Chemical Biology (& Biological Chemistry)

Ben Davis [Ben.Davis@chem.ox.ac.uk] – 4 Lectures as Part of Option II

Prior Knowledge Required

1. *1st year Biological Chemistry course*: Molecules of life. What are amino acids, peptides, proteins, sugars, nucleotides, nucleic acids – knowledge of their structures. Energy & Phosphates. Protein structure and folding. Basic principles of enzyme catalysis and inhibitor action; Michaelis-Menten kinetics. Basics of protein structure. Genetics and Protein Synthesis; transcription/translation/DNA→mRNA→protein; one letter and three letter codes for amino acids.
2. *2nd year Biological Chemistry course*: the mechanisms and principles behind primary metabolism; nature's reagents; glycolysis; CAC; oxidative phosphorylation; amino acid metablolism.

There will be one 'foundation' class (**F**) revising some of the key aspects of your 1st and 2nd year lectures as part of this course: Monday of 5th week, 5-6pm, Wolfson Seminar Room, CRL.

Books:

"Structure and Mechanism in Protein Science" Fersht; Freeman 2000 *Good on Enzyme Basics & Folding*
"An Introduction to Biotransformations in Organic Chemistry" Hanson; *A good intro to biotrans*
"Biotransformations in Organic Chemistry" Faber; *More detailed aspects of biotrans*
"Biochemistry and Molecular Biology" Elliott & Elliott; OUP *Good for quick overview & basics*
"Foundations of Chemical Biology" OCP 98 *Good as a basic introduction (e.g. folding)*
"Carbohydrate Chemistry" OCP 99 *A Masterpiece – clearly.*
"Bioinformatics" Higgins & Taylor; OUP 2004 *Detailed practical & research aspects of Bio-Info*
"Oxford Dictionary of Biochemistry and Molecular Biology" OUP 2004 *Good for Definitions*
"Bioinformatics" Lesk; OUP 2002 *Good for placing the study of Bio-Info in a proper context*
"Organic Chemistry of Biological, McMurry & Begley; Scion 2005 *Good for seeing some curly arrows (about time); concentrates mainly on biosynthesis.*
"Biochemistry" Berg, Tymoczko & Stryer 5ed; Freeman 2002 *A great all-rounder*
"Essential Genetics, A Genomics Perspective" Hartl & Jones 4ed; Jones & Bartlett 2006

Hand-outs and **Slot-ins** will be distributed throughout the course or can be downloaded from the website (see above). These will summarize key parts and learning outcomes from the course. Collect the set.

Hand-outs

- ☐ **(F) Foundation.**
- ☐ **(1) Biological Catalysis.**
- ☐ **(2) From Genome to Proteome.**
- ☐ **(3) Chemical Methods for the Proteome.**
- ☐ **(4) Case Studies in Chemical Biology.**

Slot-ins

- ☐ **Course Summary (S)**
- ☐ **Definitions (D)**
- **Techniques (T)**
  - ☐ **T1**: DNA Seqeuncing
  - ☐ **T2**: Protein Sequencing
- **Mechanisms (M)**
  - ☐ **M1**: PCR
  - ☐ **M2**: Acyl Transfer
  - ☐ **M3**: Glycosidases
- **Case Histories (CH)**
  - ☐ **CH1**: Proteome Ser Protease Tagging
  - ☐ **CH2**: Mapping the Role of PTMs
  - ☐ **CH3**: Sugar-Processing Enzymes

Topics to be Covered

(F) Foundations of Chemical Biology & Biochemistry. Overview of Genomic Basics; Genome; Genes. DNA sequencing (Sanger dideoxy **T1**). Transcription; Codons. Peptide & Protein Structure; Protein Folding & (in brief) Archictecture. Enzymes; Michaelis-Menten kinetics; inhibition modes; the serine protease mechanism.

D1, T1, S

(1) Biological Catalysis. General principles of enzyme catalysis. Overview of biological catalysts (including ribozymes) and classifications. General themes of catalysis that allow insight into other biological mechanisms. Catalytic antibodies. Acyl transfer as an illustration of dominant modes of catalysis (proteasome; proteases; ribosome; protein splicing and ligation; carbohydrate-processing enzymes).

D1, S, M2, M3

(2) From Genome to Proteome. Acyl Transfer in Protein Synthesis. The Mechanism of the Ribosome. Proteomes. Functional Genomics & Chemical Proteomics. Using Genomic Information. Medicinal and other implications of Genomics

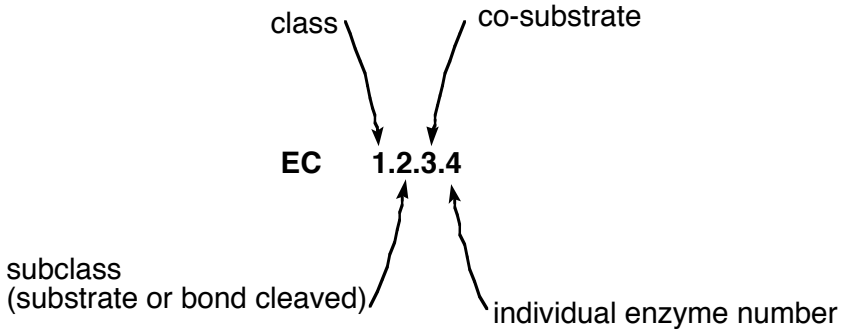
(3) Chemical Methods for the Proteome. Characterisation of Proteins. CD, GE (& in brief) sequencing of peptides. Genetic Engineering (as chemistry) including recombinant methods, mutants and the polymerase chain reaction (PCR). Extent, roles & effects of Post-translational Modifications (PTMs).

