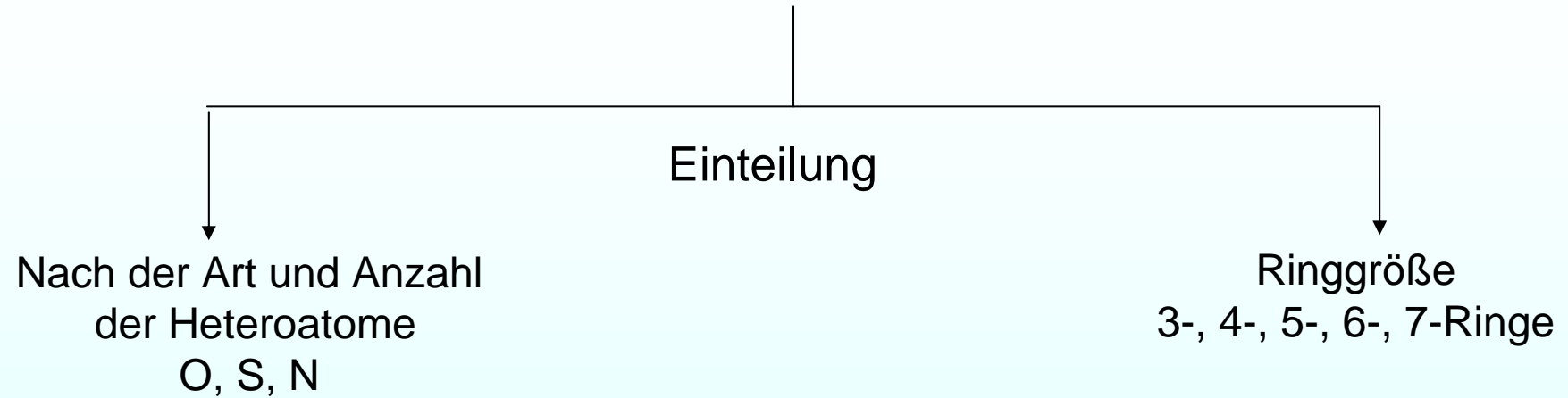
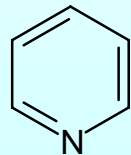


Heterocyclische Verbindungen

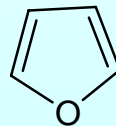
HETEROCYCLISCHE VERBINDUNGEN



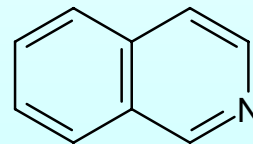
Nomenklatur: Trivialnamen



Pyridin

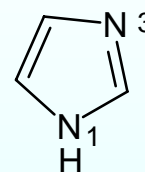
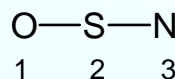
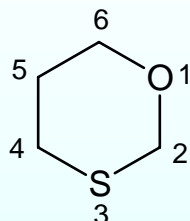
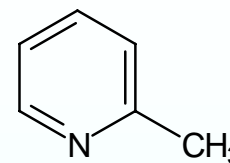
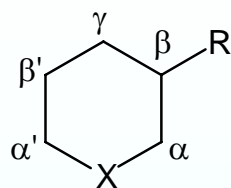
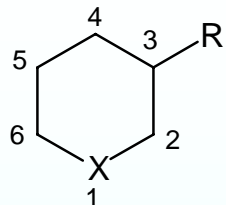


Furan



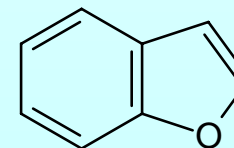
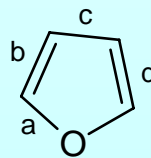
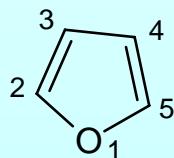
Isochinolin

Nomenklatur



Numerierung: beginnt stets am Heteroatom,
weitere Heteroatome müssen am möglichst
niedrigste Nummern bekommen

Benzoanellierte heterocyclische Verbindungen



- Prefix bezeichnet den aromatischen Ring
- Bindung der Anellierung
- Name des Heteroringes

Benzo[2,3]furan
Benzo[*b*]furan

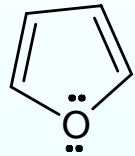
Systematische Namen nach der IUPAC Nomenklatur

Ringgröße	O		S		N	
	ungesättigt t	gesättigt	ungesättigt t	gesättigt	ungesättigt t	gesättigt
3	Oxiren	Oxiran	Thiiren	Thiiran	Azirin	Aziridin
4	Oxet	Oxetan	Thiet	Thietan	Azet	Azetidin
5	Oxol	Oxolan	Thiol	Thiolan	Azol	Azolidin
6	Oxin	Oxan	Tthiin	Thian	Azin	Azinan
7	Oxepin	Oxepan	Thiepin	Thiepan	Azepin	Azepan

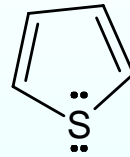
Allgemeine Eigenschaften der Heterocyclen

Aromatischer Charakter

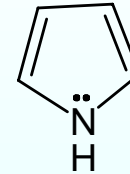
Fünfringe



Furan



Thiophen



Pyrrol

- planare Molekülstruktur
- reaktive Verbindungen in electrophilen Substitutionen

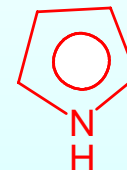
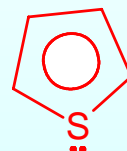
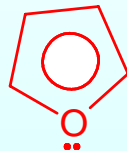
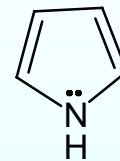
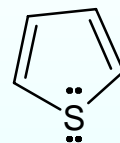
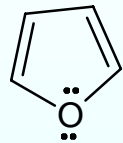


Eigenschaft von Aromaten

Elektronenstruktur

Fünfringe

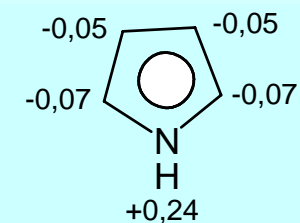
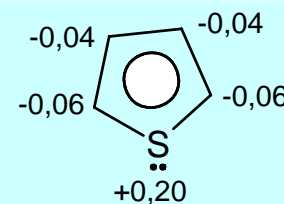
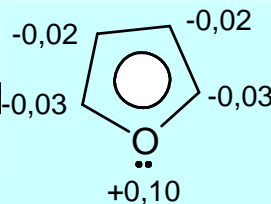
Einsames Elektronenpaar des Heteroatoms ist am delokalisierten π -System beteiligt



Kriterien der Aromatizität: - Anzahl der π -Elektronen: $4n+2$
- kontinuierliche Delokalisierung
- planare Ringstruktur

Verteilung der π -Elektronen

- Deformierung des π -Elektronesextetts
- π -elektronenreiche Heterocyclen

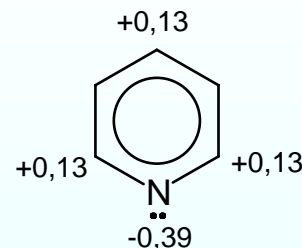
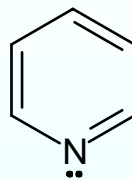


Elektronenstruktur

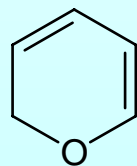
Sechsringe

Pyridin

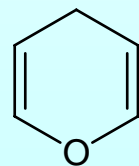
- schwache Base
- geringe Reaktivität in S_E -Reaktionen



