TOPIC

LATTICE-BASED ACCESS-CONTROL MODELS

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LATTICE-BASED MODELS

- **Denning's axioms**
- **Bell-LaPadula model (BLP)**
- **Biba model and its duality (or equivalence) to BLP**
- **Dynamic labels in BLP**

DENNING'S AXIOMS

$$< SC, \rightarrow, \oplus >$$

SC	**set of security classes**
$\rightarrow \subseteq$ **SC X SC**	**flow relation (i.e., can-flow)**
$\oplus$: **SC X SC -> SC**	**class-combining operator**

DENNING'S AXIOMS

$< SC, \rightarrow, \oplus >$

1 **SC is finite**

2 **$\rightarrow$ is a partial order on SC**

3 **SC has a lower bound L such that L $\rightarrow$ A for all A $\in$ SC**

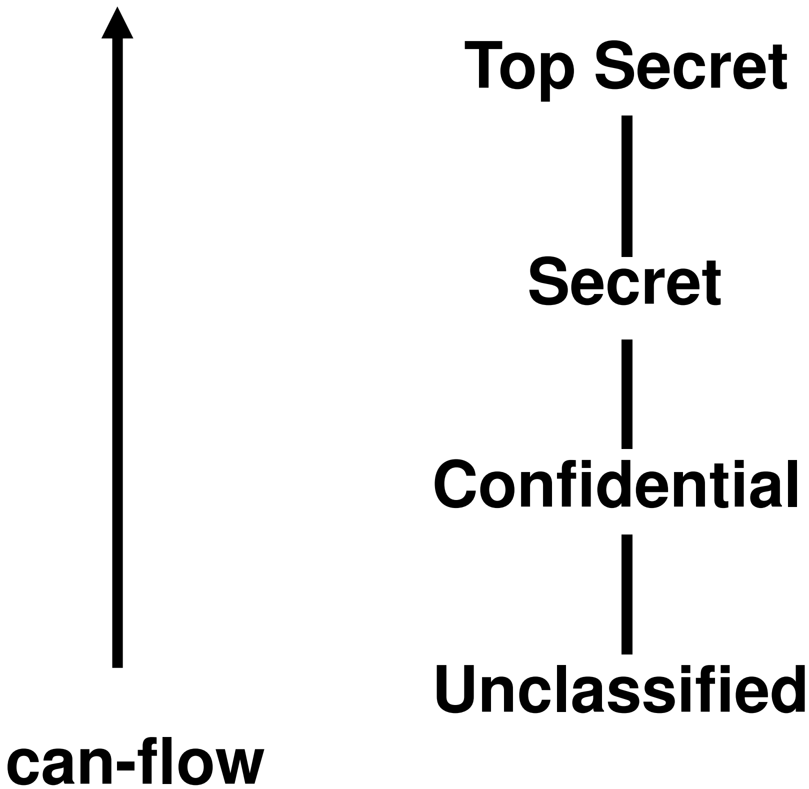
4 **$\oplus$ is a least upper bound (lub) operator on SC**

Justification for 1 and 2 is stronger than for 3 and 4. In practice we may therefore end up with a partially ordered set (poset) rather than a lattice.

DENNING'S AXIOMS IMPLY

- **SC is a universally bounded lattice**
- **there exists a Greatest Lower Bound (glb) operator $\otimes$ (also called meet)**
- **there exists a highest security class H**

