides were conjugated to KLH (Sigma) (carrier protein) to enhance immunogenicity of the hapten in the rabbit. Conjugation was performed in 10x PBS using MBS (Sigma).

Sera

Sera were obtained from the Antibody Resource Center at the University of Sheffield from: i) rabbits immunized against proteins from *B. subtilis* (Obg, YdiB, YphC, YwlC and YsxC and *S. aureus* (Gcp, SA1387); ii) rabbits immunized against KLH-conjugated peptides selected within the *S. aureus protein* SA1187 (YneS-731, YneS-733); iii) rabbits immunized against a KLH-conjugated peptide from the cyclophilin

protein from *Arabidopsis thaliana*; iv) naive (non-immune) rabbit serum; and, v) human serum from a patient convalescent from a *S. aureus* infection.

The immunization process was performed as follows. For each rabbit 200 to 500 μg of antigen (in a maximum volume of 250 ul of Phosphate Buffer Saline, PBS) were mixed with an equal volume of complete Freund's adjuvant. The solution was filtered through a 23G needle until an emulsion formed which did not separate on standing. Inoculate each rabbit with a maximum of 500 μl subcutaneously. On day 22, 43 and 64 the injection was repeated but using incomplete Freund's adjuvant. Sample bleeds were collected on day 53 and after day 64. Injection dates were flexible within a range of 3 to 6 weeks. When a suitable titre is detected in the test serum a final boost followed by bleed out 10 days later can be planned.

Sera were stored frozen being thawed and filtered through 0.2 μm pore diameter filters (Minisart High Flow, Sartorius) immediately before use in killing experiments.

Using western blot analysis (data not shown) it was shown that antibodies against the *B. subtilis* YdiB recognize a band of the size corresponding to the YdiB homolog in *S. aureus*, suggesting the species cross-reactivity of these antibodies.

Media and growth conditions

To prepare the inoculum for the serum experiments S. aureus SJF741 was grown at 37°C in Brain Heart Infusion medium (BHI; Oxoid) supplemented with erythromycin (Sigma) to a final concentration of 5 μg/ml (BHI-Ery).

Preparation of the inoculum

A single colony of S. aureus SJF741 freshly grown on BHI-Ery plates from the laboratory frozen stock was inoculated in 30 ml universals containing 5 ml of BHI-Ery and incubated overnight (between 12 to 16 hours) at 37°C in an orbital shaker (250 rpm). A 10-fold dilution in Phosphate Saline Buffer (PBS) of the resulting culture was prepared immediately before inoculation into serum.

Serum experiments

Aliquots of 200 μl from the various sera in 1.5 ml microfuge tubes were inoculated with the PBS dilution of *S. aureus* SJF741 (See Preparation of the inoculum) to a final cell density of $1x10^6$ to $1x10^7$ cells/ml, followed by incubation in a rotary shaker at 37°C. 10 ul samples were taken periodically from these serum cultures, serially diluted, and 10 ul from each dilution plated on BHI-Ery plates, which were subsequently incubated at 37°C overnight. In addition, another 10 ul sample from each serum culture was directly plated on BHI-Ery plates. Only the dilutions rendering between 1 to 40 colonies were enumerated and the number of viable cells (colony forming units, CFU) per ml determined.

RESULTS

To evaluate the staphylococcal killing abilities of the various sera, *S. aureus* was challenged with the various rabbit anti-sera and survival over time was evaluated. The results showed that S. aureus was dramatically killed within 2 to 3 hours of contact with sera (Fig 16) containing antibodies against Gcp and YneS, as well as to other surface proteins. In contrast, antibodies against cytoplasmic proteins from B. subtilis (Obg and YdiB), to a membrane protein from *Arabidopsis thaliana* (cyclophilin), and to various normal rabbit sera did not show the bactericidal phenotype (Fig. 15). Strikingly, sera from rabbits immunized against other presumed cytoplasmic proteins from *B. subtilis* (YsxC and YphC and YwlC) also revealed a killing phenotype similar to the one observed for Gcp and YneS (731 and 733) antibodies. This was unexpected since YsxC, YphC and YwlC are presumed cytoplasmic proteins and, therefore, are not surface exposed and so the antisera would not be expected to recognise them.