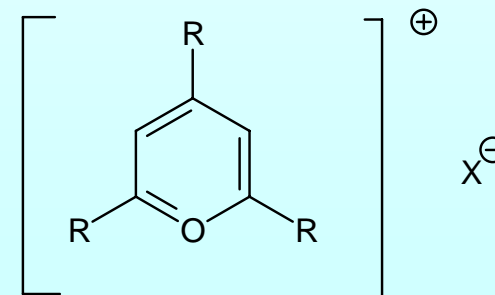
- Das einsame Elektronenpaar ist am π -Elektronensextett nicht beteiligt.
- kontinuierliche Delokalisierung von 6 p-Orbitalen
- π -elektronenarme Heteroaromaten



α -Pyran



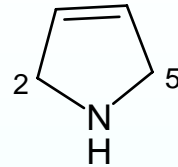
γ -Pyran
4H-Pyran



Pyrilium-Kation

Heteroalkene und Heteroalkane

Heteroalkene

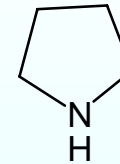
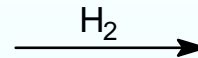
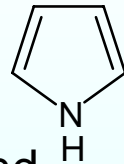


2,5-Dihydropyrrol

Gesättigte Heterocyclen:

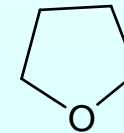
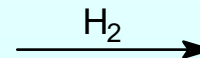
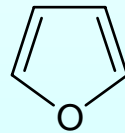
Heteroalkane

- chemische Eigenschaften sind
gleich wie bei den offenkettigen
Analoga



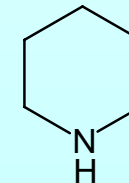
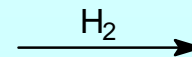
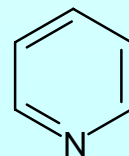
Pyrrolidin

starke Base, sekundäres Amin



Furan

Tetrahydrofuran
cyclisches Ether



Pyridin

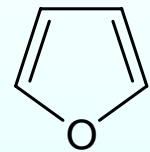
Piperidin

starke Base, sekundäres Amin

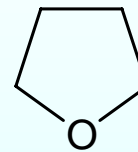
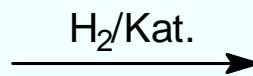
FÜNFRINGE

Fünfgliedrige Heterocyclus mit einem Heteroatom

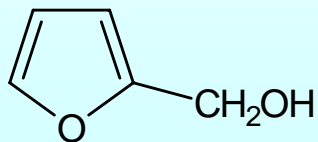
Sauerstoff: Furan-Gruppe



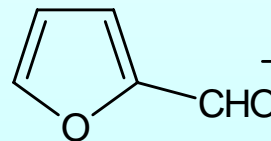
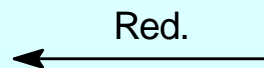
Furan
Sdp.: 32 °C



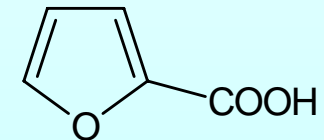
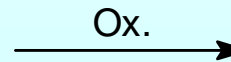
Tetrahydrofuran
Sdp.: 66 °C
cyclisches Ether



Furfurylalkohol



Furfural
Sdp.: 162 °C

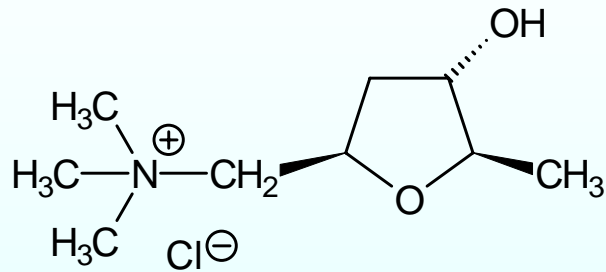


Furan-2-carbonsäure

Thiolanalog (-SH):
Aromastoff im Röstkaffee

FÜNFRINGE

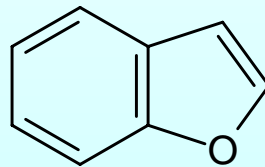
Muscarin:



Vorkommen: in giftigen
Pilzen (z.B. Fliegenpilz)

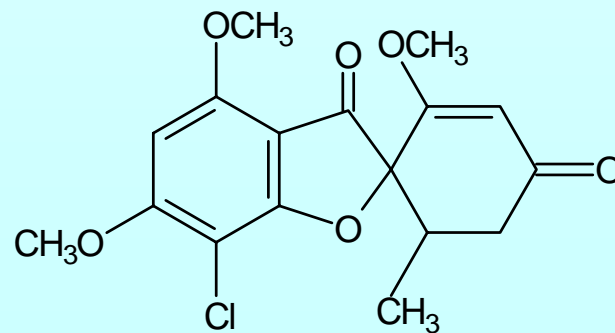


Benzofurane:



Coumaron

Griseofulvin



antimycotische Wirkung

FÜNFRINGE

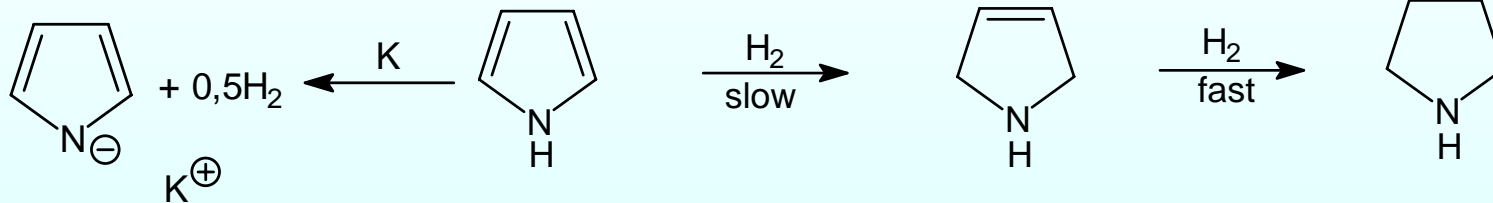
Thiophen



Thiophen
Sdp.: 84°C

Tetrahydrothiophen
Sdp.: 121 °C

Pyrrrol-Gruppe

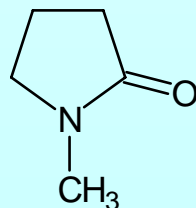


Kaliumpyrrolid

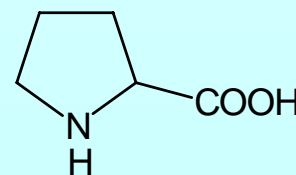
Pyrrol, Sdp.: 131 °C

Pyrrolidin
pK_B = 3,2

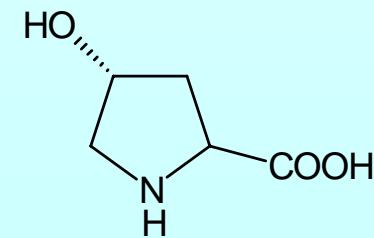
- Eigenschaften von Pyrrol:
- Siedepunkt: 131 °C (polare Moleküle)
 - schwache Säure, pK_B = 13,6, pK_S ~ 15
 - Reaktivität in S_E Reaktionen