T2, M1

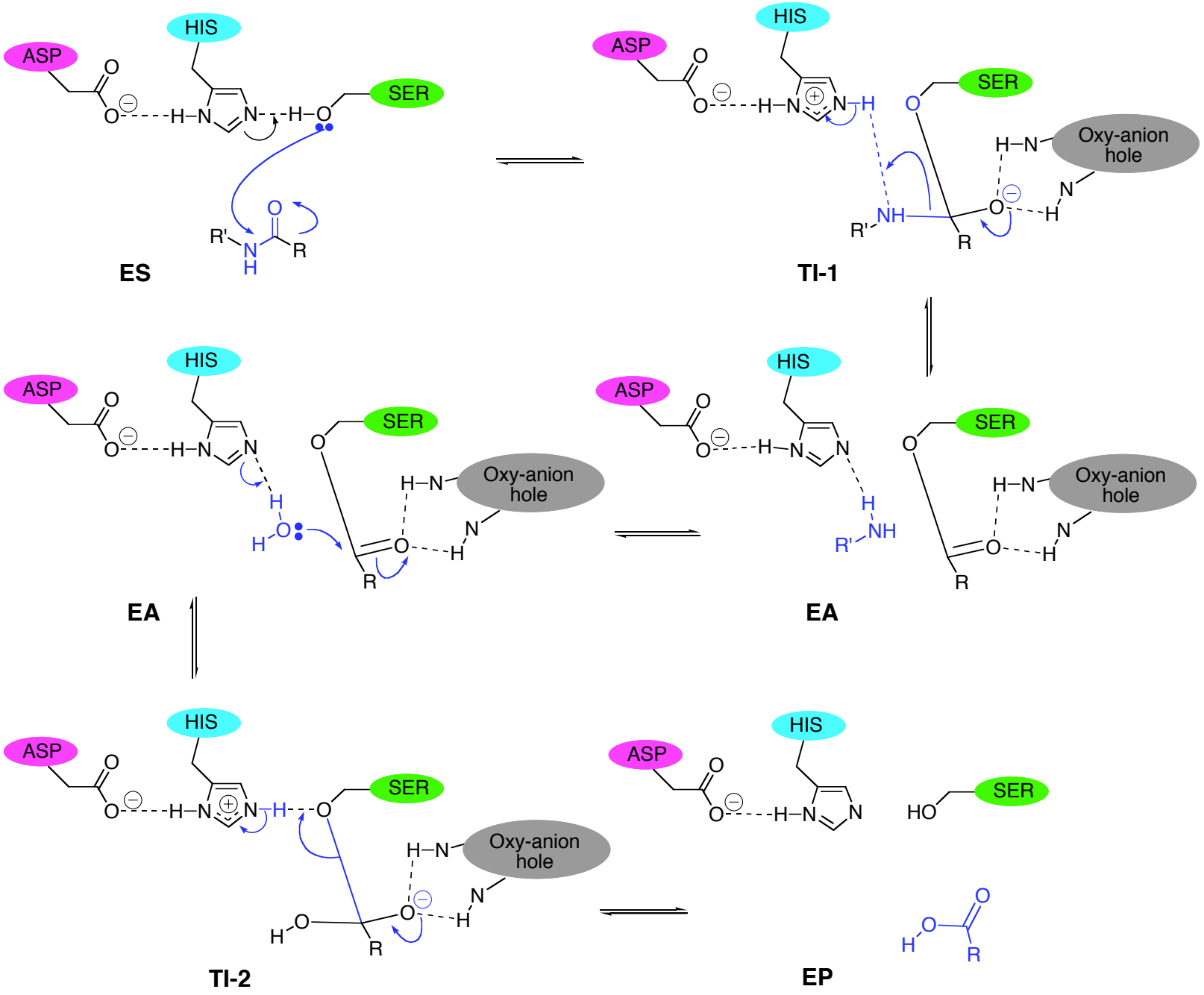
(**4) Case Studies in Chemical Biology.** Mechanism-based probes and inhibitors. Chemical strategies for elucidating biological mechanism.

CH1, CH2, CH3

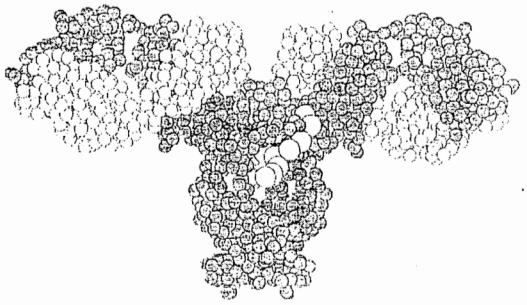
Enzyme classification
Enzyme commission 1955 (IUPAC)
EC 1.2.3.4
~20,000? exist
Online directory http://www.expasy.ch/enzyme/

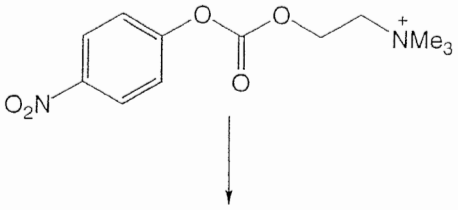


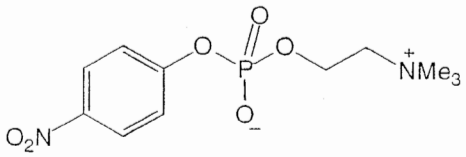
Class	Reaction Type	Number		Usage
		Classified	Available	
1. Oxidoreductases	Redox: C-H, C-C, C=C oxygenation; (de)hydrogenases	~1000	~100	25%
2. Transferases	Transfer acyl, sugar, phosphoryl, methyl	~1000	~100	10%
3. Hydrolases	Hydolyse/form esters, amides, lactones, lactams, epoxides, nitriles, anhydrides, glycosides	~1000	~300	55%
4. Lyases	Addition/elimination to C=X (X = C, N, O)	~300	~50	5%
5. Isomerases	Racemization, epimerization	~150	~10	3%
6. Ligases	Formation/cleavage of C-X (O, S, N, C)	~100	~10	2%