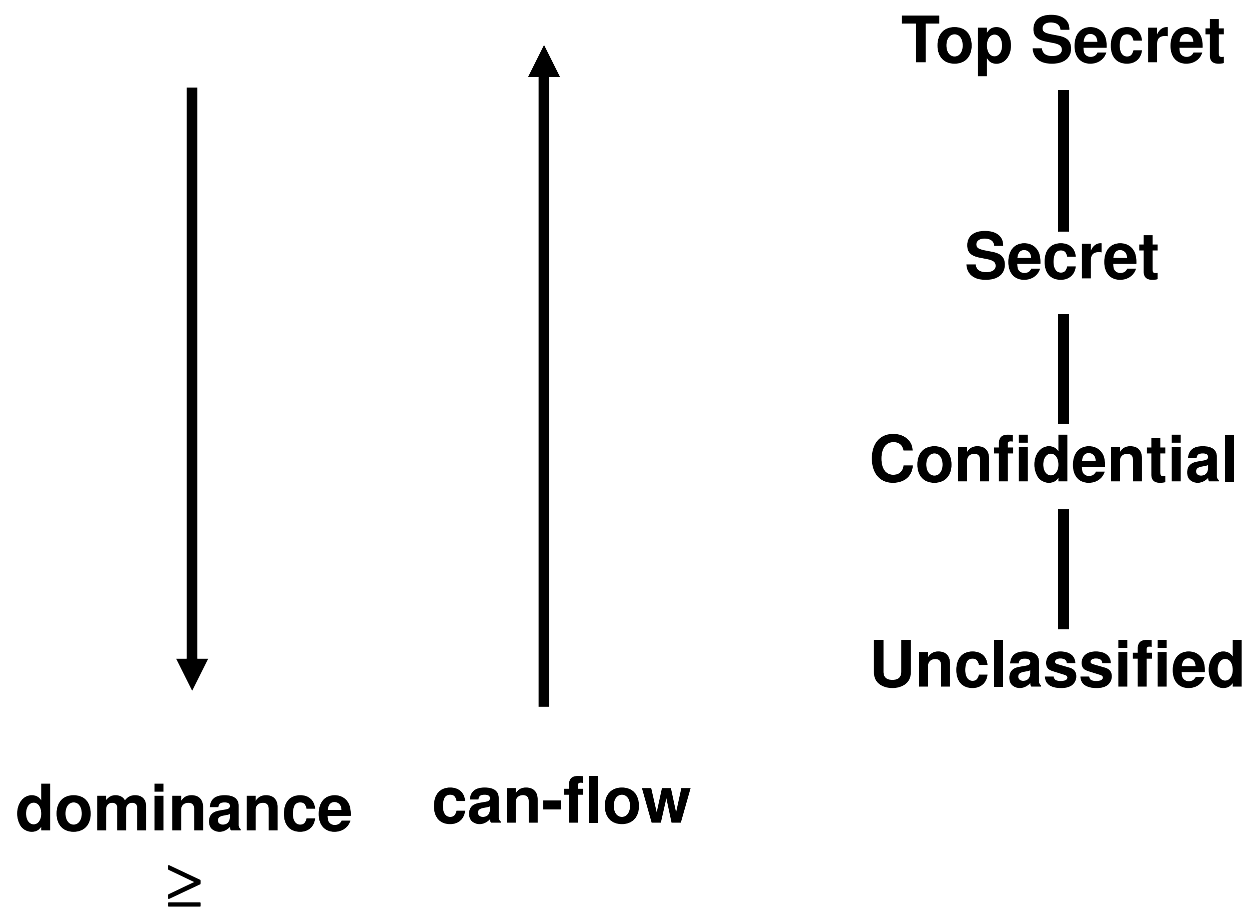
LATTICE STRUCTURES



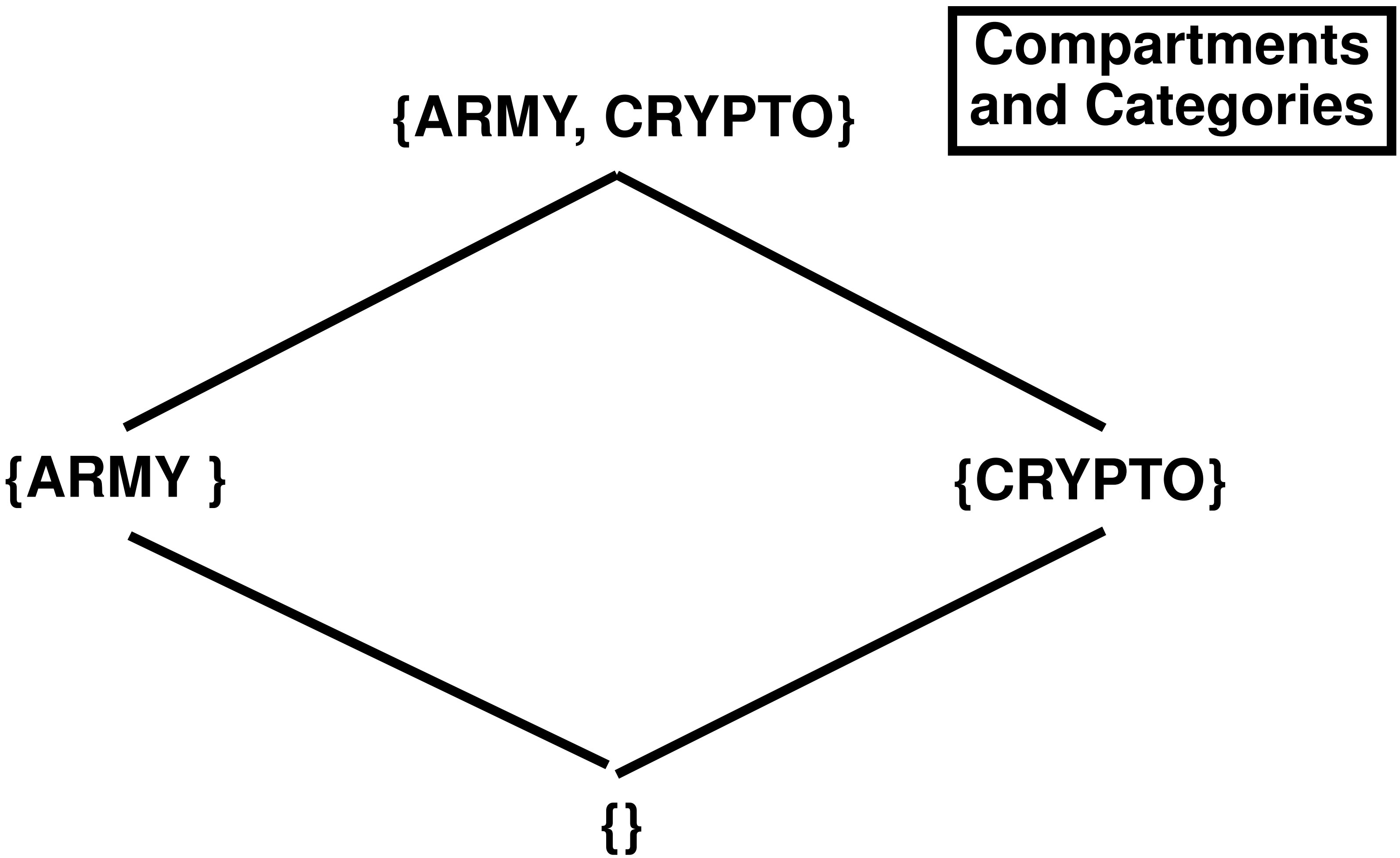
Hierarchical Classes

reflexive and transitive edges are implied but not shown

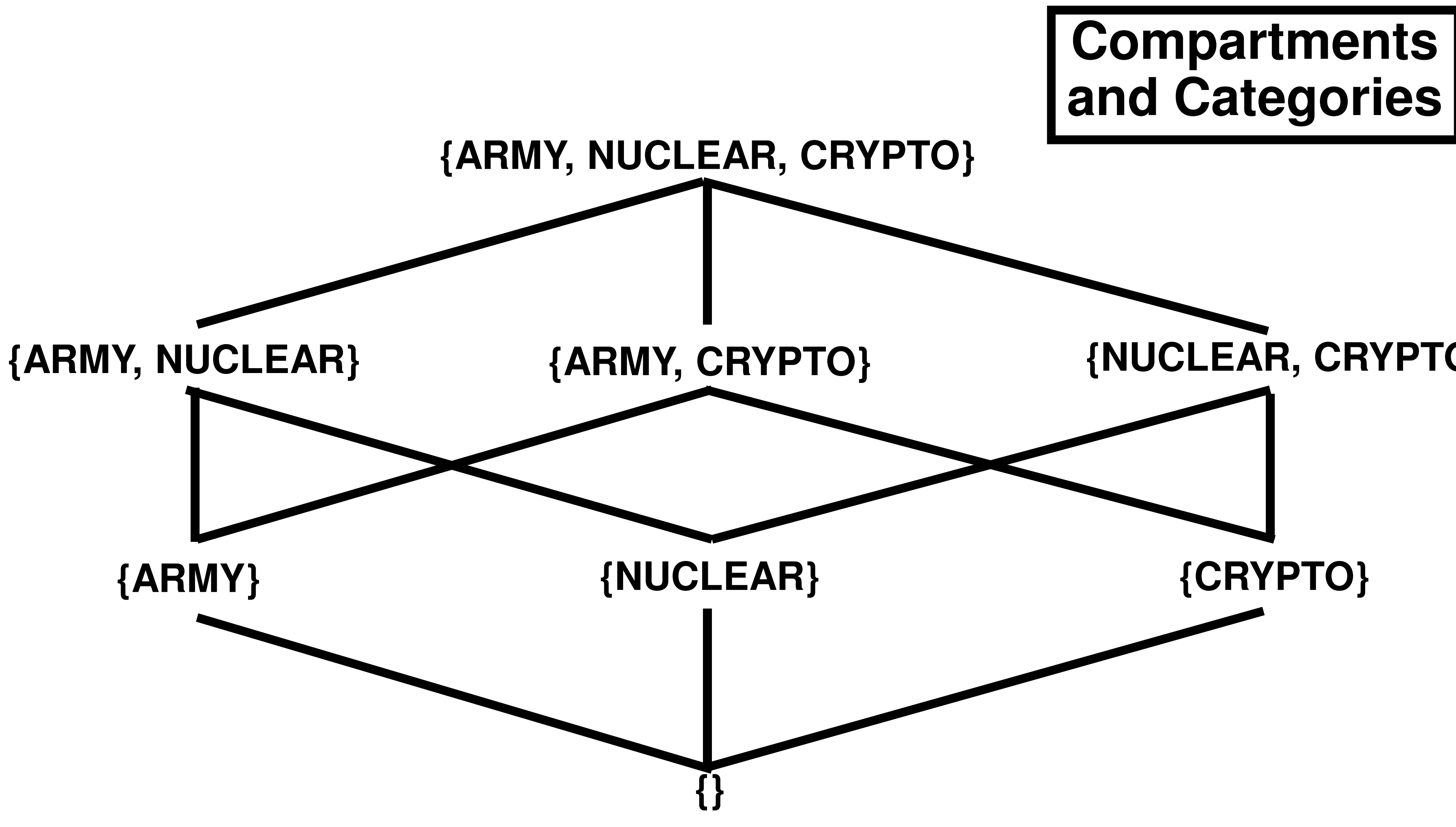
LATTICE STRUCTURES



LATTICE STRUCTURES

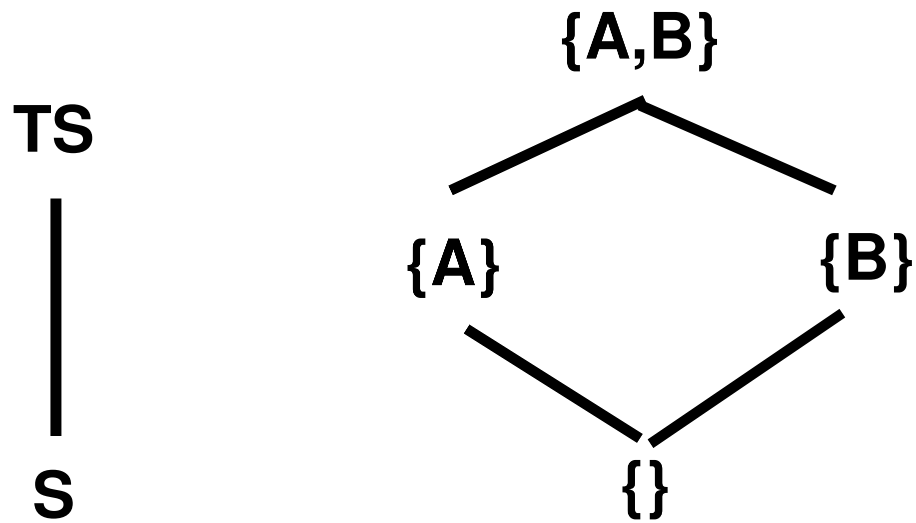


LATTICE STRUCTURES



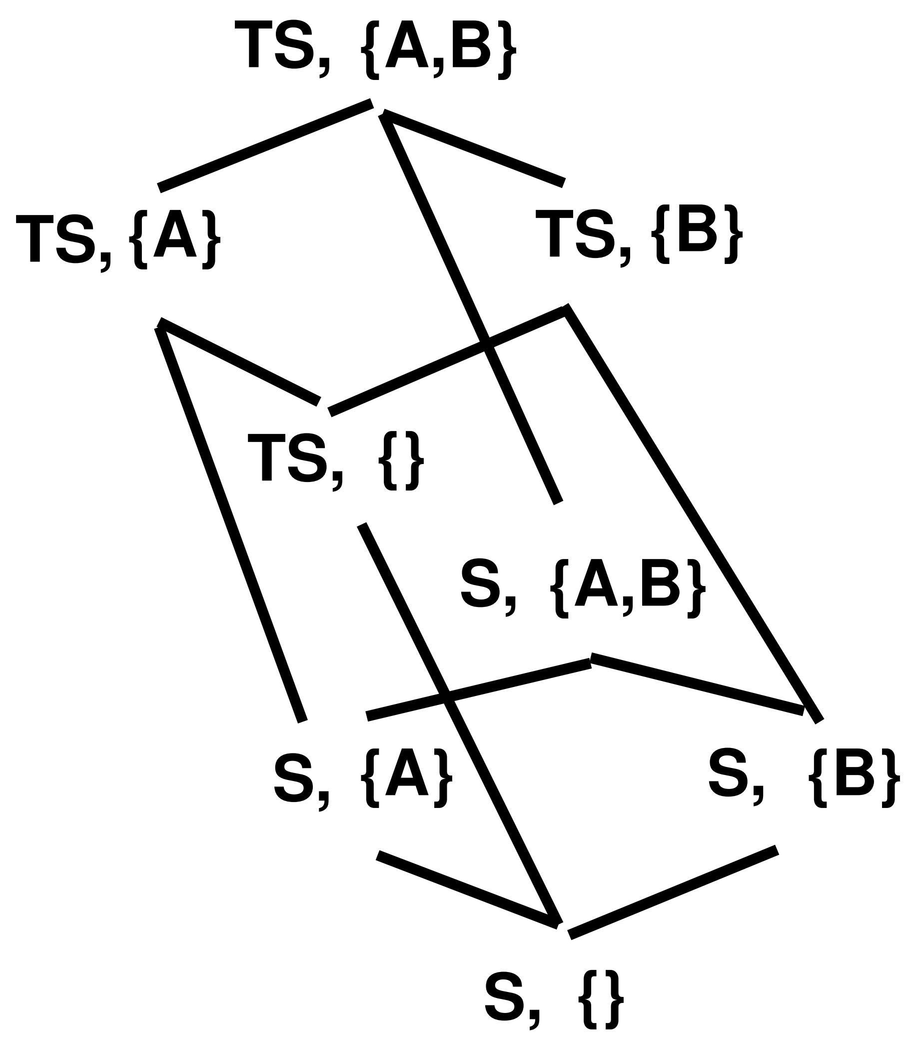