N-Methyl-2-pyrrolidon



Prolin

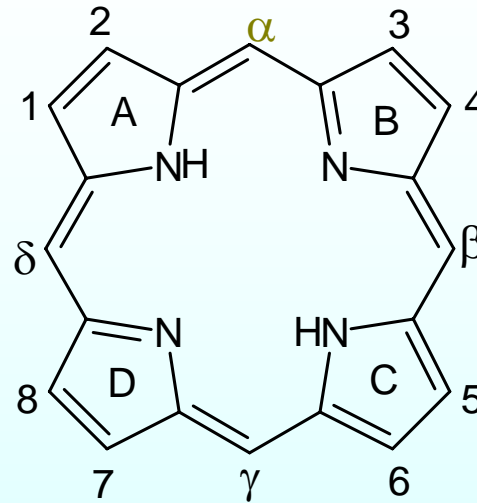


4-Hydroxyprolin

FÜNFRINGE

Porphin-Farbstoffe

- 18 π -Elektronen,
($4n+2$) $n = 4$
- kontinuierliche Delokalisierung

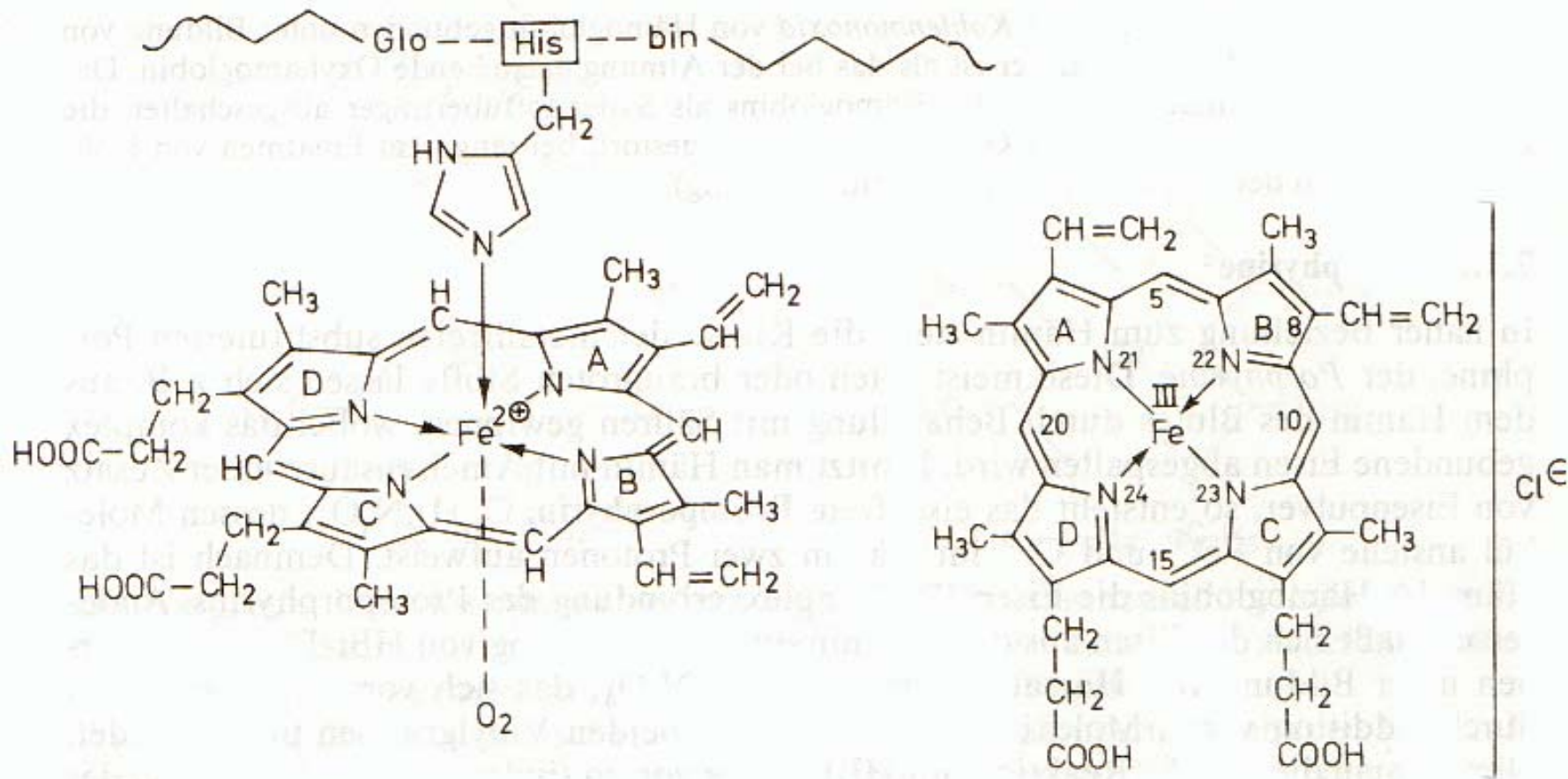


Porphin
Schmp.: > 360 °C

Stabile Verbindung
mit aromatischem Charakter,
(löslich in Salzsäure, bildet
Salze mit Metallionen)

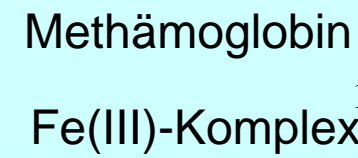
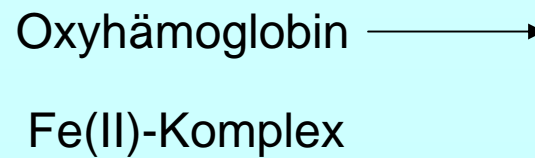
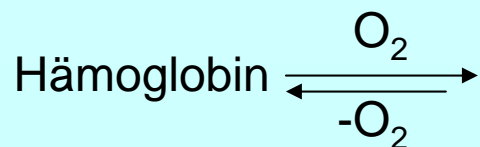
FÜNFRINGE

Hämoglobin



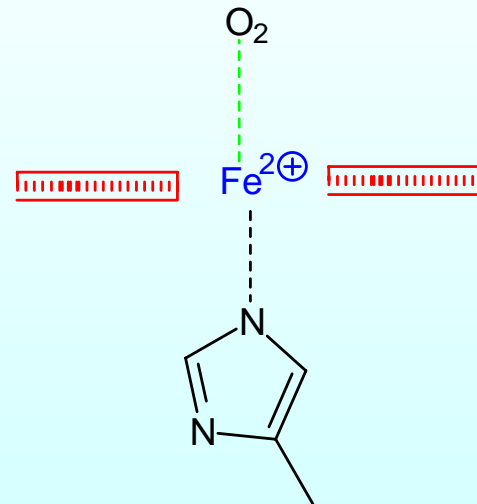
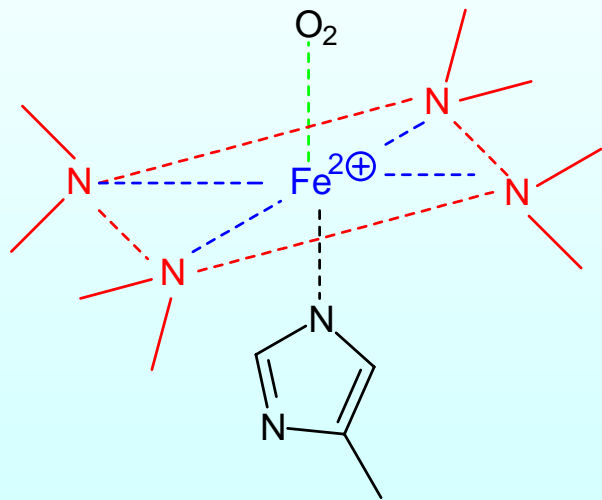
Hämoglobin