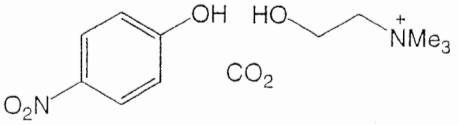

ASP
HIS
SER
Oxy-anion hole
ES
TI-1
EA
EA
TI-2
EP

Catalytic antibodies

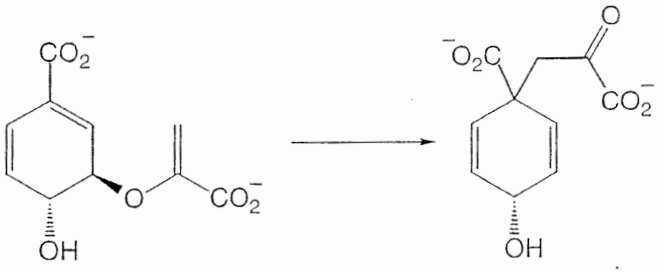




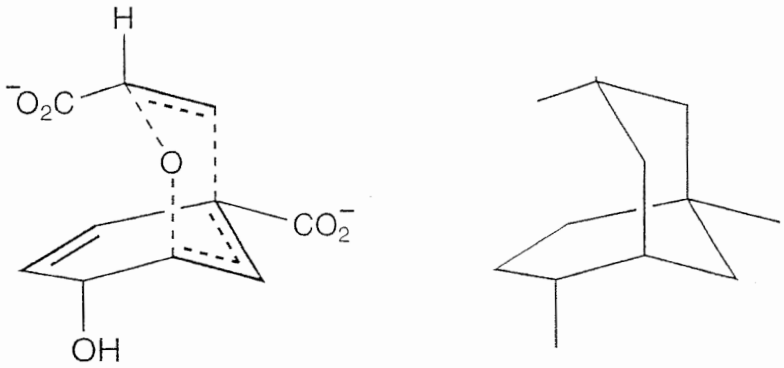




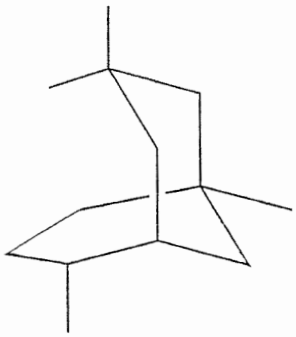
$$\frac{k_{cat}}{k_{uncat}} \approx$$



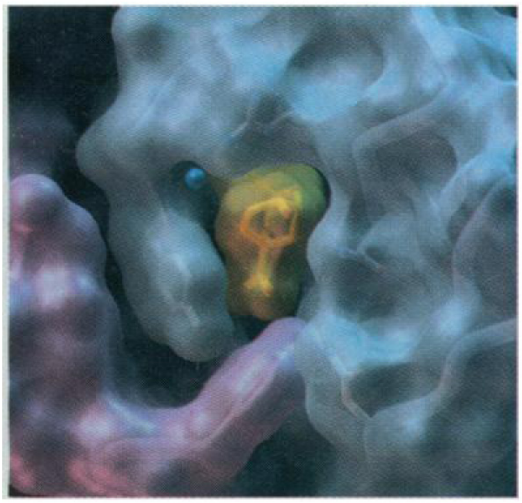
