Beta-lactam antibiotics - Cephalosporins

Targets - PBP's

Activity - **Cidal** - growing organisms (like the penicillins)

Principles of action - Affinity for PBP's
Permeability properties
Stability to bacterial enzymes

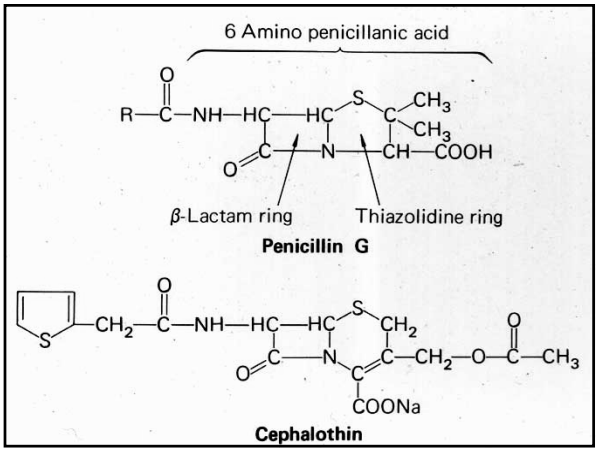
Development of C'sporins

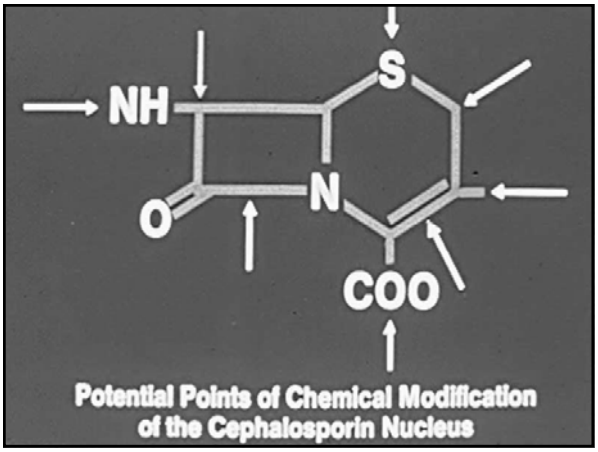
Generations - in response to clinical needs

First generation - Cephalothin (not used)
Cefazolin
oral - Cephalexin, cefaclor

Activity - Broad spectrum:
Gram positive *Streptococci, S. aureus*
Gram negative - *E.coli, Klebsiella*

No activity against *Enterococci* - different PBP's





Cephalosporins

Development - Giuseppe Brodtzu - Sardinian sewage

Cephalosporin C - Cephalothin
No meningeal penetration
Failed in meningococcal meningitis

Painful to give IM

Advantages
Cephalosporin nucleus - resistant to Staphylococcal penicillinase
Cephalosporin nucleus - more readily modified

Second generation C'sporins

Cefuroxime
Cefoxitin
Cefotetan

70's - Beta-lactamase's recognized (*H. influenzae*)
Anaerobic infections

Cefoxitin - Methoxy group - conferred beta-lactamase stability
Induction of chromosomal beta-lactamases
Bacteroides fragilis - enteric anaerobes