LATTICE STRUCTURES

Hierarchical Classes with Compartments

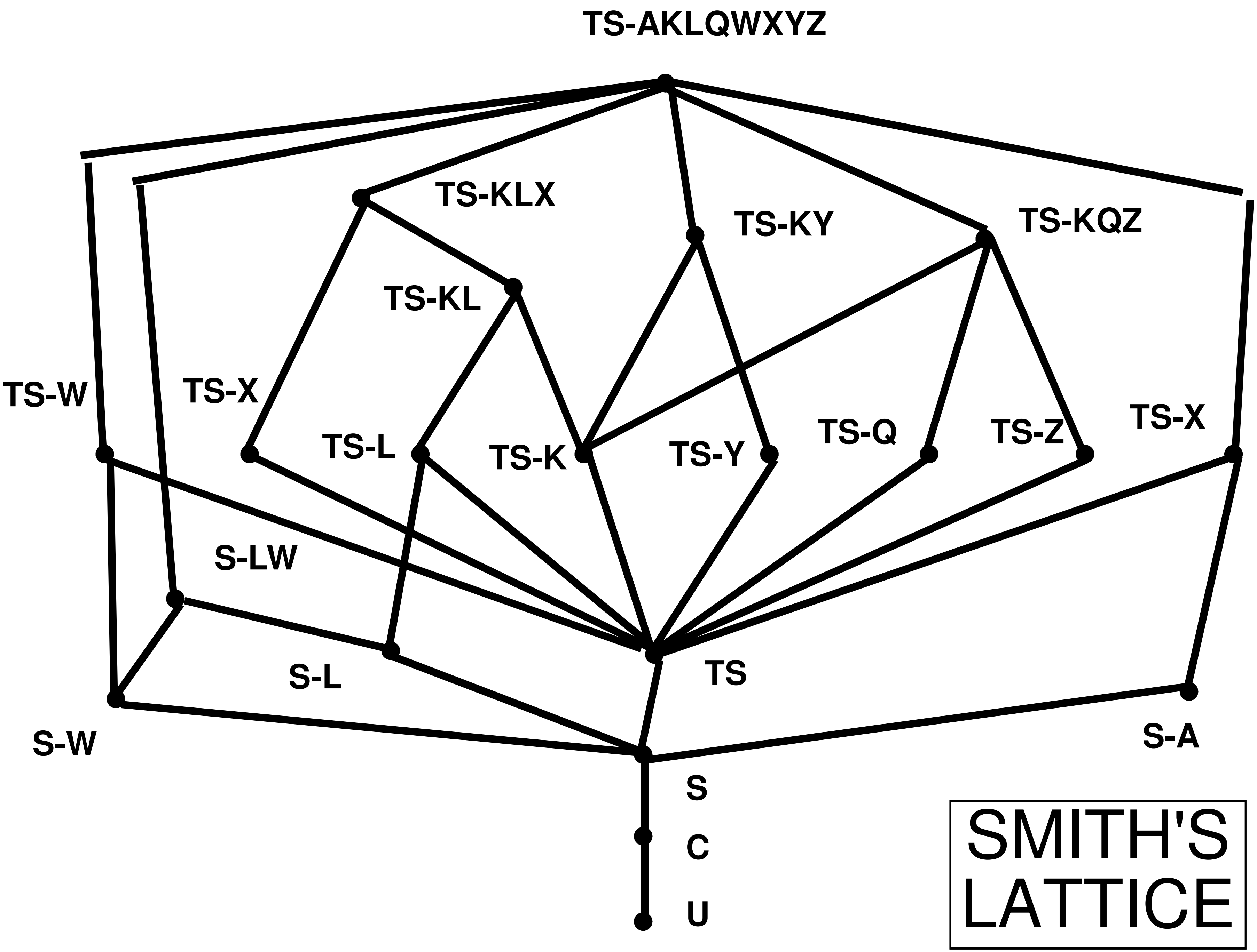


product of 2 lattices is a lattice

LATTICE STRUCTURES



Hierarchical Classes with Compartments


TS-AKLQWXYZ
TS-KLX
TS-KY
TS-KQZ
TS-KL
TS-W
TS-X
TS-L
TS-K
TS-Y
TS-Q
TS-Z
TS-X
S-LW
S-L
TS
S-W
S-A
S
C
U
SMITH'S LATTICE

SMITH'S LATTICE