This work suggests the location of YsxC in the membrane fraction of *S. aureus*. This work has further demonstrated that the killing effect is mediated through a heat-labile component (inactivated by heat treatment, See Material and Methods) present in serum, likely to correspond to some of the components of the complement (Fig. 16).

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CLAIMS

1. A vaccine composition comprising an antigenic polypeptide encoded by an isolated nucleic acid sequence selected from the group consisting of:

i) a nucleic acid sequence as shown in SEQ ID NO: 6;

ii) a nucleic acid sequence as in (i) which encodes a polypeptide expressed by a pathogenic organism; and

iii) a nucleic acid sequence having at least 95%, 98% or 99% identity to SEQ ID NO: 6.

2. The composition as claimed in claim 1 wherein the antigenic polypeptide is expressed by a pathogenic organism.

3. The composition as claimed in claim 2 wherein the pathogenic organism is a bacterium.

4. The composition as claimed in claim 3 wherein the bacterium is a gram-positive bacterium.

5. The composition as claimed in claim 4 wherein the bacterium is selected from the group consisting of: *Bacillus subtillis, Staphylococcus aureus, Staphylococcus epidermidis, Enterococcus faecalis, Mycobacterium tuberculosis, Streptococcus group B, Streptoccocus pneumonia, Helicobacter pylori, Neisseria gonorrhoea, Streptococcus group A, Borrelia burgdorferi, Coccidiodes immitis, Histoplasma sapsulatum, Neisseria meningitidis type B, Shigella flexneri, Escherichia coli, Haemophilus influenza, Listeria monocytogenes, Bacillus anthracis, Corynebacterium diptheriae, Clostridium tetani, Mycoplasma spp* and *Treponema pallidum*.

6. The composition as claimed in claim 5 wherein the bacterium is of the genus *Staphylococcus spp.*

7. The composition as claimed in claim 6 wherein the bacterium is *Staphylococcus aureus.*

8. The composition as claimed in claim 1 wherein the antigenic polypeptide comprises the amino acid sequence shown in SEQ ID NO: 13.

9. The composition as claimed in any one of claims 1-8 wherein the vaccine further comprises a carrier and/or adjuvant.

10. A vector comprising a nucleic acid sequence having at least 95%, 98% or 99% identity to SEQ ID NO: 6 and encoding an antigenic polypeptide.

11. A method for the production of a recombinant antigenic polypeptide comprising:

(i) providing a cell transformed/transfected with a vector according to claim 10;

(ii) growing said cell in conditions suitable for the production of said polypeptides; and

(iii) purifying said polypeptide from said cell, or its growth environment.

12. A cell or cell-line transformed or transfected with a vector according to claim 10.

13. An isolated antibody or at least an effective binding part thereof which binds to an antigenic polypeptide wherein the antigenic polypeptide is encoded by an isolated nucleic acid sequence selected from the group consisting of:

(i) SEQ ID NO: 6 ; and

(ii) sequences having at least 95%, 98% or 99% identity to SEQ ID NO: 6 .

14. The antibody of claim 13, wherein the antibody is a polyclonal or monoclonal antibody.

15. The antibody of claim 13 or 14, wherein the antibody is a chimeric antibody produced by recombinant methods to contain the variable region of said antibody with an invariant or constant region of a human antibody.

16. The antibody of claim 13 or 14, wherein the antibody is humanized by recombinant methods to combine the complementarity determining regions of said antibody with both the constant (C) regions and the framework regions from the variable (V) regions of a human antibody.

17. An isolated antibody or at least an effective binding part thereof which binds to an antigenic polypeptide having an amino acid sequence selected from the group consisting of:

(i) SEQ ID NO: 13; and

(ii) sequences having at least 95%, 98% or 99% identity to SEQ ID NO: 13.

18. The antibody of claim 17, wherein the antibody is a polyclonal or monoclonal antibody.

19. The antibody of claim 17 or 18, wherein the antibody is a chimeric antibody produced by recombinant methods to contain the variable region of said antibody with an invariant or constant region of a human antibody.