chorismate

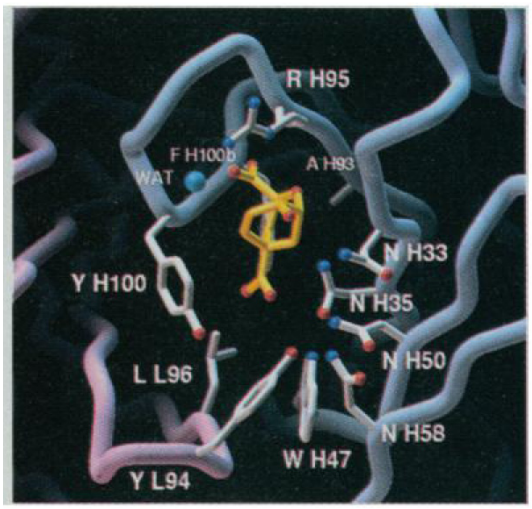


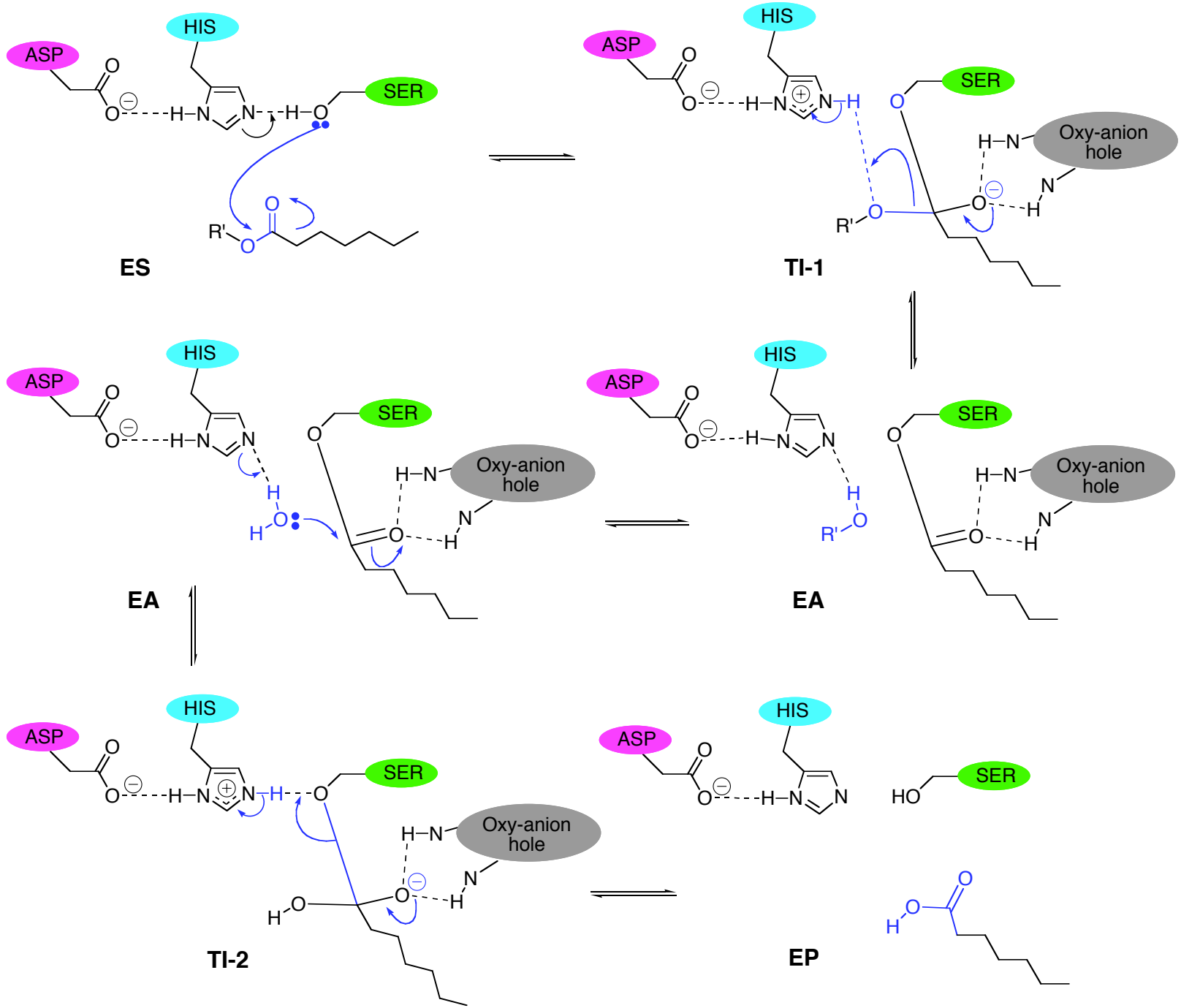
transition state analogue

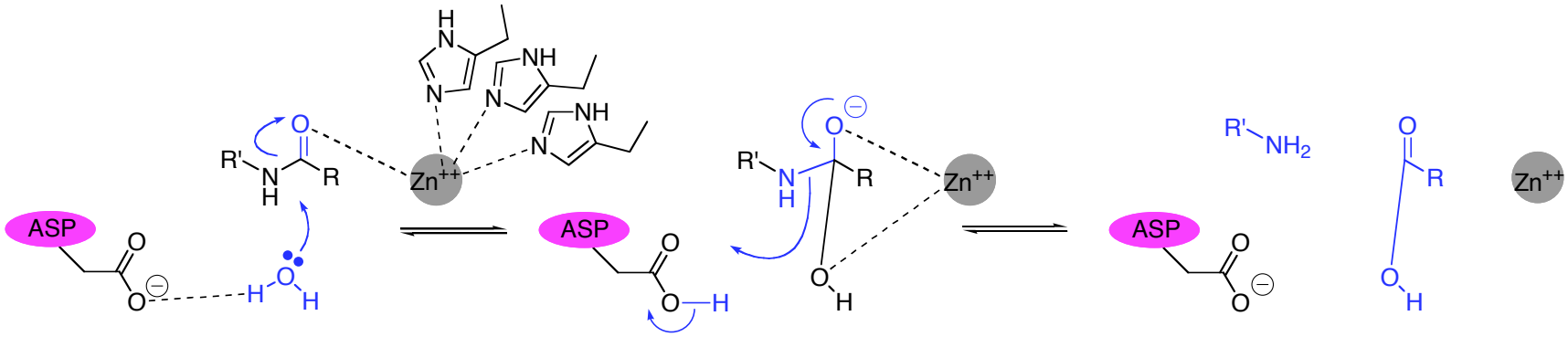


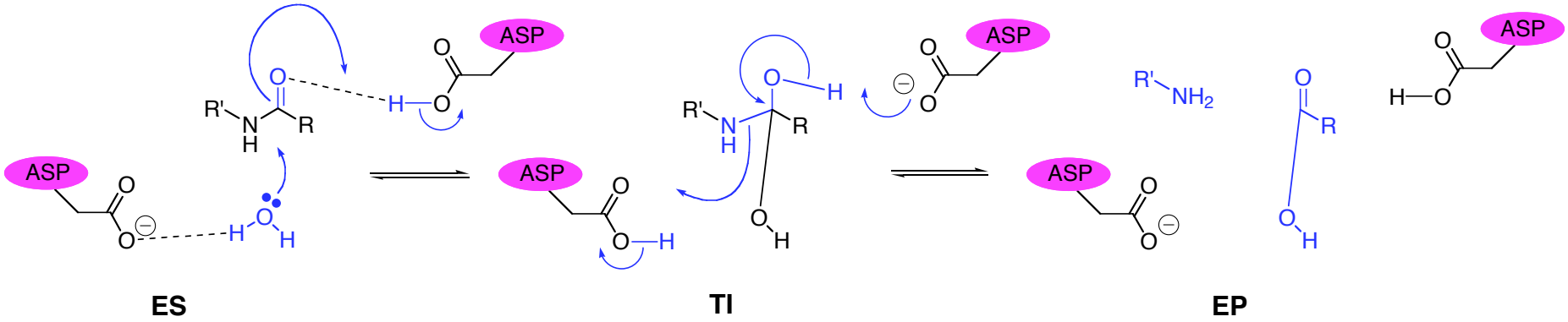
$$\frac{k_{cat}}{k_{uncat}} \approx$$

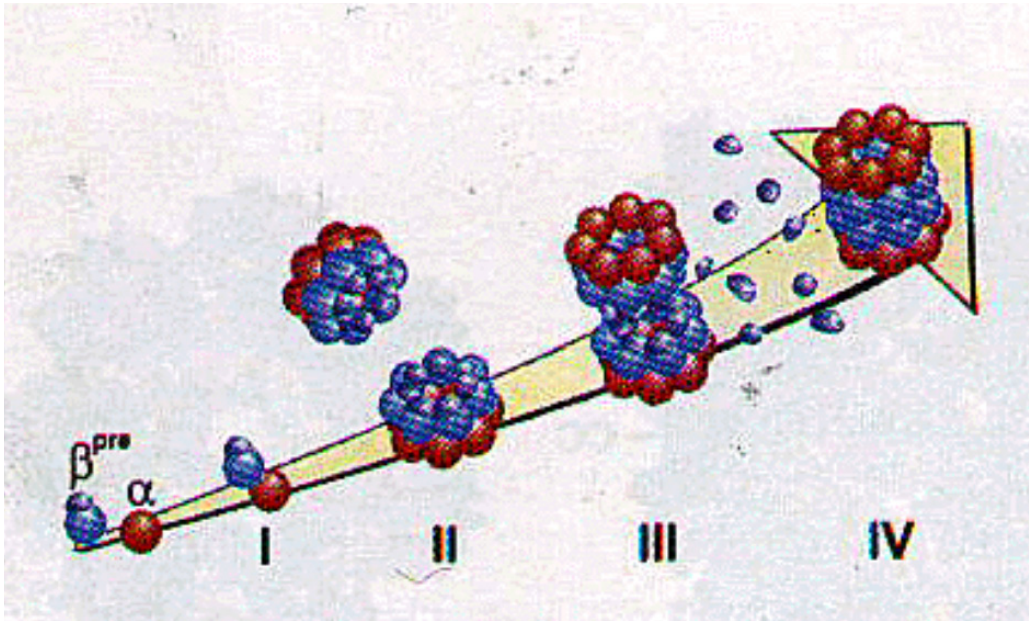