- **With large lattices a vanishingly small fraction of the labels will actually be used**
  - **Smith's lattice: 4 hierarchical levels, 8 compartments, therefore**

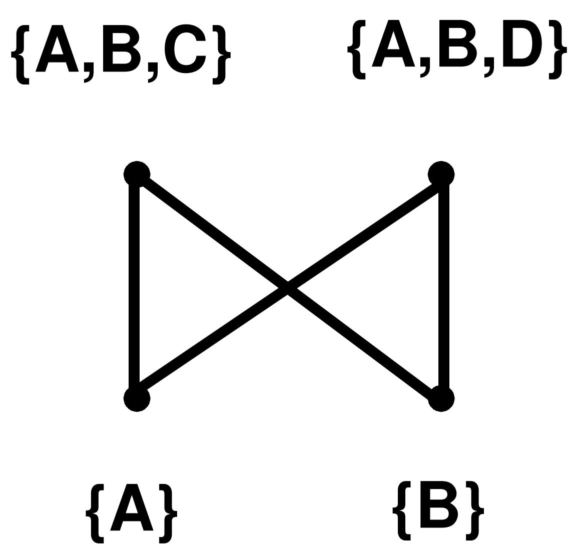
    number of possible labels = 4*2^8 = 1024

    Only 21 labels are actually used (2%)
  - **Consider 16 hierarchical levels, 64 compartments which gives 10^20 labels**