20. The antibody of claim 17 or 18, wherein the antibody is humanized by recombinant methods to combine the complementarity determining regions of said antibody with both the constant (C) regions and the framework regions from the variable (V) regions of a human antibody.

21. A method for preparing a hybridoma cell-line comprising the steps of:

i) immunizing an immunocompetent mammal with an immunogen comprising at least one polypeptide having an amino acid sequence of SEQ ID NO: 13;

ii) fusing lymphocytes of the immunized immunocompetent mammal with myeloma cells to form hybridoma cells;

iii) screening monoclonal antibodies produced by the hybridoma cells of step (ii) for binding activity to the amino acid sequence of (i);

iv) culturing the hybridoma cells to proliferate and/or to secrete said monoclonal antibody; and

v) recovering the monoclonal antibody from the culture supernatant.

22. A vector comprising a nucleic acid sequence encoding a chimeric antibody according to claim 15 or a humanised antibody according to claim 16.

23. A cell or cell line transformed or transfected with the vector of claim 22.

24. A method for the production of a humanised or chimeric antibody comprising:

i) providing a cell transformed or transfected with a vector according to claim 22;

ii) growing said cell in conditions suitable for the production of said antibody; and purifying said antibody from said cell, or its growth environment.

25. Use of a vaccine composition as claimed in claim 1 in the manufacture of a medicament for the treatment or prophylaxis of a microbial infection.

26. The use as claimed in claim 25 wherein the microbial infection is a bacterial infection caused by a bacterial pathogen derived from a bacterial species selected from the group consisting of: *Staphylococcus* spp, *Staphylococcus aureus, Staphylococcus pyrogenes, Staphylococcus epidermidis; Enterococcus spp, Enterococcus faecalis; Lysteria spp; Pseudomonas spp, Mycobacterium spp, Mycobacterium tuberculosis, Enterobacter spp, Campylobacter spp, Salmonella spp, Streptococcus spp, Streptococcus group A* or *B, Streptoccocus pneumonia, Helicobacter spp, Helicobacter pylori, Neisseria spp, Neisseria gonorrhea, Neisseria meningitidis; Borrelia burgdorferi spp; Shigella spp, Shigella flexneri, Escherichia coli spp, Haemophilus spp, Haemophilus influenzae, Chlamydia spp, Chlamydia trachomatis, Chlamydia pneumoniae, Chlamydia psittaci; Francisella tularensis; Bacillus*

spp, Bacillus anthracis, Clostridia spp, Clostridium botulinum, Yersinia spp, Yersinia pestis, Treponema spp, Burkholderia spp, Burkholderia mallei and *B pseudomallei.*

27. Use of an antibody as claimed in any one of claims 13-20 in the manufacture of a medicament for the treatment of a microbial infection.

Fig 1

atgggtaaacctgtcgtagccattgtcgggagaccaaatgtaggaaaatccacaatcttt
aaccggattgcgggagaaagaatttcaatagtagaagataccctggcgtgacaagggat
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attgatatcggtgatgagccgttttagcgcagattcgccagcaagctgaaatcgccatg
gatgaagcggacgtgattattttatggtgaacggccgtgaaggcgtgacagctgctgat
gaagaagtggcgaaaattttgtaccgcacaaaaaagcctgttgttttagcggttaataaa
ctggataacacagaaatgagagcgaatatttatgattttattcgctaggctttggcgag
ccgtatccaatttcgggaacacacggactcggactgggtgatttactggatgccgttgca
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gtggcggttgtgctggatggcgaagaaggcattattgaacaggacaagcgtatcgccggt
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gatccggaactgatgcatttttcatacgaacggtttttagaaaaccgaatcagagacgcg
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Fig 2

atgaaagtcacaaagtcagaaatcgtgatcagtgcagtaaaaccggaacagtaccctgaa
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caaacattaaatattgatccggaagacgagctgatcctcttttcttcagaaacgaaaaag

ggaaaagacgaagcttggggagcgatcaaaaaaatgataaaccgg

Fig 3

atgaaaacgaaaagatggtttgtggatgtaactgacgagttatccacaaatgatccacaa

attgcacaagcagccgctttgctccgagaaaatgaggtcgttgcctttccgacagaaaca

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gaatcctttccggatacaggtgtcggtcttgctattatgaacaggctgatgaaagccgcc