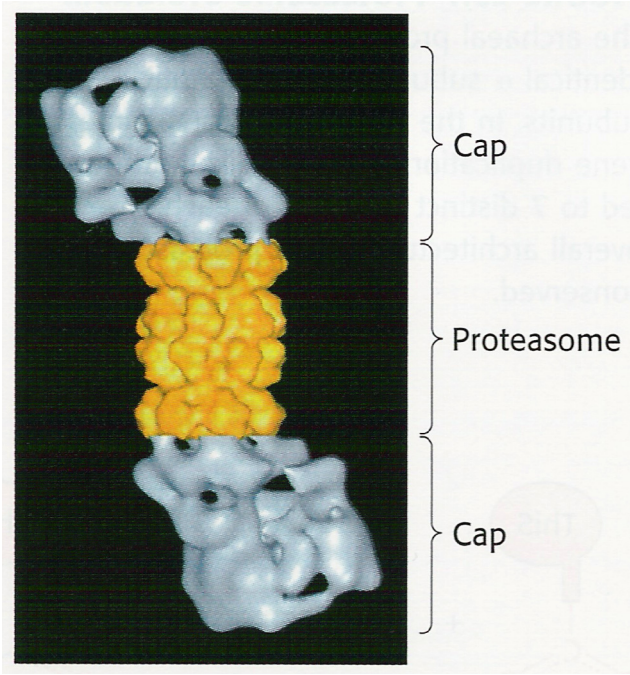


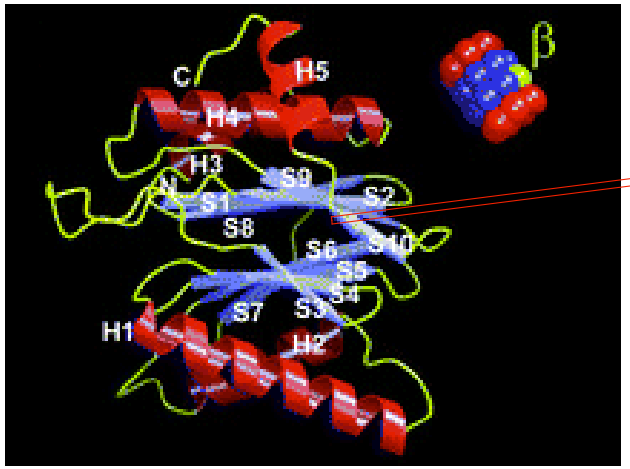

ASP
HIS
SER
Oxy-anion hole
ES
TI-1
EA
EA
TI-2
EP

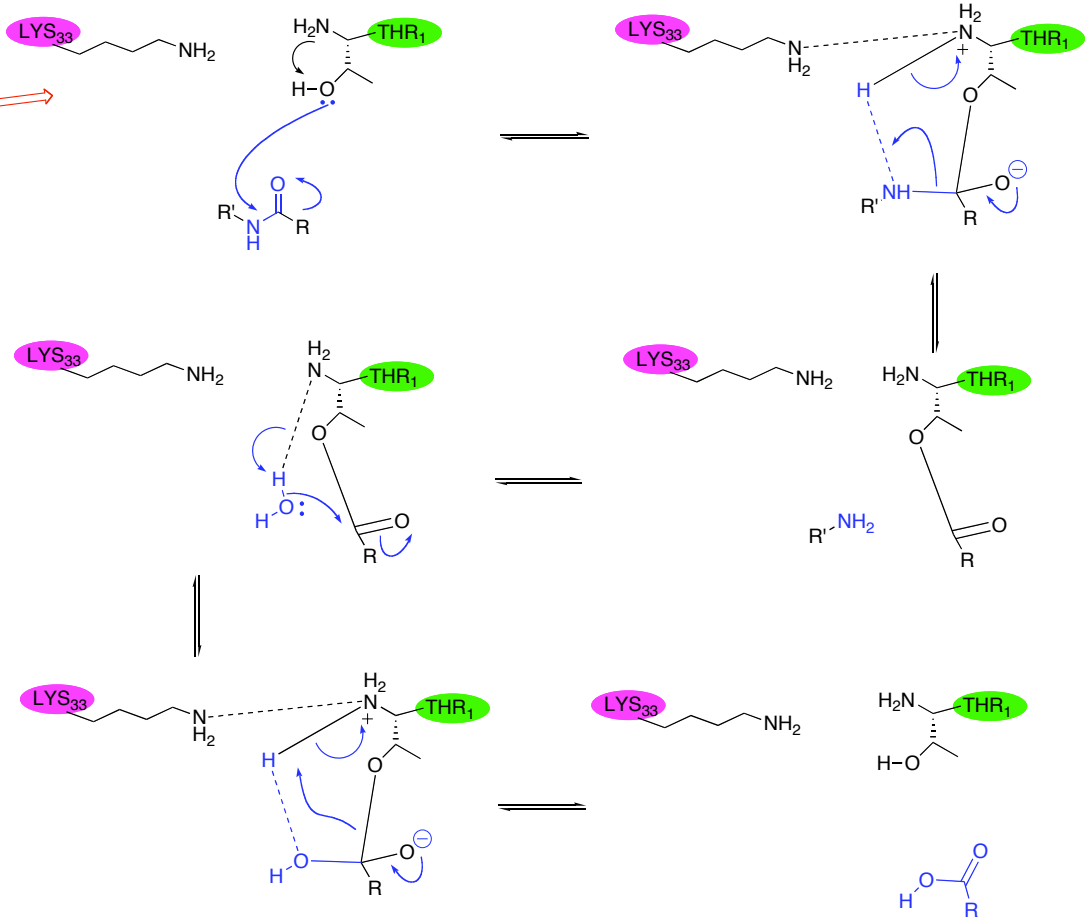

ASP
R'
N
H
R
O
Zn++
NH
R'NH2
ES
TI
EP

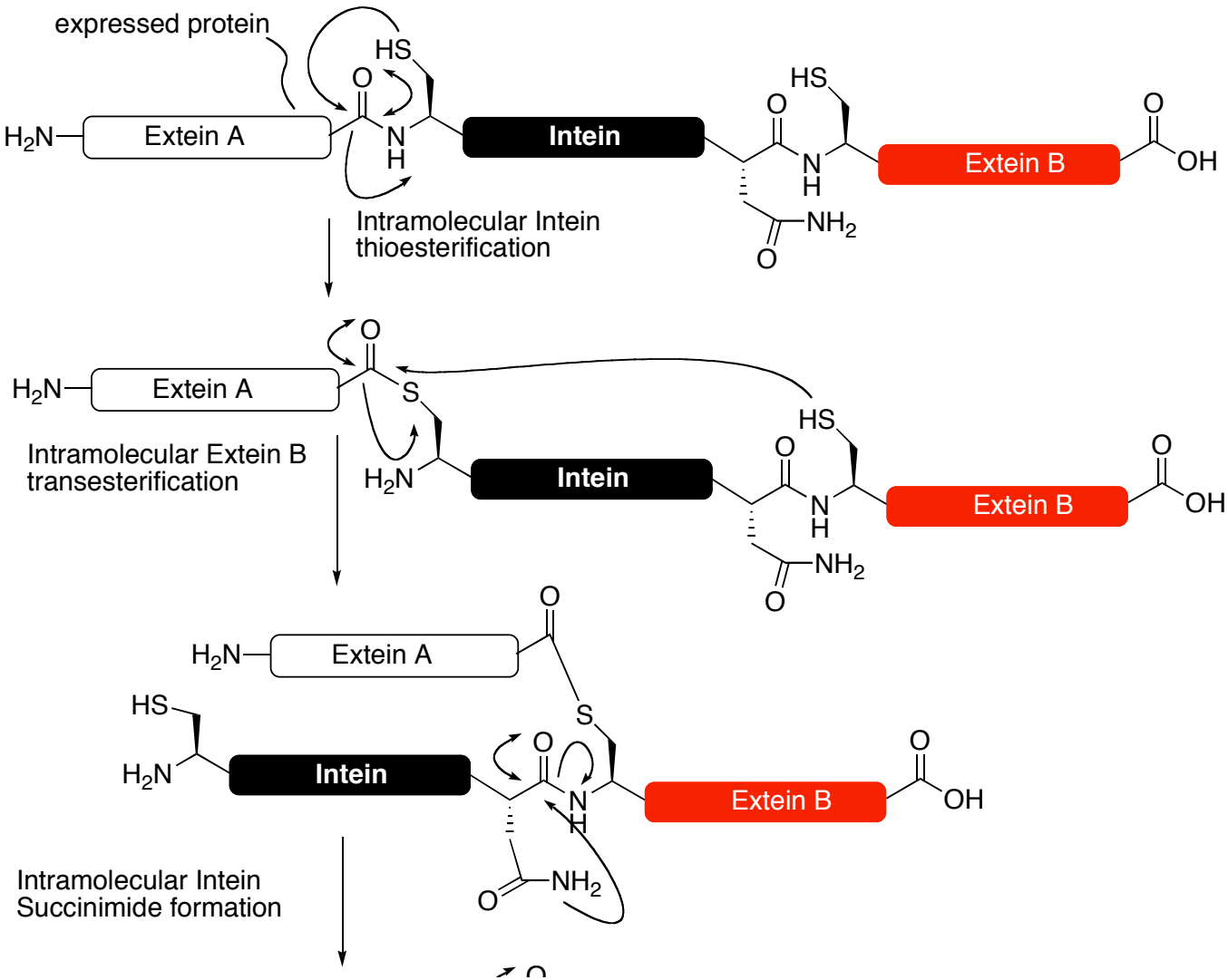

ASP
R'
N
H
R
O
H
ES
TI
EP

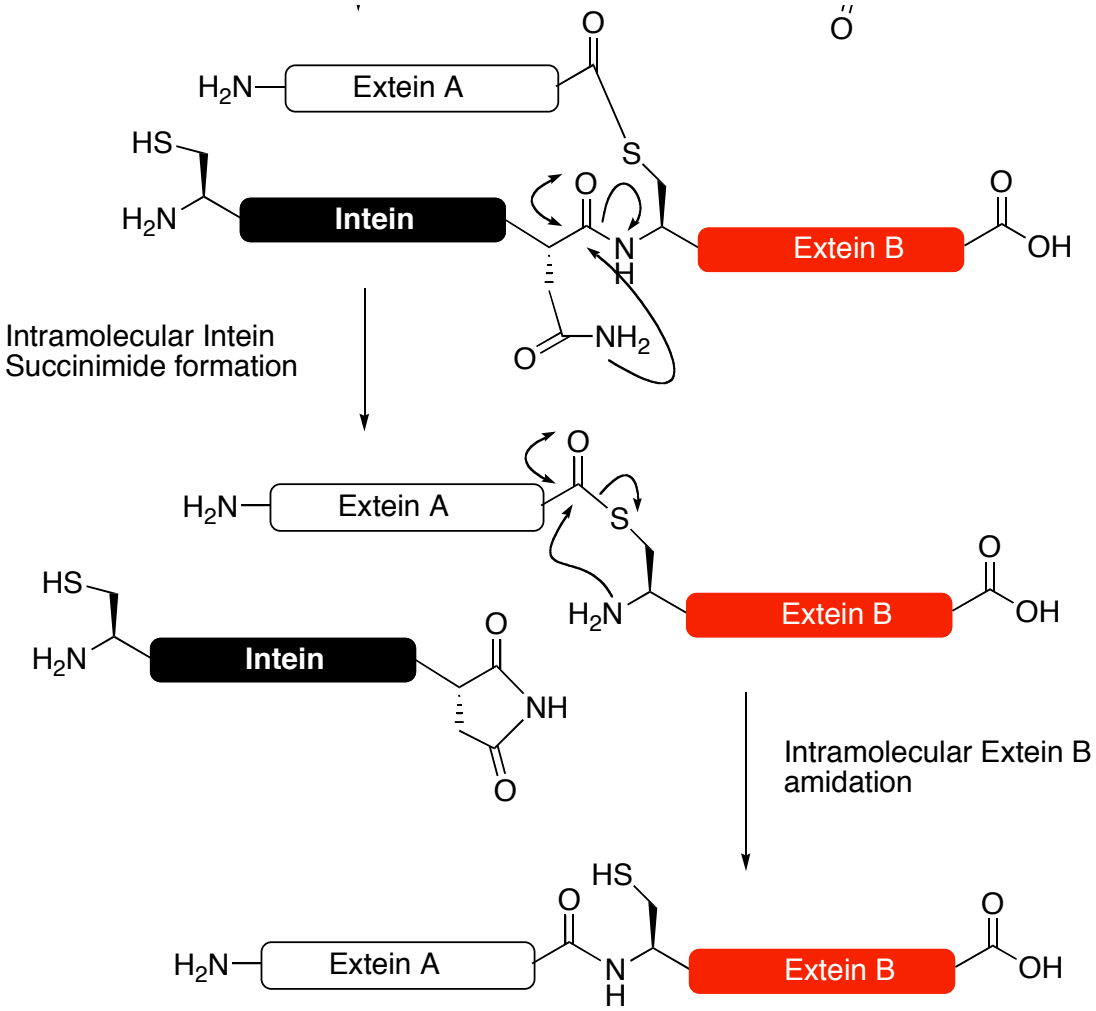