Cefuroxime - Respiratory tract infections - community acquired

Kinetics of c'sporin binding

Affinity for receptor - PBP

Permeability characteristics of the porin

Beta-lactamase production - within periplasmic space

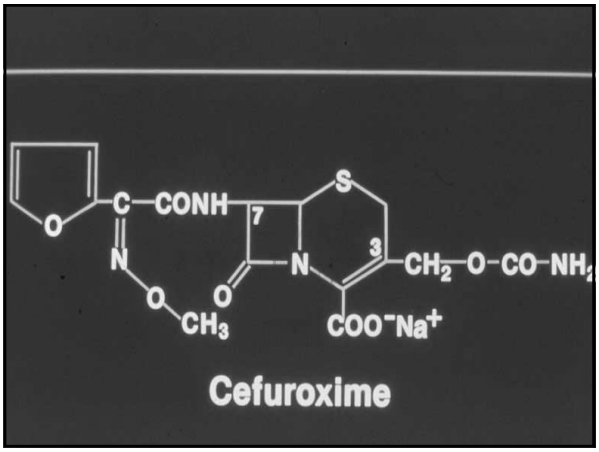
Third generation c'sporins

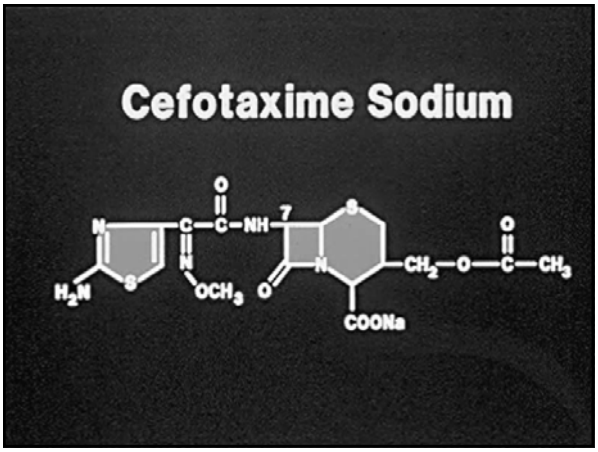
Cefotaxime
Ceftriaxone
Ceftazidime
Cefipime (4th?)

Highly active - Cefotaxime - *S. pneumo*
N. meningitidis, gets across BBB

Ceftriaxone - even more active - Single dose IM
get meningeal levels - Long half life !!!
N. gonorrhoeae, use in unreliable patients -
Cover *S. pneumonia* bacteremia

Use in meningitis -





Third generation C'sporins

80's - Intensive care - nosocomial infections

↓

Multi-Resistant Gram negative organisms

Chromosomal beta-lactamase - C'sporinase
Inducible
Plasmid mediated enzymes - mutants with
both Penicillinase and C'sporinase activity

Permeability limitations

IMPORTANT PHARMACOKINETIC VARIABLES OF NEW CEPHALOSPORINS

Agent	Serum protein binding (%)	Metabolism	Peak serum levels (μg/ml) 1g*	Peak serum levels (μg/ml) 0.5g†	Half-Life (hours) Ccr>90	Half-Life (hours) Ccr>10	Vd (L)	Urinary recovery (%)
Moxalactam	50	-	60	24	2	19	19	75
Cefotaxime	38	+	42	12	1.1	2.5	27	55
Desacetyl cefotaxime	23	+	7	3	1.6	11	-	30
Ceftizoxime	31	-	87	14	1.4	25	18	85
Ceftriaxone	83-96	-	150	50	8	11-16	9	60*
Ceftazidime	17	-	80	18	1.8		16	75
Cefoperazone	90	-	125	26	1.9	2.5	12	25

*Based on intravenous infusion over 30 minutes.
†Intramuscularly

H.C. Neu, Bull. N.Y. Acad. Med., 60:327, 1984

Ceftazidime/Cefepime - anti-*Pseudomonas*

Used the side groups which have increased permeability through *P.aeruginosa* porins -

? Induction (low level) of chromosomal C'sporinase

Beta-lactamase stable -

less activity against gram positive organisms

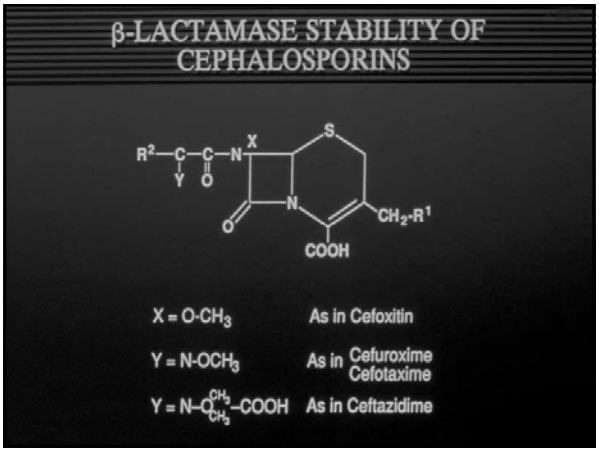
Carbapenems

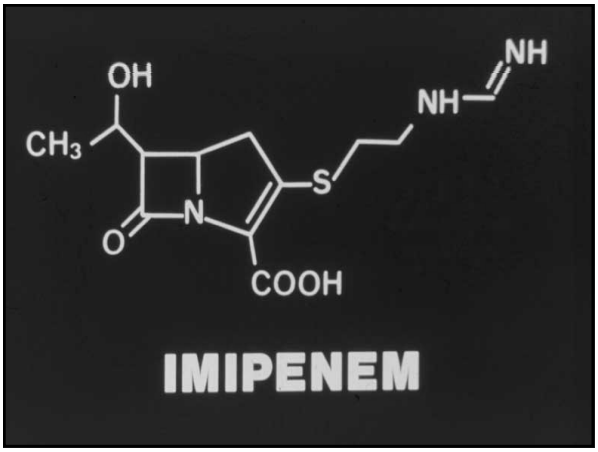
Imipenem
Meropenem
Ertapenem

Beta-lactam class - PBP-2 major target
Permeability - separate porin

Huge spectrum - Aerobes, anaerobes
everything EXCEPT
Enterococci
Stenotrophomonas etc.