ggaggaagagtgattcgc

Fig 4

ttaccagttcacgcagatggccctattagt

Fig 5

ttgaagattttaaatatgtttctttagca

Fig 6

(a)

atgactaaagatatattaatactagctgttgaaacaagttgtgatgaaacaagcgttagt
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aaacgatttggcggtgtcgttcccgaagtggcaagtagacatcacgttgaaggtataaca
acaacaataaacgaggctctagtggatgccgatgtatcaatggaagatattgatgccata
gcggttaca

(b)

atgactaaagatatattaatactagctgttgaaacaagttgtgatgaaacaagcgttagt
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cgatttgctgatttagcattaaatgggcacagcaatatagatttagaagagtattctgca
gaataa

Fig 7

MGKPVVAIVGRPNVGKSTIFNRIAGERISIVEDTPGVTRDRIYSSAEWLNYDFNLID
TGG
IDIGDEPFLAQIRQQAEIAMDEADVIIFMVNGREGVTAADEEVAKILYRTKKPVVL
AVNK
LDNTEMRANIYDFYSLGFGEPYPISGTHGLGLGDLLDAVAEHFKNIPETKYNEEVI
QFCL
IGRPNVGKSSLVNAMLGEERVIVSNVAGTTRDAVDTSFTYNQQEFVIVDTAGMR
KKGKVY
ETTEKYSVLRALKAIDRSEVVAVVLDGEEGIIEQDKRIAGYAHEAGKAVVIVVNK
WDAVD
KDESTMKEFEENIRDHFQFLDYAPILFMSALTKKRIHTLMPAIIKASENHSLRVQTN
VLN
DVIMDAVAMNPTPTHNGSRLKIYYATQVSVKPPSFVVFVNDPELMHFSYERFLEN
RIRDA
FGFEGTPIKIFARARK

Fig 8

MKVTKSEIVISAVKPEQYPEGGLPEIALAGRSNVGKSSFINSLINRKNLARTSSKPG
KTQ
TLNFYIINDELHFVDVPGYGFAKVSKSEREAWGRMIETYITTREELKAVVQIVDLR
HAPS

NDDVQMYEFLKYYGIPVIVIATKADKIPKGKWDKHAKVVRQTLNIDPEDELILFSS

ETKK

GKDEAWGAIKKMINR

Fig 9

MKTKRWFVDVTDELSTNDPQIAQAAALLRENEVVAFPTETVYGLGANAKNIDA

VKKIYEA

KGRPSDNPLIVHIADISQLEDLTGPAPEKAKTLMKRFWPGALTLILPCKPDALSPRV

TAG

LETVAIRMPDHPLALALIRESGLPIAAPSANLSGKPSPTKAEHVAHDLDGRIAGIVD

GGP

TGIGVESTVLSCADDIPVLLRPGGITKEQIEAVIGPIHVDKGLSDQNEKPISPGMKYT

HY

APTAPLAICEGSPFRIQHLIQEYQQGGRRVGVLTTEEKAGVYSADYVKSCGRRAQ

LETVA

AGLYDALRSFDENKVDFIIAESFPDTGVGLAIMNRLMKAAGGRVIR

Fig 10

LPVHADGPIS

Fig 11

LKIFKYVSLA

Fig 12

(a)

MTKDILILAVETSCDETSVSVIKNGRDILSNTVLSQIESHKRFGGVVPEVASRHHVE
GITTTINEALVDADVSMEDIDAIAVT

(b)