β^pre
α
I
II
III
IV


Cap
Proteasome
Cap


C
H5
β
H4
H3
S9
S1
S2
S8
S6
S10
S5
S4
S7
S3
H1
H2

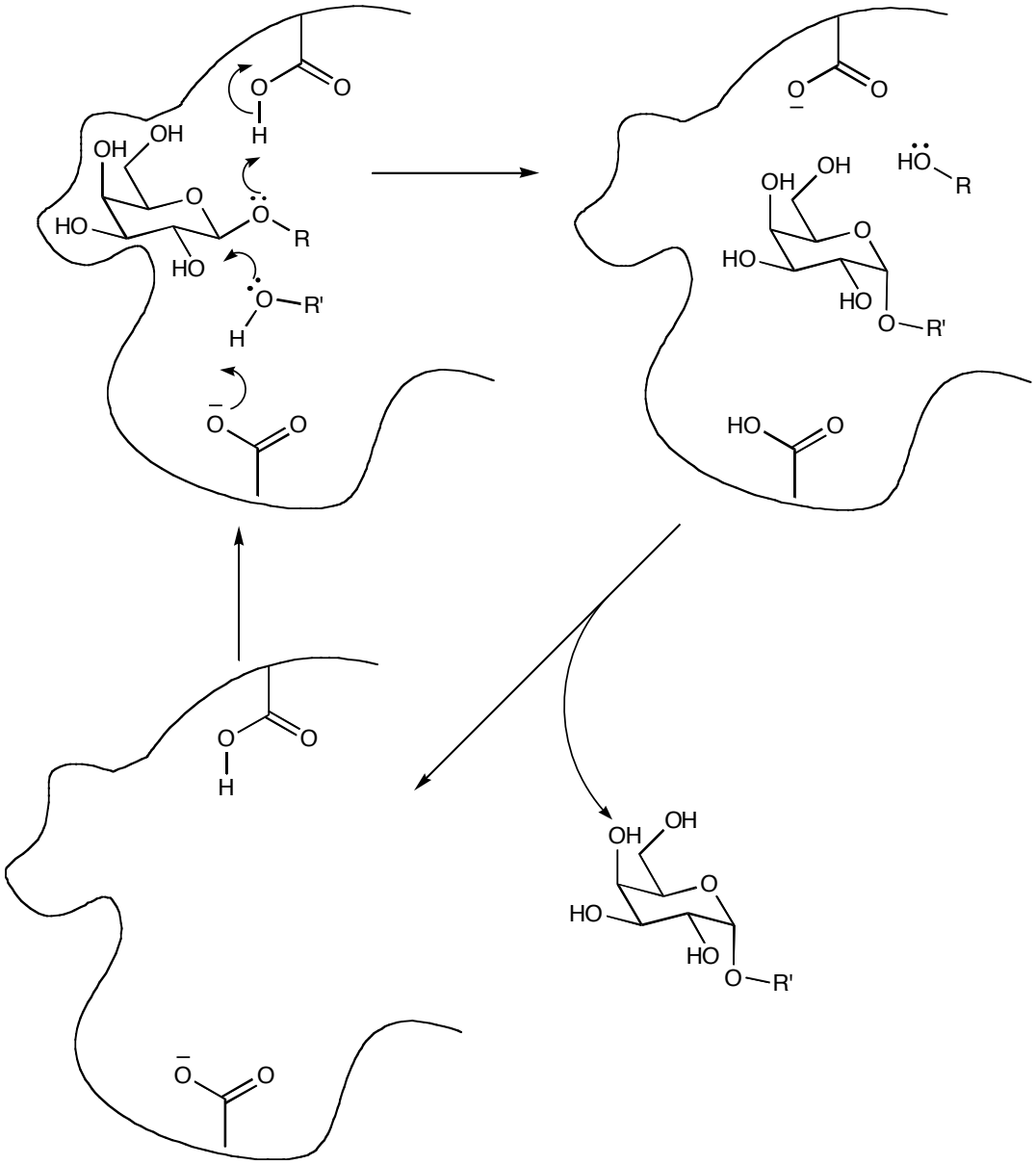

LYS33
NH2
H2N
THR1
H–O
O
R'
N
H
R
H2
N
+
H
NH
O
R
R'NH2


expressed protein
HS
O
H_2N
Extein A
N
H
Intein
HS
O
N
H
Extein B
O
OH
NH_2
O
Intramolecular Intein
thioesterification
O
H_2N
Extein A
S
Intramolecular Extein B
transesterification
H_2N
HS
O
Intein
N
H
Extein B
O
OH
NH_2
O
O
H_2N
Extein A
S
HS
H_2N
Intein
O
N
H
Extein B
O
OH
O
NH_2
Intramolecular Intein
Succinimide formation
O


Extein A
Intein
Extein B
Intramolecular Intein
Succinimide formation
Intramolecular Extein B
amidation