Häm

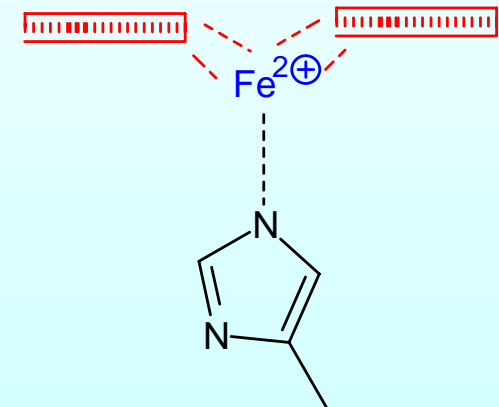


FÜNFRINGE

Koordination im Hämoglobin



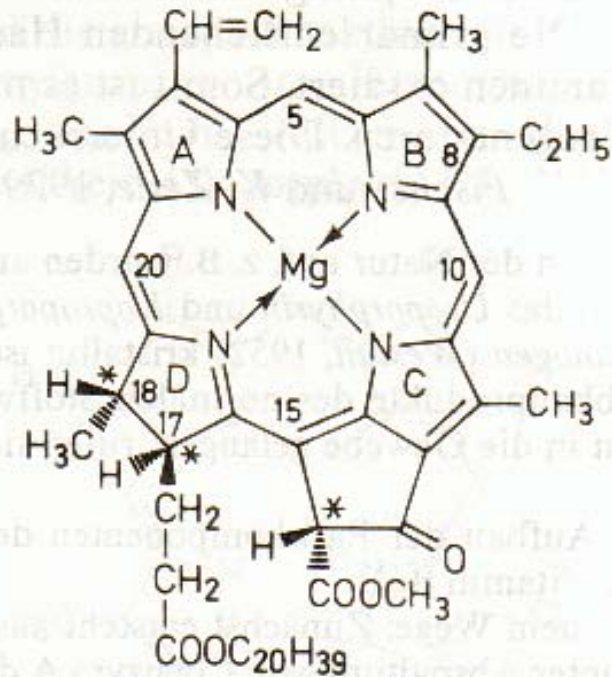
Koordinationszahl: 6



5

FÜNFRINGE

Chlorophyll



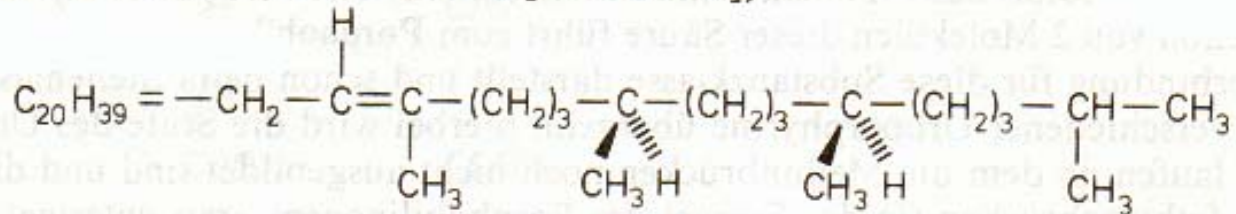
- 7,8-Dihydroporphin
- Zentralkation: Mg²⁺
- Phytolrest, C₂₀
- ungesättigter Alkohol

Chlorophyll-a: bläulich grün (3)

Chlorophyll-b: gelblich grün (1)

grüner Pflanzenfarbstoff,
biochemische Funktion bei der Photosynthese

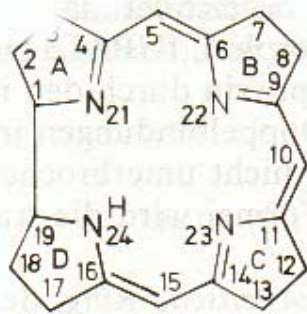
Chlorophyll a (Schmp. 117–120 °C [390–393 K])



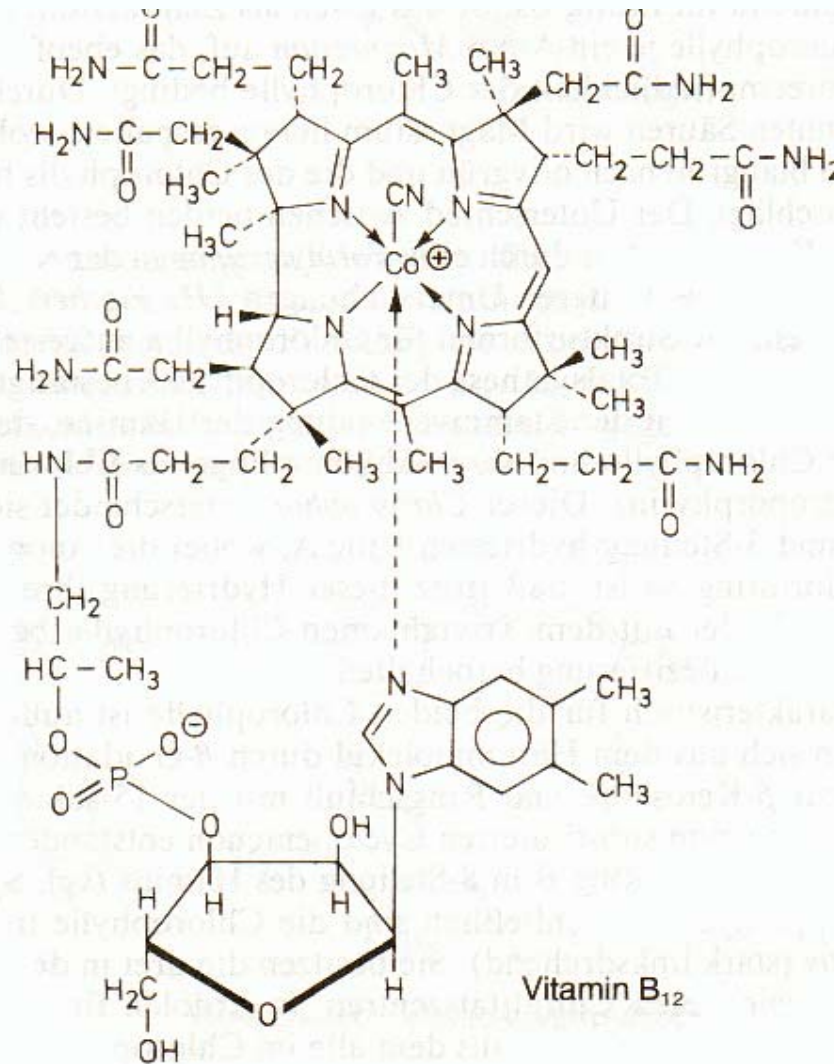
Phytolrest ((2E)-(7R, 11R)-3,7,11,15-Tetramethyl-2-hexadecenyl)

FÜNFRINGE

Vitamin B₁₂ : **Corrin-Gerüst:** teilweise gesättigtes, modifiziertes Porphin mit Co³⁺
Verwendung: bei der Behandlung der perniziösen Anämie