MTKDILILAVETSCDETSVSVIKNGRDILSNTVLSQIESHKRFGGVVPEVASRHHVE
GIT

TTINEALVDADVSMEDIDAIAVTEGPGLIGALLIGVNAAKALAFAYDKPLIPVHHIA
GHI

YANHIEEPLTFPLIALIVSGGHTELVYMKDHLSFEVIGETRDDAVGEAYDKVARTI
GLNY

PGGPQVDRLAAEGEDTYSFPRVWLDKDSYDFSFSGLKSAVINQLHNQRQKNIPIE
ANVA

TSFQNSVVEVLTEKAIQACKEYSVQRLIVAGGVASNKGLRQSLADQCKVNDIQLTI
PSPK

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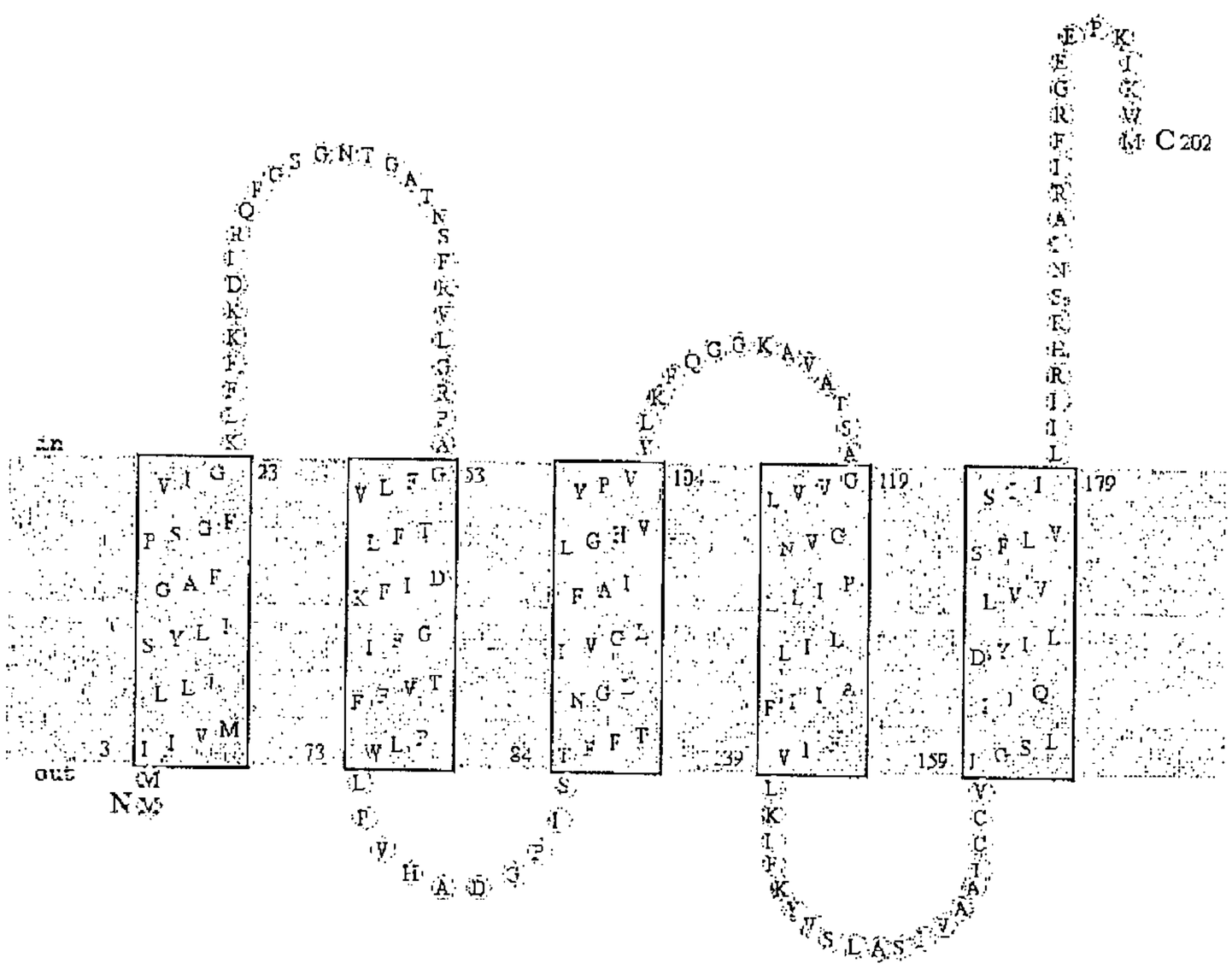
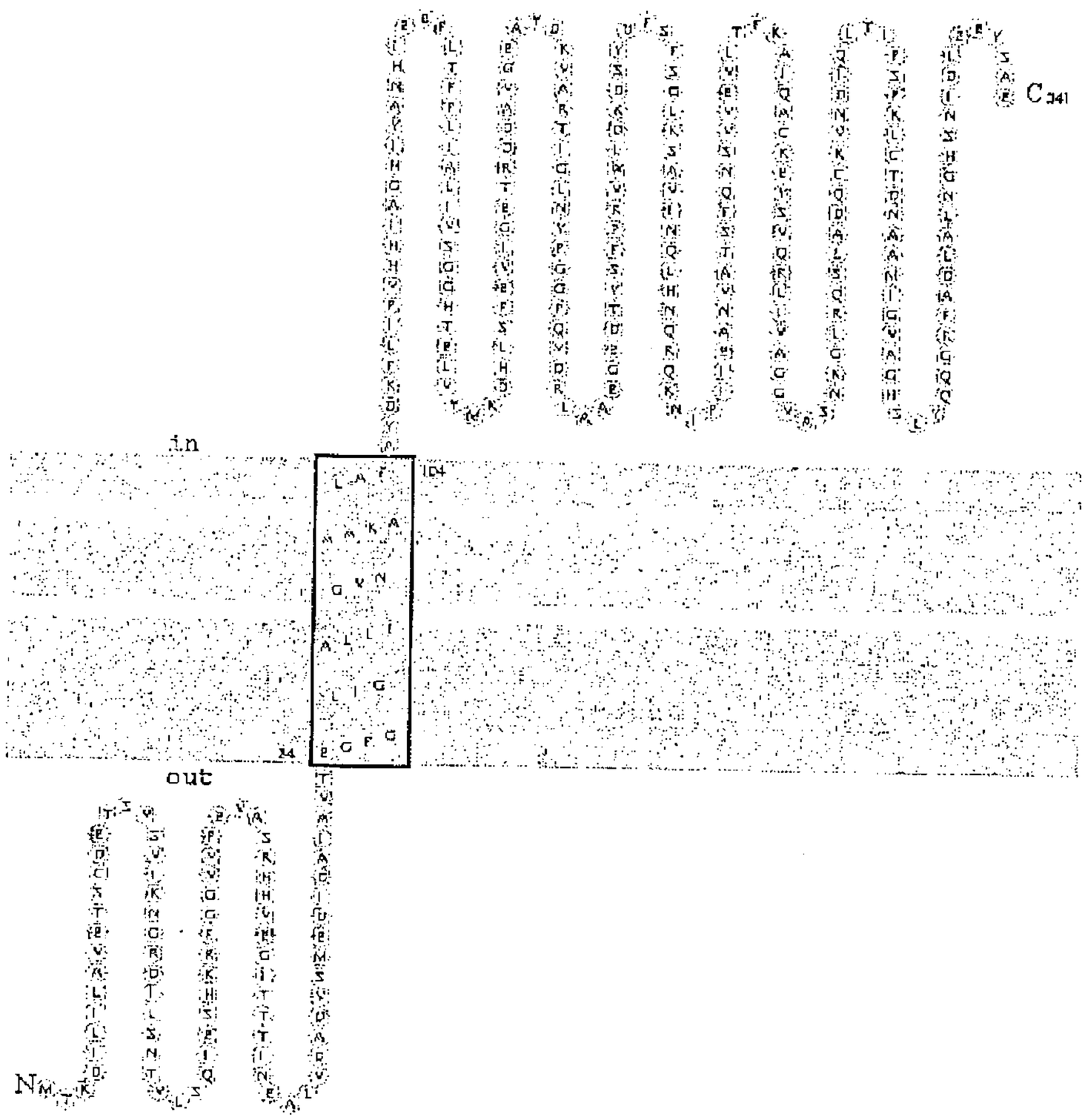
Fig 13