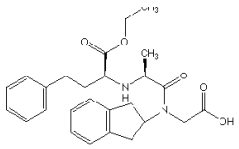
Concern - CNS side effects - Imipenem ??





Cefepime – Fourth generation

Increased beta-lactamase stability
Also better Gram positive -

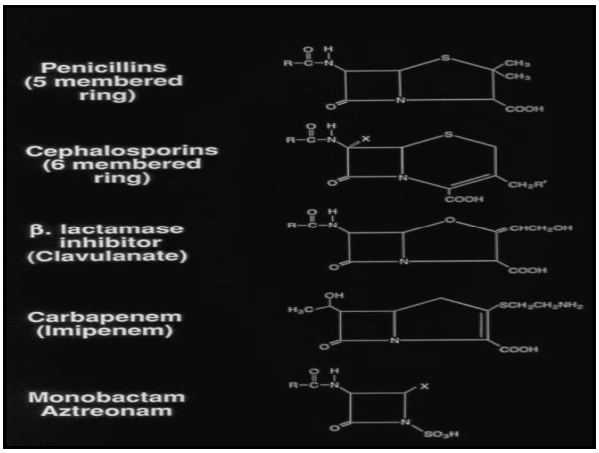


Monobactams - Aztreonam

Only binds to Gram negative PBP's

No real beta-lactam ring - therefore beta-lactamase stable

Narrow spectrum - Only aerobic gram negative rods
Use - instead of an aminoglycoside



Pharmacology

Charged - hydrophilic - do not enter phagocytic cells

Variably protein bound (Ceftriaxone - highly bound)
Variable half-lives

Metabolism - Cefotaxime - Liver - desacetyl derivative - active

Excretion - Renal - Tubular secretion and glomerular filtration

Use of the cephalosporins:

First generation - Oral - surgical prophylaxis - skin soft tissue infections - taste good - "house cephalosprorin"

Second generation - Some oral - some parenteral
Selected uses – community acquired infections

Parenteral - Third generation

Increased - due to resistant *S. pneumoniae* - *susceptible* to cefotaxime and ceftriaxone

Gram negative infections - hospital acquired - selection of resistant organisms

Beta-lactams – side effects

penicillin – c'sporin cross reactivity – 3-7% (depending on the drug)

Hypersensitivity – Rash
IgE-mediated allergy – Anaphylaxis

Major determinants – minor side effects
Minor determinants –MAJOR reactions

Diarrhea
Neutropenia

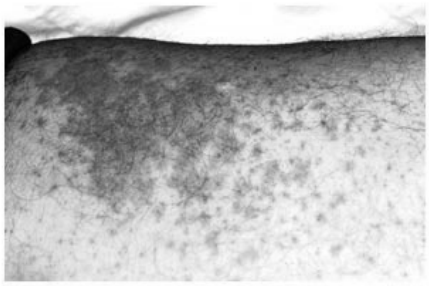
CNS – high doses -
especially the carbapenems

Resistance Rates

MYSTIC program (USA 199-2006)
>100 medical centers

Resistance to carbapenems
Enterobacteriaciae (9,396 organisms) 0.5%
***Pseudomonas aeruginosa* (3,100 organisms) 7.2%**

All (20,051) 2.8%



Gruchalla R and Pirmohamed M. N Engl J Med 2006;354:601-609

Adverse Reactions to Cephalosporins

TABLE 1. ADVERSE REACTIONS TO CEPHALOSPORINS.

TYPE OF REACTION	FREQUENCY	REFERENCES
	%	
Dermatologic	1.0–2.8	Norrby,[1] Sanders et al.,[2] Arndt and Jick,[3] Platt[4]
Positive direct antiglobulin test	1.0–2.0	Sanders et al.,[2] Platt,[4] Meyers[5]
Anaphylaxis	0.0001–0.1	Gadde et al.,[6] Sogn et al.[7]
Fever	0.5–0.9	Sanders et al.,[2] Meyers[5]
Eosinophilia	2.7–8.2	Sanders et al.,[2] Platt[4]