Corrin

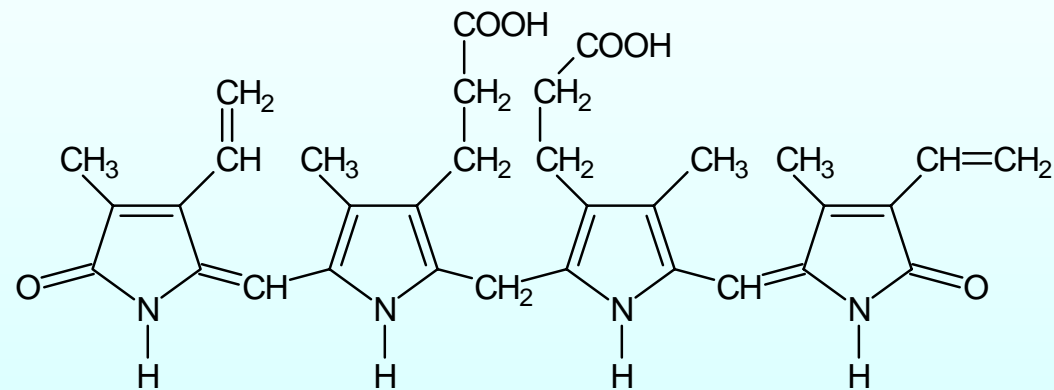


Vitamin B₁₂

FÜNFRINGE

Gallenfarbstoffe

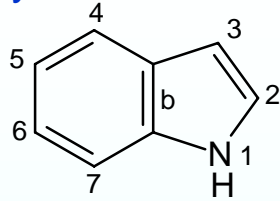
- Abbauprodukt von Häm



Bilirubin

FÜNFRINGE

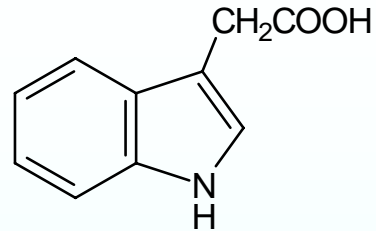
Benzopyrrole



Indol

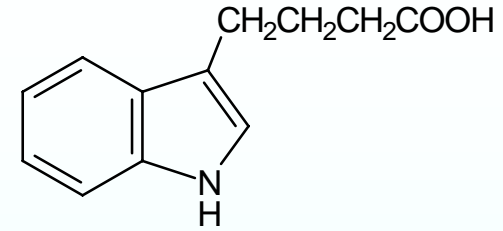
Benzo[*b*]pyrrol

Vorkommen: -Jasminöl
- Steinkohlenteer

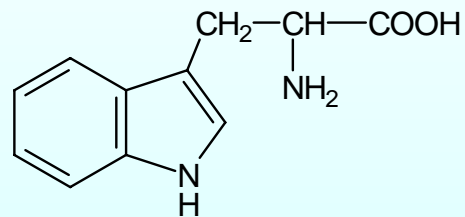


3-Indolyllessigsäure

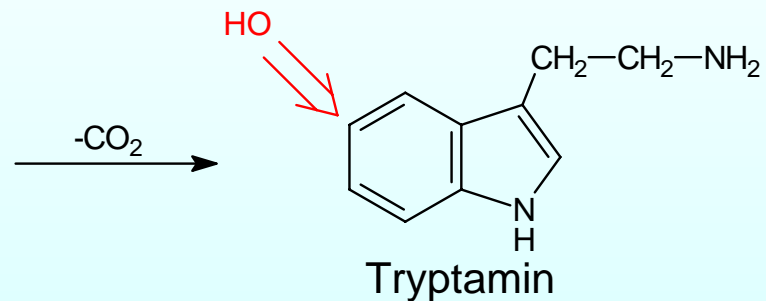
pflanzliche Wachststoffe, Phytohormone, oder Auxine)



3-Indolylbuttersäure



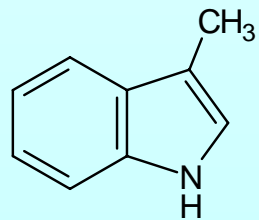
Tryptophan



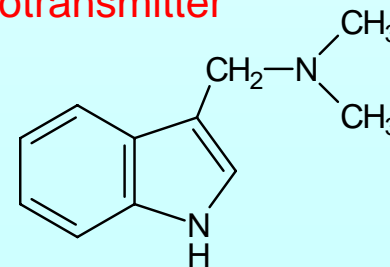
Tryptamin

5-Hydroxytryptamin = Serotonin

Vorkommen: in Blutserum,
- reguliert den Blutkreislauf
- Neurotransmitter



Skatol
(3-Methylindol)



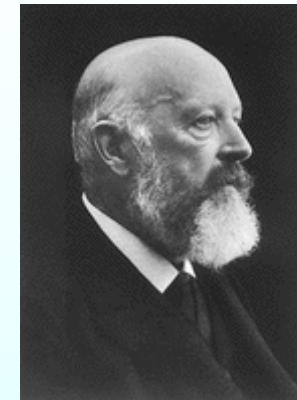
Gramin
3-Dimethylaminoindol

Färberwaid (Deutsche Indigo)

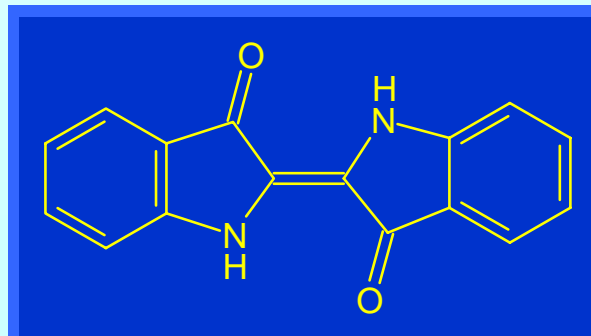
Isatis tinctoria



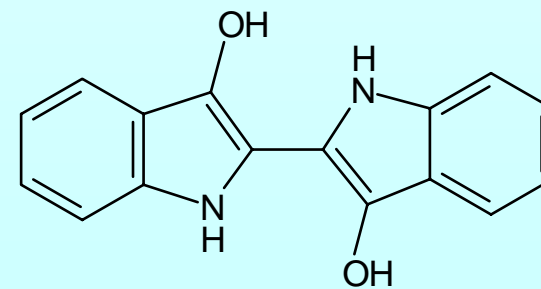
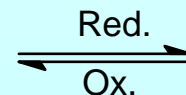
Der Waidstein in Sömmerda, mit ihm wurde im Mittelalter Färberwaid zerkleinert



Adolf v. Baeyer
1835-1917



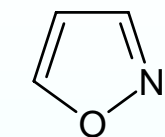
Indigo (blau)



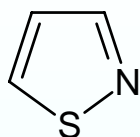
Leukoindigo (farblos)



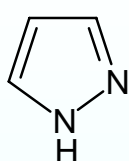
Fünfringe mit zwei Heteroatomen



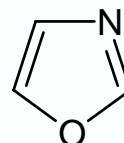
Isoxazol



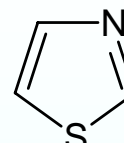
Izothiazol



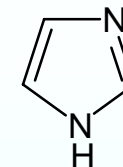
Pyrazol



Oxazol



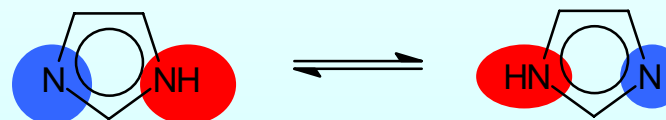
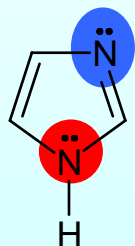
Thiazol



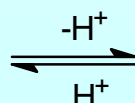
Imidazol

- Verbindungen mit aromatischem Charakter
- geringe Reaktivität in elektrophilen Substitutionen
- schwache Basen

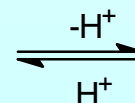
Imidazol



Imidazol-Kation



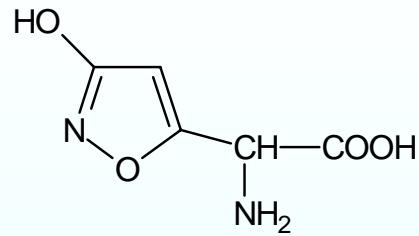
Imidazol



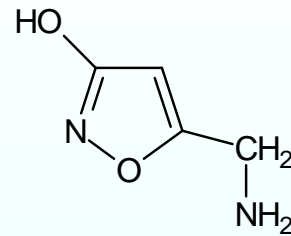
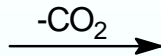
Imidazol-Anion