5

Fig 14



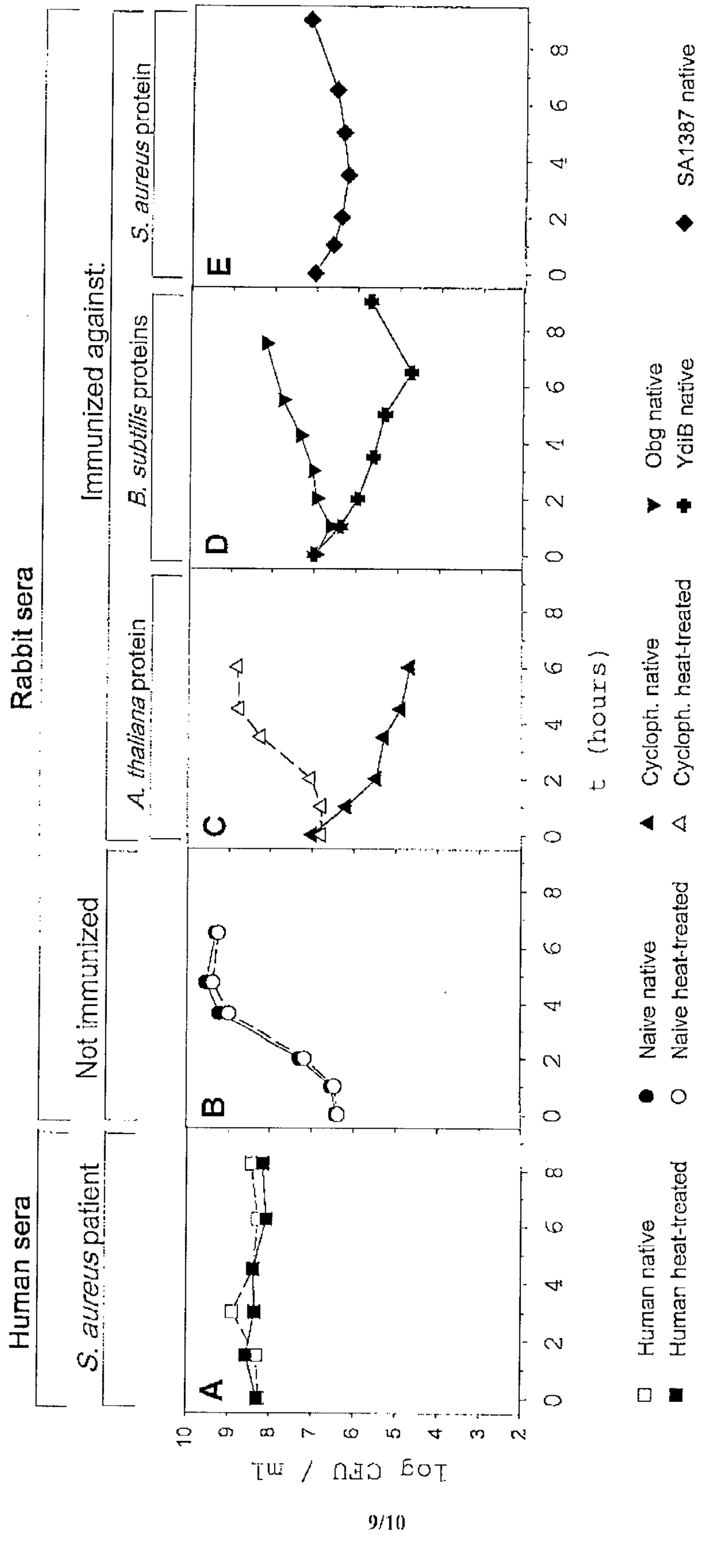

Human sera
S. aureus patient
Not immunized
Rabbit sera
Immunized against:
A. thaliana protein
B. subtilis proteins
S. aureus protein
A
B
C
D
E
log CFU / mL
t (hours)
Human native
Human heat-treated
Naive native
Naive heat-treated
Cycloph. native
Cycloph. heat-treated
Obg native
YdiB native
SA1387 native

Fig. 15.