Kelkar P and Li J. N Engl J Med 2001;345:804-809

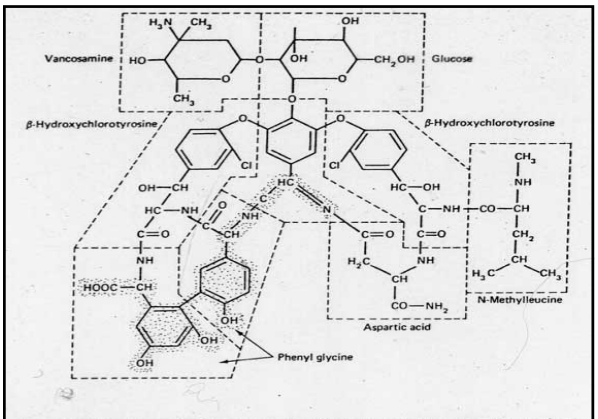
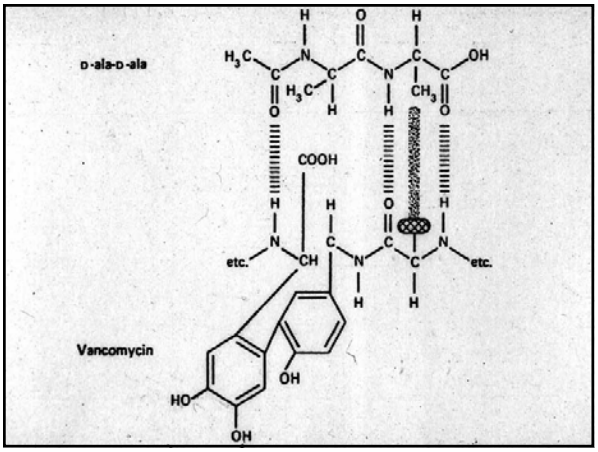


Figure 6.25 Structure of vancomycin. The stippled area indicates the residues involved in the interaction with the mucopeptide precursor.

C'sporins

Intrinsic resistance - enterococci - different targets

Acquired resistance - active change
- Acquisition of an enzyme
- Induction of an enzyme
- Selection of a mutation
- Alteration in permeability



Vancomycin

History - Developed in the 50's - anti-Staph drug

Re-"discovered" - MRSA - and MRSE -
Staphylococci with altered PBP-2A
mecA gene - no longer binds penicillin
(C'sporins don't bind either)

Target - **D-ala-D-ala** - pentapeptide
blocks two steps in cell wall synthesis

Cidal - Only gram positives - Highly resistant *S. pneumo*

Methicillin resistant *Staphylococci*

- ***mecA*** **mutations - altered PBP's**
-
- **often linked to overexpression of beta-lactamase**
-
- **Use different class of antimicrobial agent**

Vancomycin - properties

Small glycoprotein (MWt @ 1,450) derived from *Nocardia orientalis*

Activity - most G(+) bacteria including Streptococci, Corynebacteria, Clostridia, Listeria, and Bacillus species.

Bactericidal at levels 0.5 - 3 mg/L

Staphylococci including ß-lactamase producing and methicillin resistant species are killed at levels <10 mg/L

Side effects of vancomycin:

Red man syndrome - histamine-mediated erythematous flushing of the face, neck and trunk, a reaction which occurs during the infusion, and may be associated with hypotension.

Nephrotoxicity and ototoxicity ?? < 1% of pts
especially those receiving other "toxic' drugs
like aminoglycosides.

A relationship between vancomycin level and nephrotoxicity or ototoxicity has not been established.

It is now widely believed that the earlier reports of nephrotoxicity may have been related to impurities in the product.

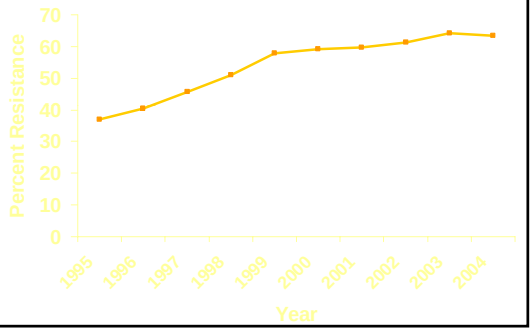
Use of Vancomycin

Staphylococci – resistant to penicillin – "methicillin resistant - Altered PBP's

Coagulase-negative staphylococci – Catheter infection

S. aureus* – MRSA – Methicillin Resistant *Staphylococcus aureus

Methicillin (oxacillin)-resistant *Staphylococcus aureus* (MRSA) Among ICU Patients, 1995-2004



Vancomycin - Pharamacokinetic properties

Vd @ 0.7 L/kg
Protein binding @ 55%
Elimination: > 90% renal

Half-life @ 7 hrs (with normal CLcr)

Vancomycin is not removed by standard HD or PD, but it is removed by CVVH

MRSA - types

Nosocomial – Multi-resistant – large chromosomal insertions – *mecA* cassette

Community – SCC's (small covalent circles)
Integrated elements along with the recombinases

Epidemiology - few major types

Very common – moving back into the hospital

Community Acquired MRSA

Increasingly common – smaller mobile genetic unit

Still susceptible to other antibiotics (unlike hospital –acquired)

Often relatively virulent – Panton-Valentine toxin ?
Hemolysins
Skin- soft tissue infections
Fulminant pneumonias

Adolescents

Up to 70% of outpatient isolates !!!! At some centers

Vancomycin resistance ?