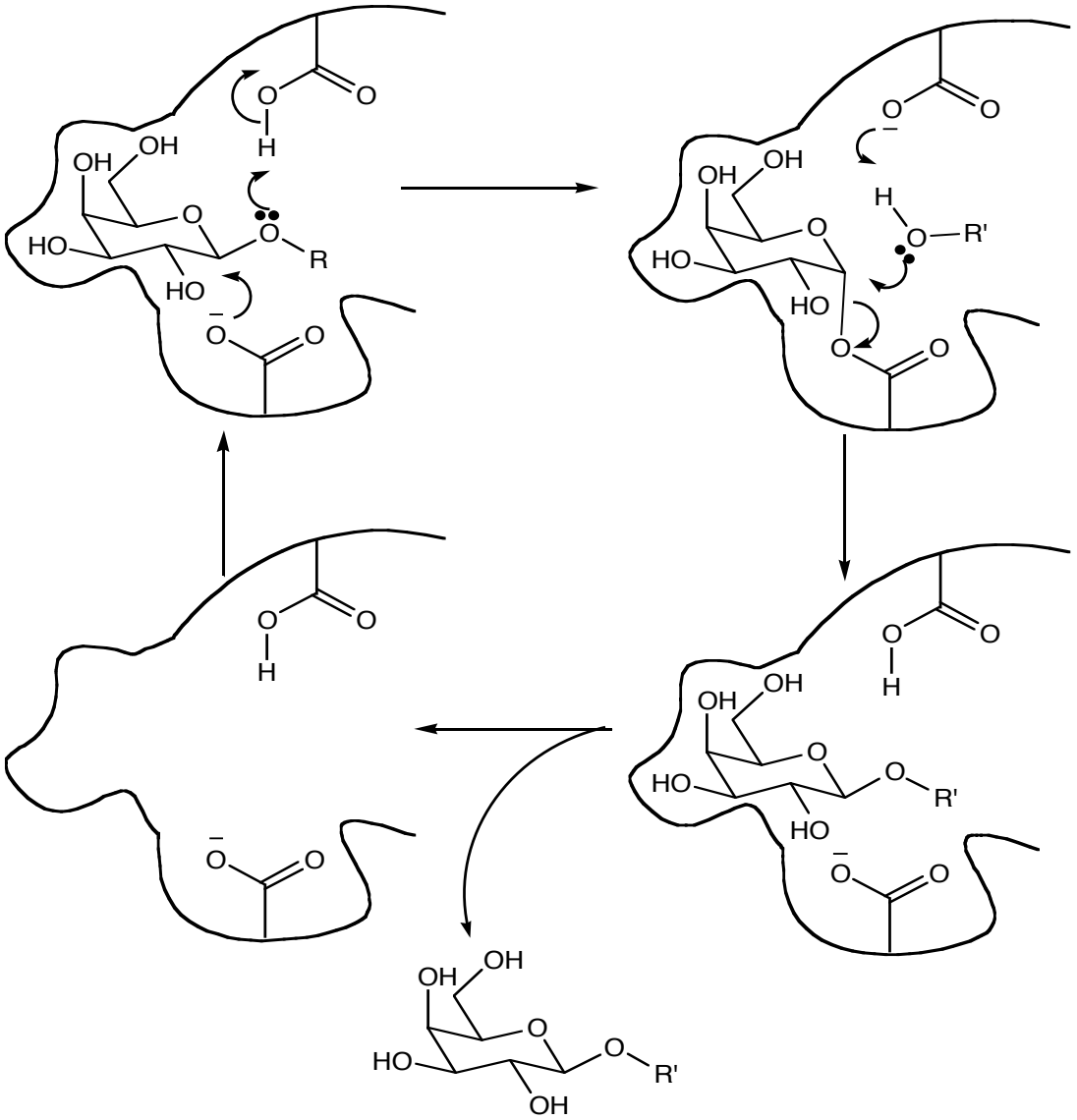
Inverting Glycosidases

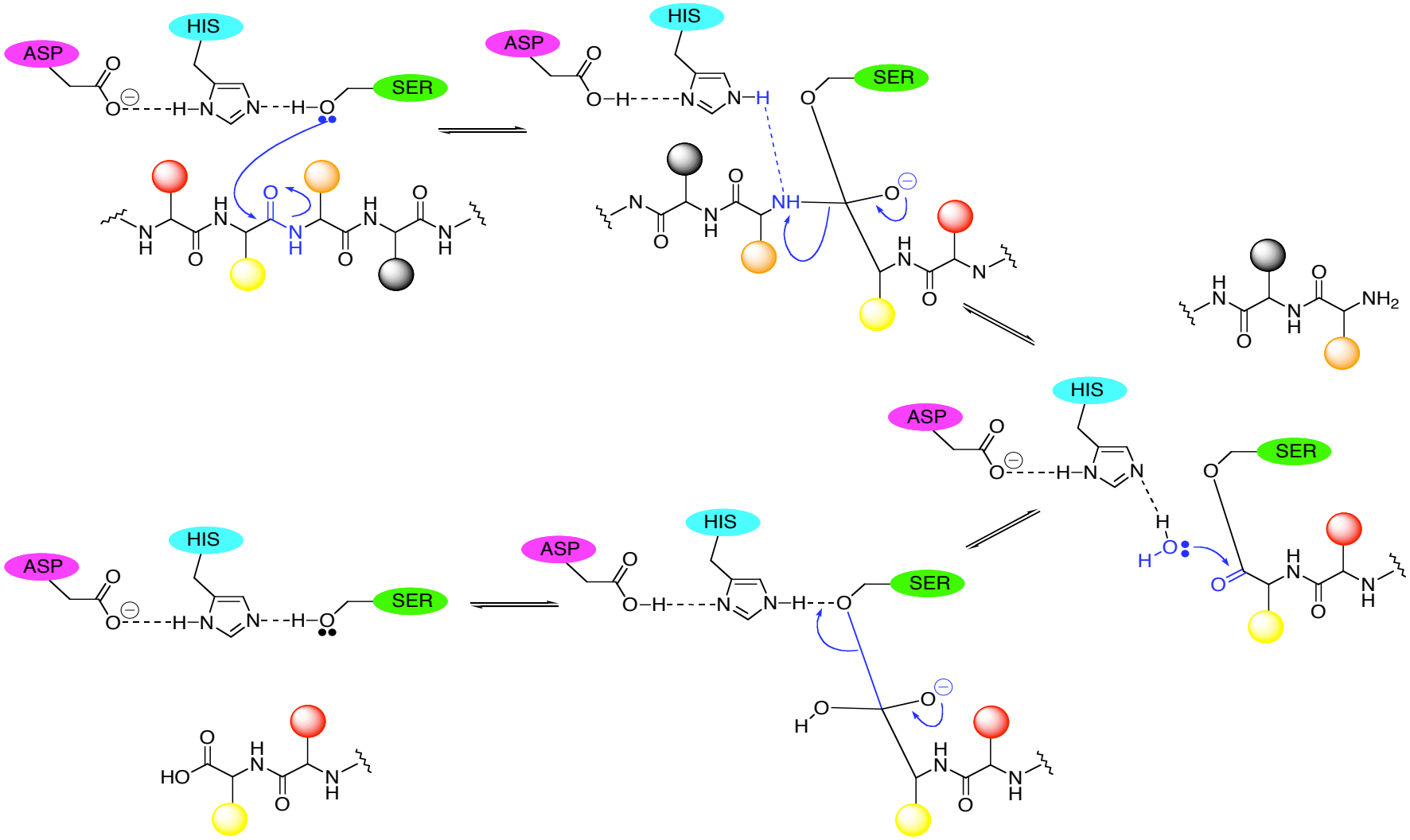
•See the similarity with Aspartyl Proteases



Retaining Glycosidases

•See the similarity with Serine Proteases (with a different nucleophile – *why*?)




ASP
HIS
SER
ASP
HIS
SER
NH2
ASP
HIS
SER
ASP
HIS
SER
HO