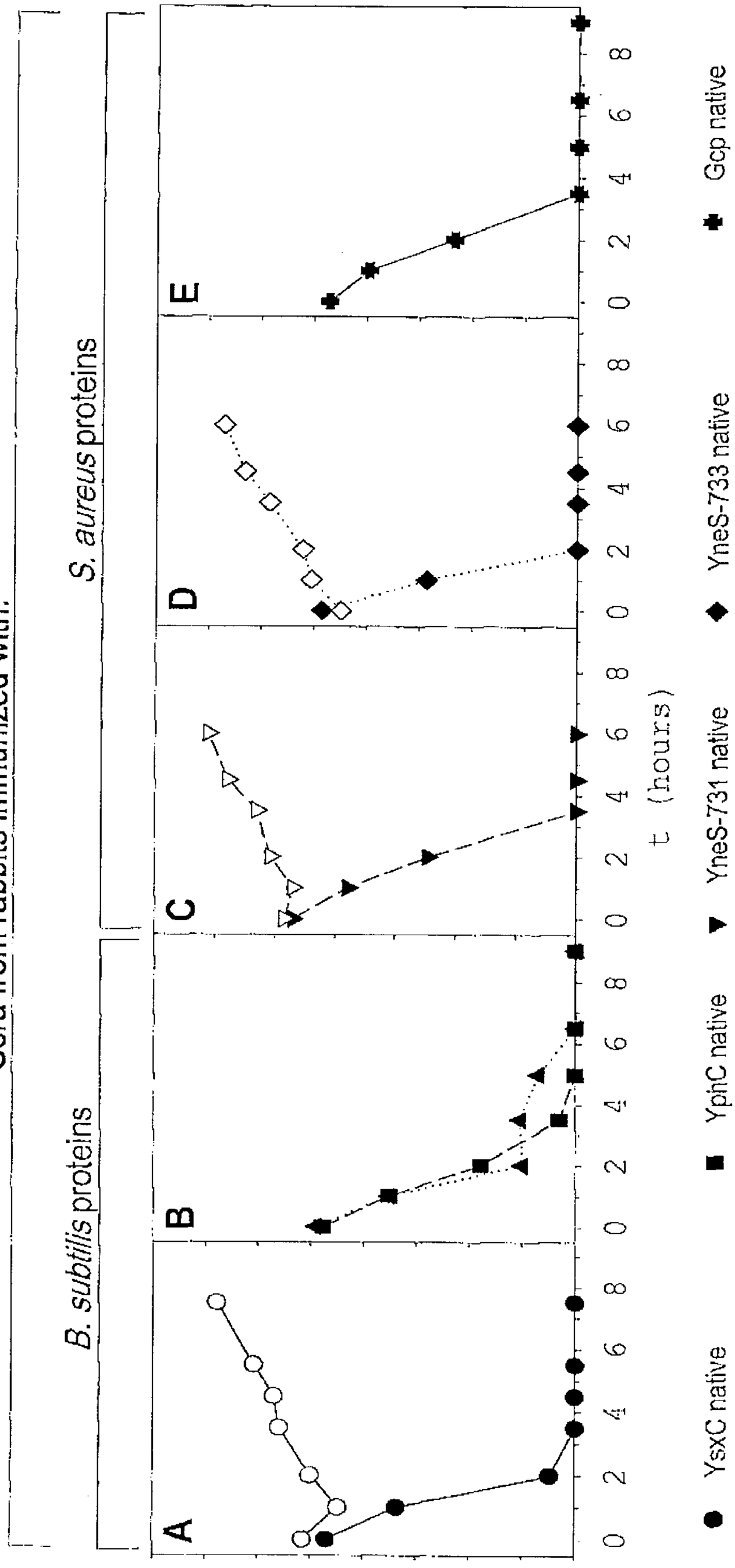

Sera from rabbits immunized with:
B. subtilis proteins
S. aureus proteins
A
B
C
D
E
0
2
4
6
8
t (hours)
YsxC native
YsxC heat-treated
YphC native
YwlC native
YneS-733 native
YneS-733 heat-treated
Gcp native

Fig. 16.

atgggtaaacctgtcgtagccattgtcgggagaccaaatgtaggaaaatccacaatcttt
aaccggattgcgggagaaagaatttcaatagtagaagataccccctggcgtgacaagggat
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