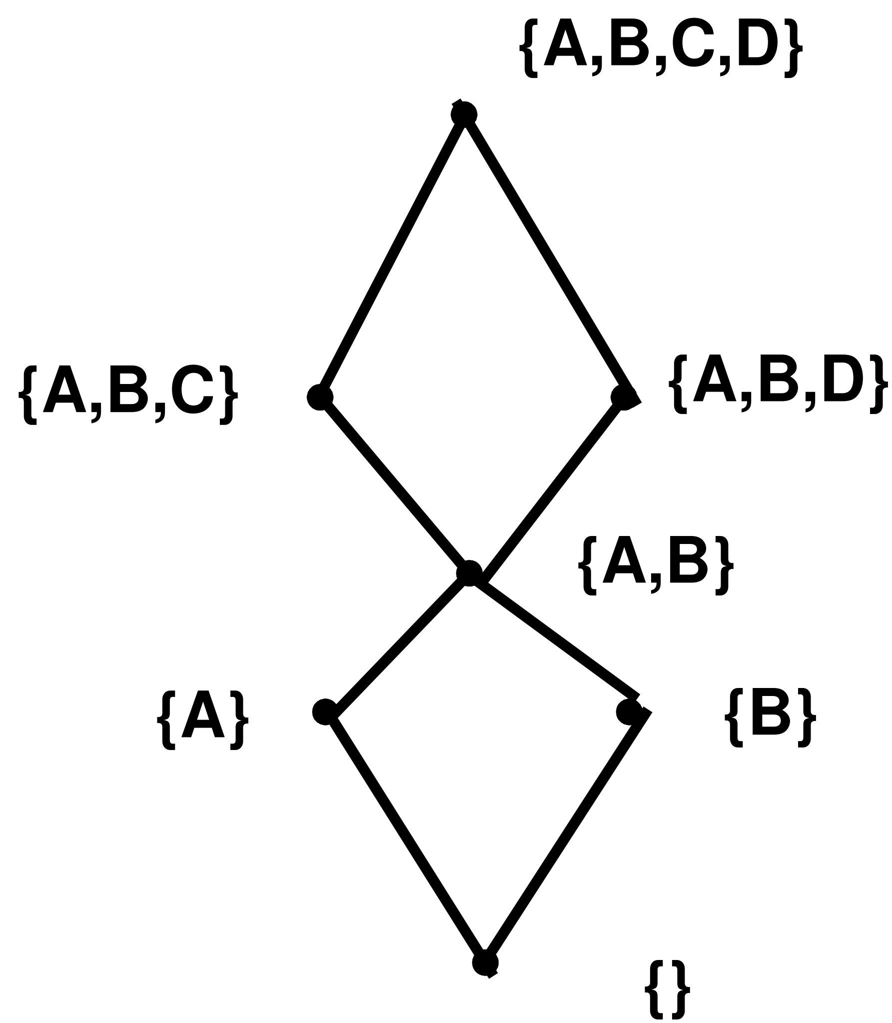
EMBEDDING A POSET IN A LATTICE

- Smith's subset of 21 labels do form a lattice. In general, however, selecting a subset of labels from a given lattice
  - may not yield a lattice, but
  - is guaranteed to yield a partial ordering
- Given a partial ordering we can always add extra labels to make it a lattice