Fünfringe mit zwei Heteroatomen

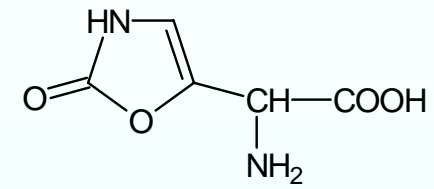
Oxazol- und Thiazol-Derivate



Ibotensäure

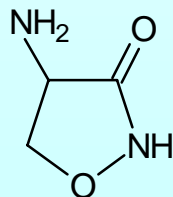


Muscimol

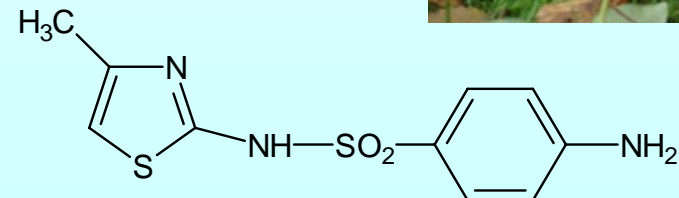


Muscazon

Vorkommen: in giftigen Pilzen



Cycloserin
(Antibiotikum)



Ultraseptyl
Sulfonamid mit antibakterieller
Wirkung

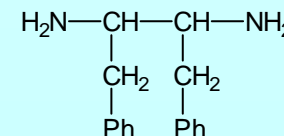
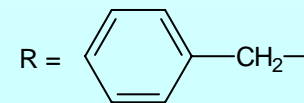
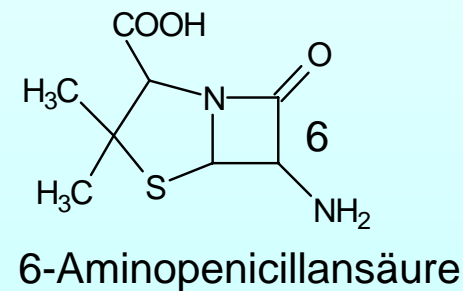
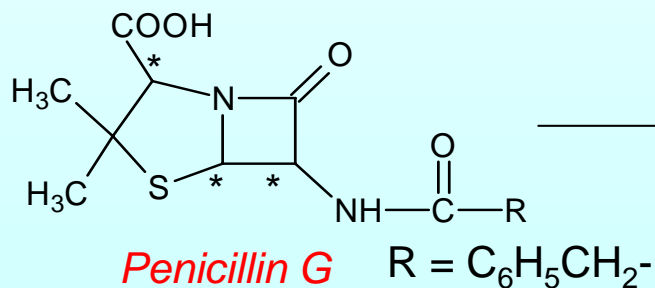
Fünfringe mit zwei Heteroatomen

Penicillin

Antibiotika sind chemisch definierte, ursprünglich von Pilzen oder Mikroorganismen produzierte Wirkstoffe, die das Wachstum oder die Vermehrung bestimmter Bakterien oder Mikroorganismen hemmen.

- Entdeckung: *Fleming*, 1928
- Struktur: 1943-45
- erzeugt von Schimmelpilzgattungen z.B. *Penicillium notatum*, *Penicillium chrysogenum*

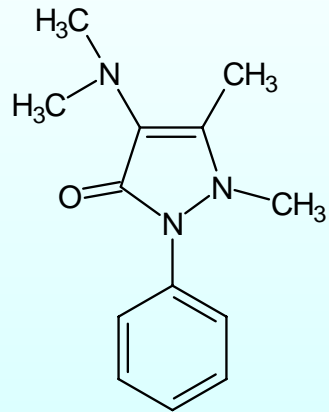
(Thiazolidin, β -Lactam-Ring)



Salz mit Dibenzyl-
ethyldiamin

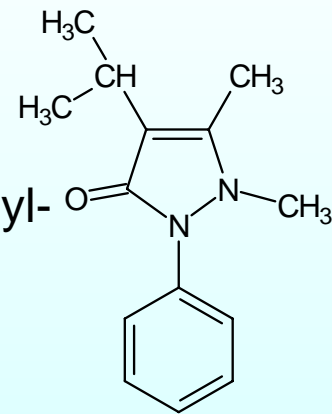
Fünfringe mit zwei Heteroatomen

Pyrazol-Gruppe

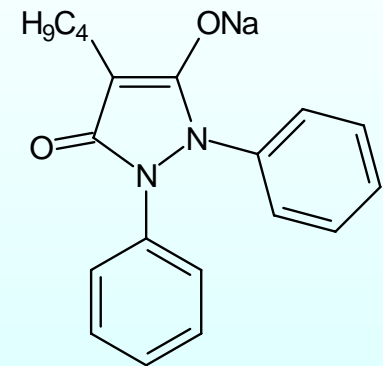


Aminophenazon
(1-phenyl-2,3-dimethyl-
4-dimethylamino-
5-pyrazolon)

antipyretische und analgetische Wirkung



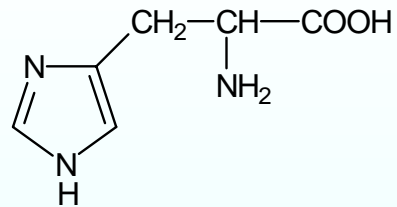
Propyphenazon



Phenylbutazon
(antirheumatische
Wirkung)

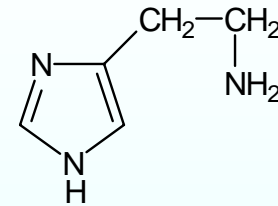
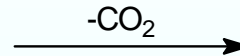
Fünfringe mit zwei Heteroatomen

Imidazol-Gruppe



Histidin

Baustein der Proteine

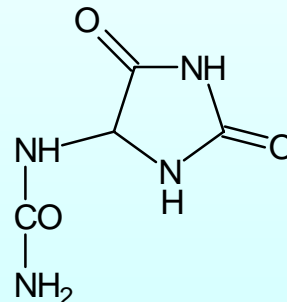


Histamin

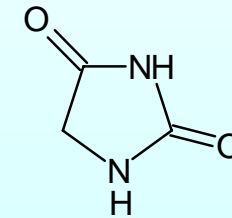
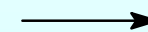
biogenes Amin



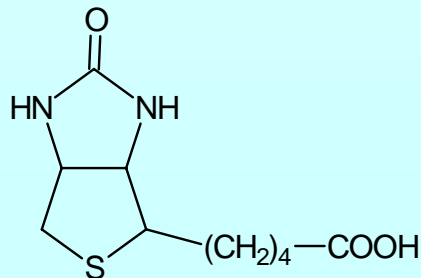
Harnsäure



Allantoin



Hydantoin



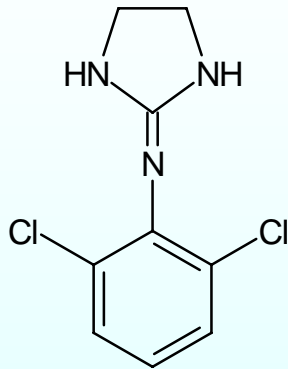
Biotin

Biowachsstoff (Biosfaktor): unentbehrlich für die Vermehrung von Hefezellen und anderen Microorganismen

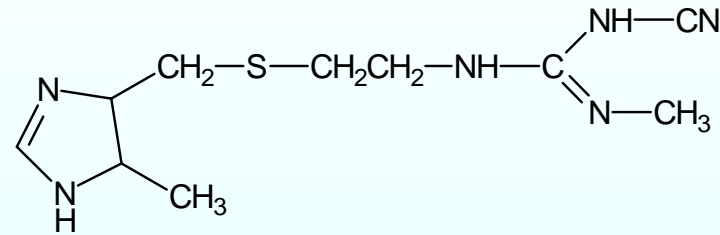
In Menschen: notwendig zur normalen Funktion der Haut