Widespread use - empiric therapy for *S. aureus* infection?

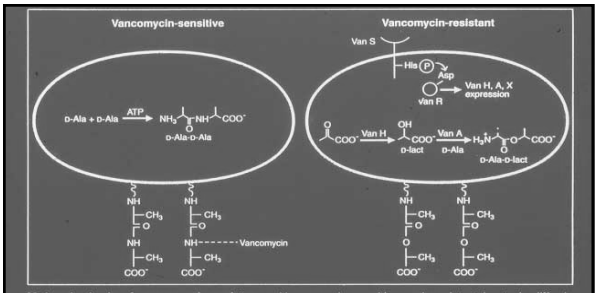
Development of resistance:

Enterococci
? Staphylococci

Invasive Methicillin-Resistant Staphylococcus aureus Infections in the United States
JAMA. 2007;298:1763-1771.

8987 observed cases of invasive MRSA

invasive MRSA was 31.8 per 100 000



Molecular logic of vancomycin resistance. Vancomycin-sensitive and -resistant bacteria differ in a critical component of their cell wall. Sensitive bacteria (**left**) synthesize PG strands that terminate in D-Ala-D-Ala; vancomycin binds avidly to these termini, thereby disrupting cell wall synthesis and leading to cell lysis. Resistant bacteria (**right**) harbor a transposable element encoding nine genes that contribute to the resistance phenotype. The gene products include a transmembrane protein (Van S) that senses the presence of the drug and transmits a signal—by transfer of a phosphoryl group—to a response regulator protein (Van R) that activates transcription of the other resistance genes. The combined activities of Van H and Van A lead to synthesis of a depsipeptide, D-Ala-D-lactate, which can be incorporated into the PG strands of the cell wall. The altered PG termini do not affect the structural integrity of the cell wall, but substantially reduce its affinity for vancomycin, thereby rendering the bacteria resistant to the drug.

Deadly Bacteria Found to Be More Common

Article Tools Sponsored By
By KEVIN SACK
Published: October 17, 2007 NY TImes

ATLANTA, Oct. 16 — Nearly 19,000 people died in the United States in 2005 after being infected with virulent drug-resistant bacteria that have spread rampantly through hospitals and nursing homes, according to the most thorough study of the disease's prevalence ever conducted.

Staph Infections Reported at Schools Across the Country
Jeanna Duerscherl/Associated Press/Roanoke Times

Students stand outside Staunton River High School in Moneta, Va. where a high school student infected with an antibiotic-resistant staph infection has died prompting Bedford County to close all 21 of its schools for a thorough cleaning.

Article Tools Sponsored By
By THE ASSOCIATED PRESS
Published: October 17, 2007

RICHMOND, Va., Oct. 17 — A high school student hospitalized for more than a week with an antibiotic-resistant staph infection died on Monday, as schools across the country were reporting outbreaks of staph infections, including the antibiotic-resistant strain.

Vancomycin resistance

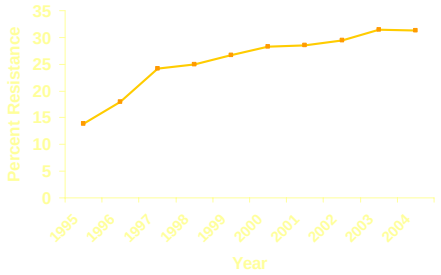
VRE = Vancomycin resistant enterococci
? From oral use of vancomycin

Selection of enterococci – altered cell wall structure

Several mechanisms:
D-ala-D-ala changed to a lactate
No metabolic cost

Several Vanco resistance cassettes

Vancomycin-resistant *Enterococi*
Among ICU Patients,
1995-2004



Source: National Nosocomial Infections Surveillance (NNIS) System

Vanco resistant *S. aureus*

- VISA – Vanco intermediate –
  MIC's 4-16 micrograms/ml

Multiple point mutations
Thickened peptidoglycan layer
? Sponge effect
(GISA = glycopeptide-intermediate strains)