EMBEDDING A POSET IN A LATTICE



$\Rightarrow$



such embedding is always possible

BLP BASIC ASSUMPTIONS

- **SUB = {S1, S2, ..., Sm}, a fixed set of subjects**
- **OBJ = {O1, O2, ..., On}, a fixed set of objects**
- **R $\supseteq$ {r, w}, a fixed set of rights**
- **D, an m $\times$ n discretionary access matrix with D[i,j] $\subseteq$ R**
- **M, an m $\times$ n current access matrix with M[i,j] $\subseteq$ {r, w}**

BLP MODEL
(LIBERAL STAR-PROPERTY)

- **Lattice of confidentiality labels**

$$\Lambda = \{\lambda 1, \lambda 2, ..., \lambda \mathbf{p}\}$$

- **Static assignment of confidentiality labels**

$$\lambda\text{: } \mathbf{SUB} \cup \mathbf{OBJ} \rightarrow \Lambda$$

- **M, an m $\times$ n current access matrix with**
  - **r $\in$ M[i,j] $\Rightarrow$ r $\in$ D[i,j] $\wedge$ λ(Si) $\geq$ λ (Oj)** **simple security**
  - **w $\in$ M[i,j] $\Rightarrow$ w $\in$ D[i,j] $\wedge$ λ(Si) $\leq$ λ (Oj)** **star-property**

BLP MODEL (STRICT STAR-PROPERTY)

- **Lattice of confidentiality labels**

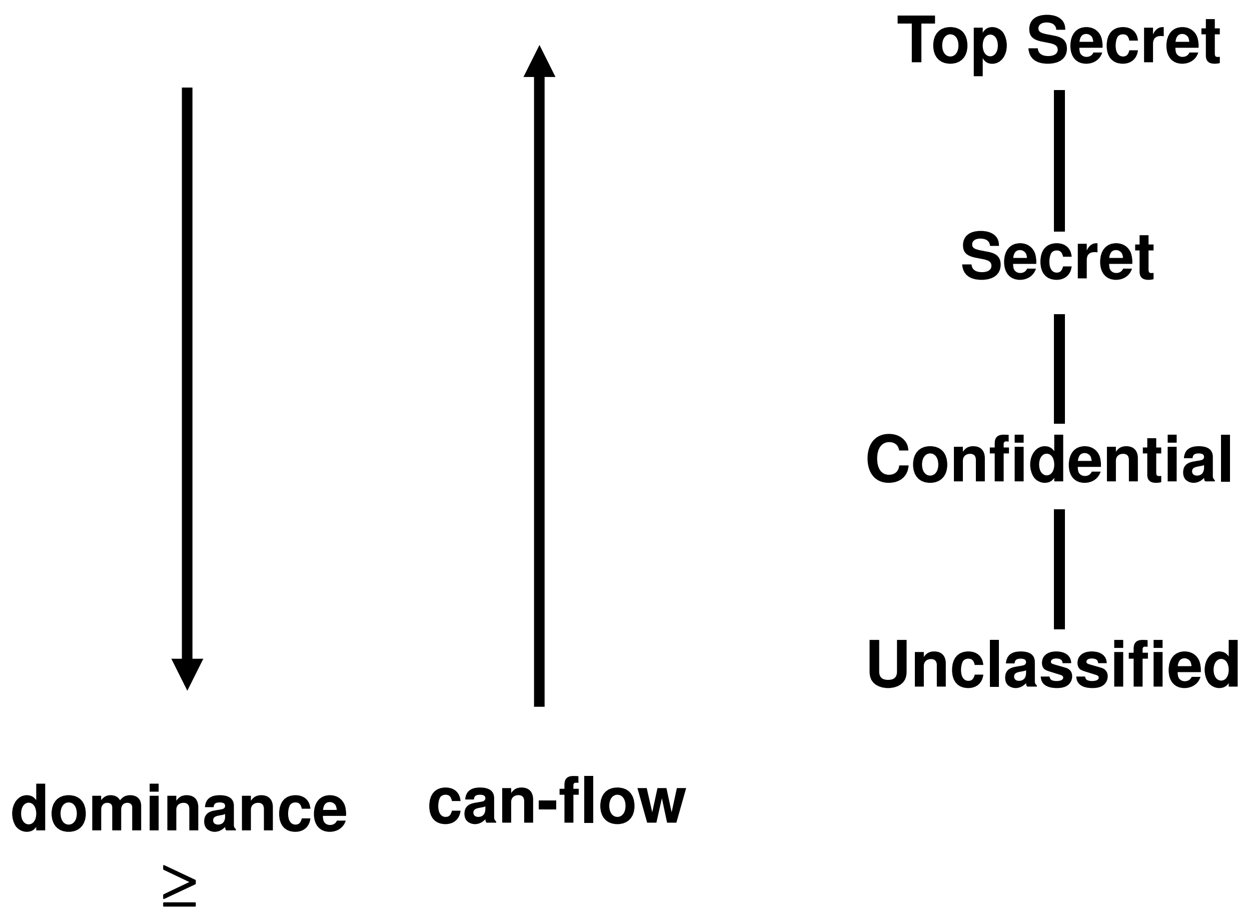
$$\Lambda = \{\lambda 1, \lambda 2, ..., \lambda \mathbf{p}\}$$