Fünfringe mit zwei Heteroatomen

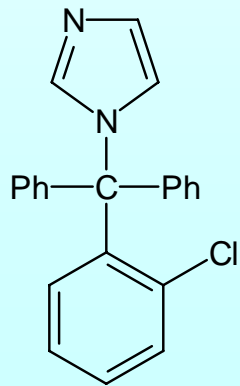
Arzneimittel mit Imidazol-Gerüst



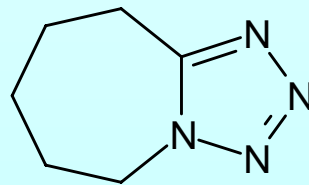
Clonidin
antihypertensiv



Cimetidin
Anw.: Ulcus-Therapie



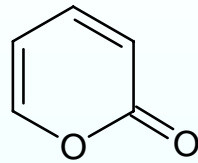
Clotrimazol
Antimykotikum



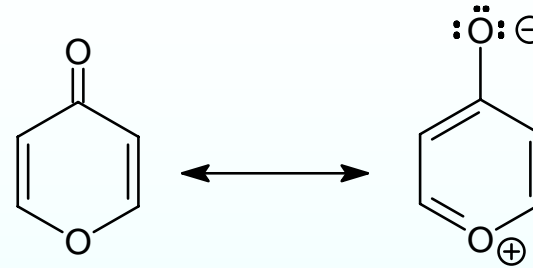
Cardiazol
(Pentamethylentetrazol)
- stimuliert den Blutkreislauf und die Herztätigkeit,
- regt das Atmungszentrum an

SECHSRINGE

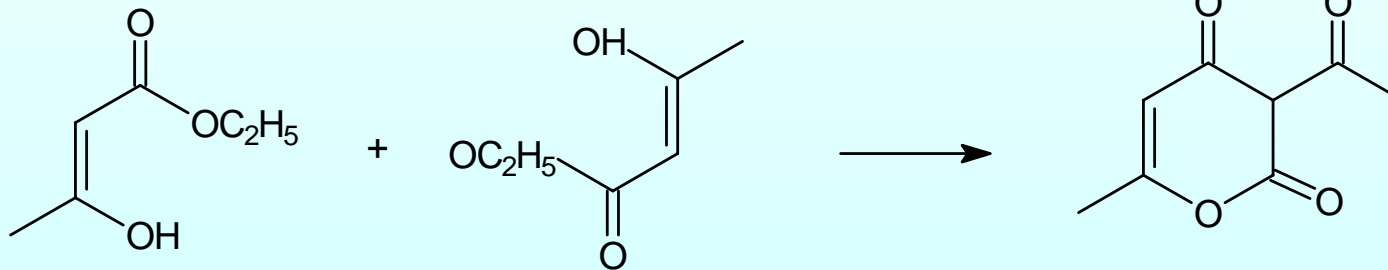
Pyran-Gruppe



α -Pyrone



γ -Pyrone



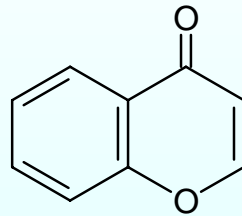
Dehydracetsäure
fungizid,

Verwendung:

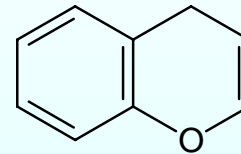
- Lebensmittelindustrie
- Bierindustrie

SECHSRINGE

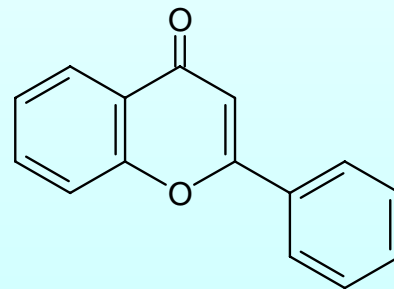
Benzoanellierte γ -Pyrone-Derivate



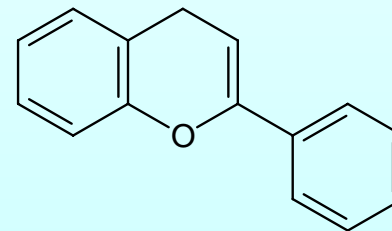
Chromon



Chroman



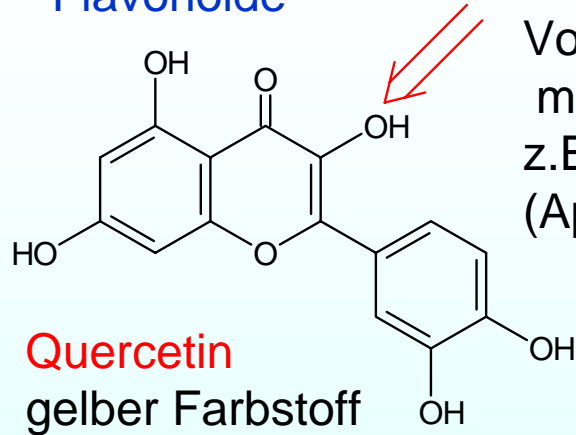
Flavon



Flavan

SECHSRINGE

Flavonoide

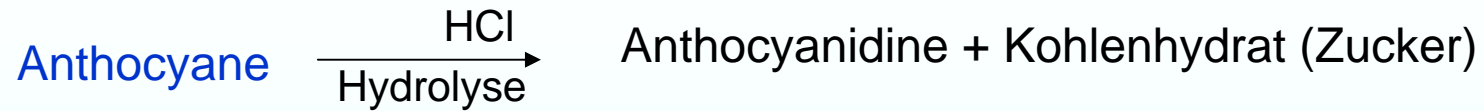


Vorkommen: in verschiedenen Pflanzen,
meistens in Form von Glycosiden,
z.B. in der Rinde der amerikanischen Eiche (*Quercus velutina*)
(Apfel, Wein, Zwiebel, Bohnen, Brokkoli)

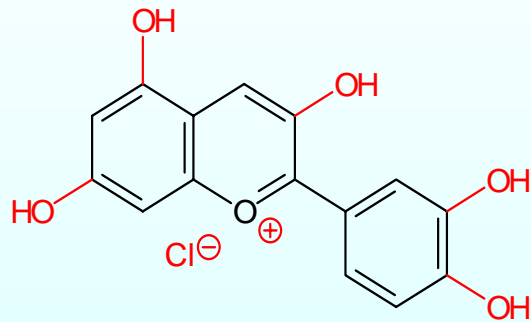


SECHSRINGE

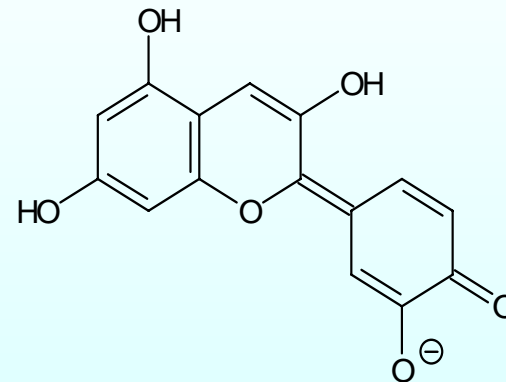
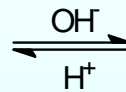
Anthocyane



pH abhängige Farbe



Flavylium-Kation
Cyanidinchlorid
pH = 3, rot

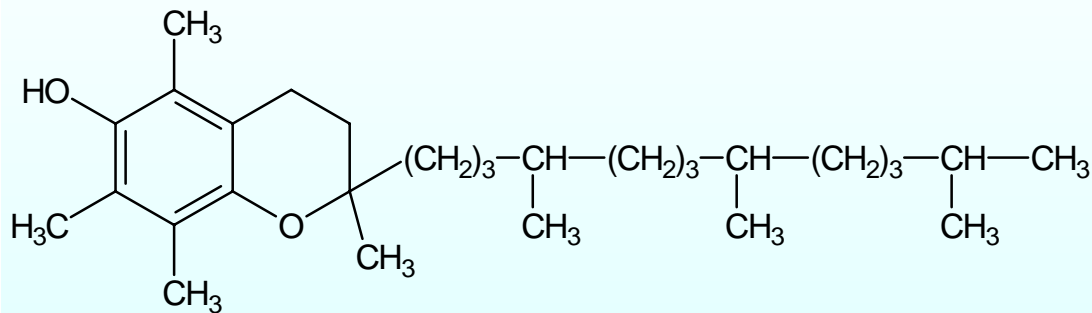


Cyanidin phenolat
pH = 11, blau



SECHSRINGE

Vitamin E (α -Tocopherol)