- **Static assignment of confidentiality labels**

$$\lambda\text{: } \mathbf{SUB} \cup \mathbf{OBJ} \rightarrow \Lambda$$

- **M, an m $\times$ n current access matrix with**
  - **r $\in$ M[i,j] $\Rightarrow$ r $\in$ D[i,j] $\wedge$ λ(Si) $\geq$ λ (Oj)** **simple security**
  - **w $\in$ M[i,j] $\Rightarrow$ w $\in$ D[i,j] $\wedge$ λ(Si) $=$ λ (Oj)** **star-property**

BLP MODEL


Top Secret
Secret
Confidential
Unclassified
dominance
≥
can-flow

STAR-PROPERTY

- **applies to subjects not to users**
- **users are trusted (must be trusted) not to disclose secret information outside of the computer system**
- **subjects are not trusted because they may have Trojan Horses embedded in the code they execute**
- **star-property prevents overt leakage of information and does not address the covert channel problem**

BIBA MODEL

- **Lattice of integrity labels**

$$\Omega = \{\omega 1, \omega 2, ..., \omega \mathbf{q}\}$$

- **Assignment of integrity labels**

$$\omega\text{: } \mathbf{SUB} \cup \mathbf{OBJ} \rightarrow \Omega$$

- **M, an m $\times$ n current access matrix with**
  - **r** $\in$ **M[i,j]** $\Rightarrow$ **r** $\in$ **D[i,j]** $\wedge$ ω**(Si)** $\leq$ ω **(Oj)** **simple integrity**
  - **w** $\in$ **M[i,j]** $\Rightarrow$ **w** $\in$ **D[i,j]** $\wedge$ ω**(Si)** $\geq$ ω**(Oj)** **integrity confinement**

EQUIVALENCE OF BLP AND BIBA

- **Information flow in the Biba model is from top to bottom**
- **Information flow in the BLP model is from bottom to top**
- **Since top and bottom are relative terms, the two models are fundamentally equivalent**

EQUIVALENCE OF BLP AND BIBA

HI (High Integrity)	**LI (Low Integrity)**
|	|
LI (Low Integrity)	**HI (High Integrity)**

$\Rightarrow$

BIBA LATTICE | **EQUIVALENT BLP LATTICE**

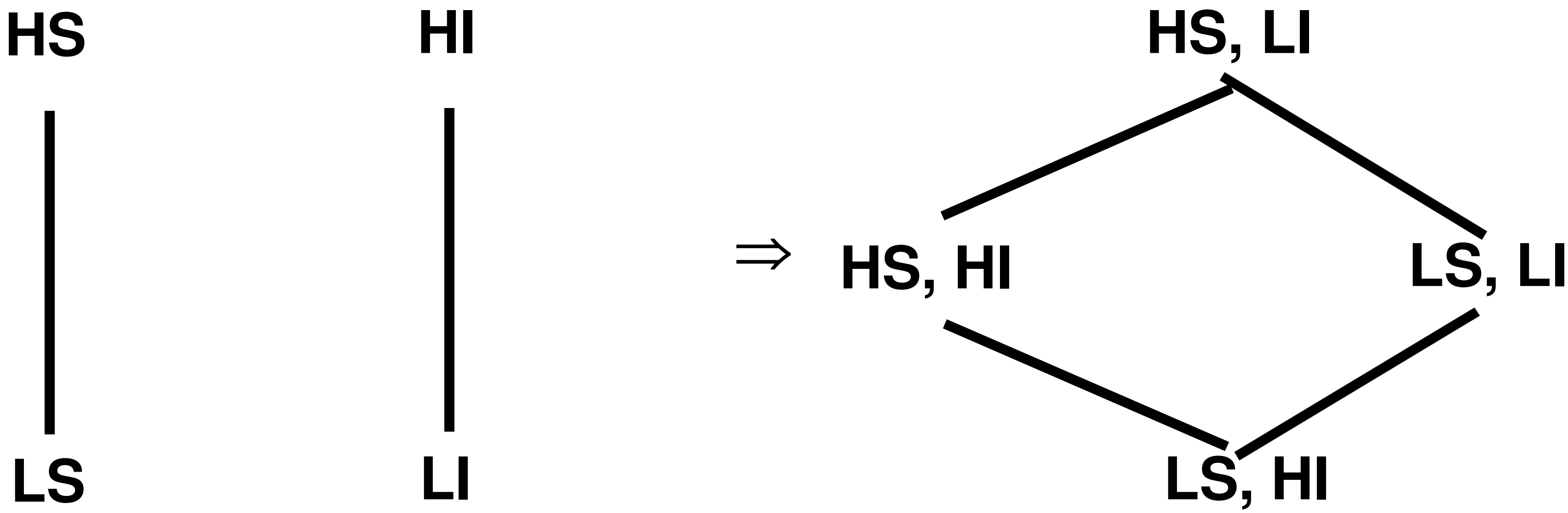
EQUIVALENCE OF BLP AND BIBA

BLP LATTICE		EQUIVALENT BIBA LATTICE
HS (High Secrecy)		**LS (Low Secrecy)**
|	$\Rightarrow$	|
LS (Low Secrecy)		**HS (High Secrecy)**

BLP LATTICE

EQUIVALENT BIBA LATTICE

COMBINATION OF DISTINCT LATTICES



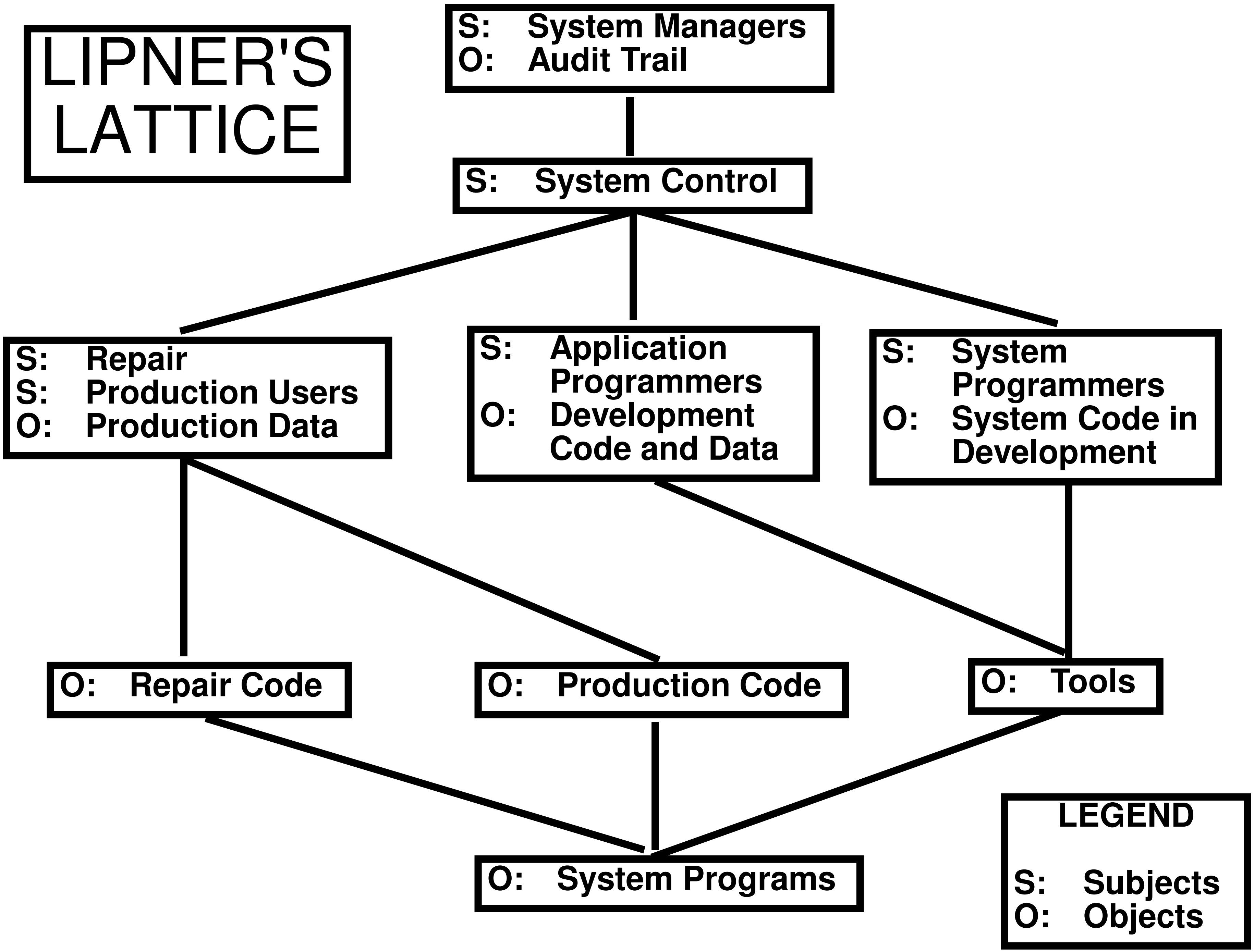
BLP **BIBA**

GIVEN

EQUIVALENT BLP LATTICE

BLP AND BIBA

- **BLP and Biba are fundamentally equivalent and interchangeable**
- **Lattice-based access control is a mechanism for enforcing one-way information flow, which can be applied to confidentiality or integrity goals**
- **We will use the BLP formulation with high confidentiality at the top of the lattice, and high integrity at the bottom**


LIPNER'S LATTICE
S: System Managers
O: Audit Trail
S: System Control
S: Repair
S: Production Users
O: Production Data
S: Application Programmers
O: Development Code and Data
S: System Programmers
O: System Code in Development
O: Repair Code
O: Production Code
O: Tools
O: System Programs
LEGEND
S: Subjects
O: Objects

LIPNER'S LATTICE

- **Lipner's lattice uses 9 labels from a possible space of 192 labels (3 integrity levels, 2 integrity compartments, 2 confidentiality levels, and 3 confidentiality compartments)**
- **The single lattice shown here can be constructed directly from first principles**

LIPNER'S LATTICE

- **The position of the audit trail at lowest integrity demonstrates the limitation of an information flow approach to integrity**
- **System control subjects are exempted from the star-property and allowed to**
  - **write down (with respect to confidentiality)**

  or equivalently
  - **write up (with respect to integrity)**

DYNAMIC LABELS IN BLP

- **Tranquility (most common):**
  λ is static for subjects and objects

- **BLP without tranquility may be secure or insecure depending upon the specific dynamics of labelling**

- **Noninterference can be used to prove the security of BLP with dynamic labels**

DYNAMIC LABELS IN BLP

- **High water mark on subjects:**
  λ is static for objects
  λ may increase but not decrease for subjects

  Is secure and is useful

- **High water mark on objects:**
  λ is static for subjects
  λ may increase but not decrease for subjects

  Is insecure due to disappearing object signaling channel