- beeinflusst die Fruchtbarkeit
- Antioxidant in der Lebensmittelchemie

Besonders reiche Vitamin-E-Quellen sind:

[Weizenkeimöl](#) (174–176 mg/100 g)

[Sonnenblumenöl](#) (60 mg/100 g)

[Leinsamen](#) (57 mg/100 g)

[Walnussöl](#) (39 mg/100 g)

[Maiskeimöl](#) (31–34 mg/100 g)

[Distelöl](#) (29–45 mg/100 g)

[Sesamöl](#) (28 mg/100 g)

[Haselnüsse](#) (27 mg/ 100 g)

[Erdnussöl](#) (25 mg/100 g)

[Rapskernöl](#) 25 mg/100 g)

[Mandeln](#) (25 mg/100 g)

[Palmöl](#) (25 mg/100 g)

[Rapsöl](#) (20 mg/100 g)

[Sojaöl](#) (17–25 mg/100 g)

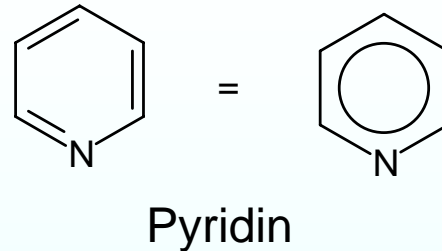
[Olivenöl](#) (12–40 mg/100 g)

[Schwarzwurzeln](#) (6 mg/100 g)

[Leinöl](#) (5,8 mg/100 g)

SECHSRINGE

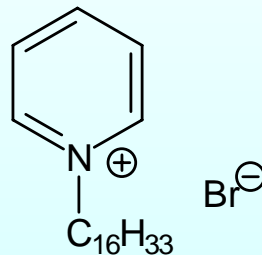
Pyridingruppe



- farblose Flüssigkeit mit unangenehmem Geruch
- elektrophile Substitution am C-3 unter extremen Bedingungen
- schwache Base, $pK_B = 8,8$

Pyridinderivate

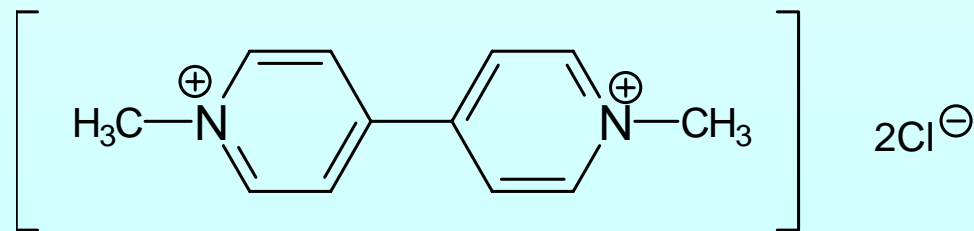
- Alkylierte Pyridinderivate



Cetylpyridinium bromide

- löslich in Wasser,
- kationaktives Detergens

Invertseife

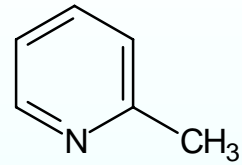


1,1'-Dimethyl-4,4'-bipyridyliumdichlorid

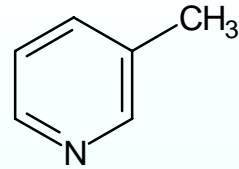
Paraquat

Totalherbizid $LD_{50} = 35 \text{ mg/kg}$ (geschätzt)

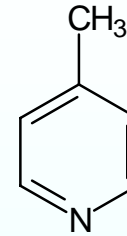
SECHSRINGE



α -Picolin

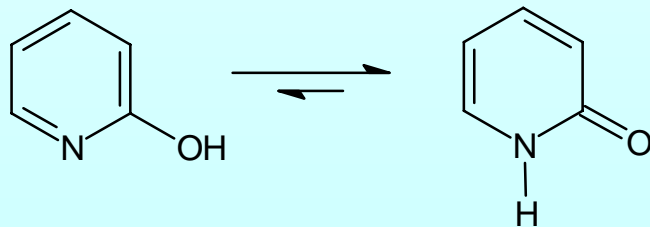


β -Picolin



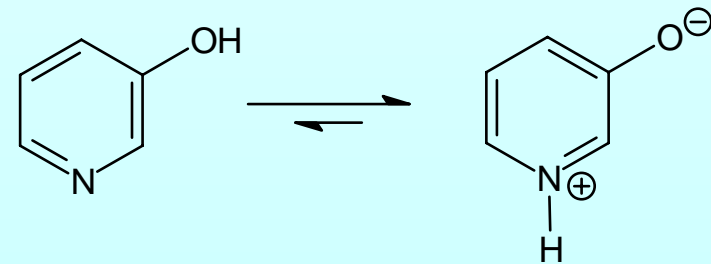
γ -Picolin

Hydroxypyridine



2-Hydroxy-pyridin

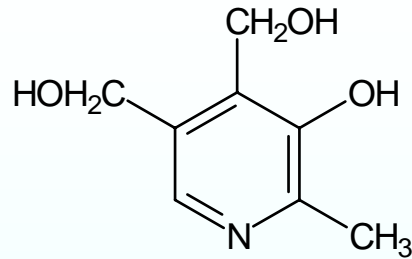
2-(1*H*)-pyridon



3-Hydroxypyridin
(zwitterionische Form)

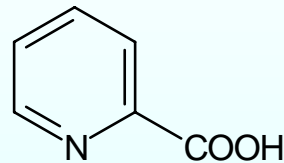
SECHSRINGE

Vitamin B₆
Pyridoxin

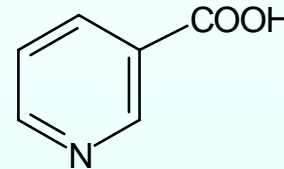


Mangel in Vitamin B₆: - Nervosität
- Schlaflosigkeit
- Schwäche

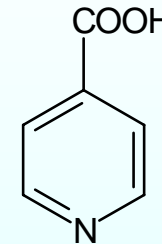
Säuren



Picolinsäure

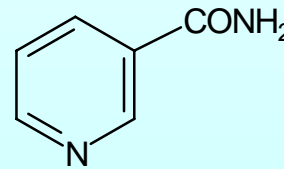


Nicotinsäure

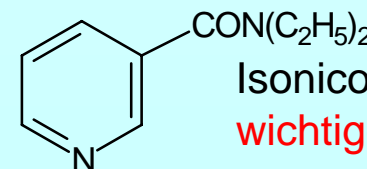


Isonicotinsäure

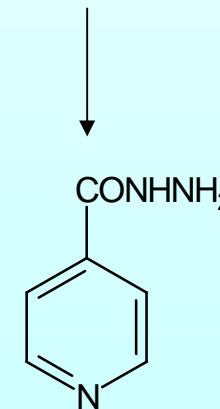
Nicotinamid
- Bestandteil des Enzyms NAD



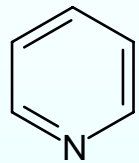
Nicotinsäurediethylamid
Analeptikum



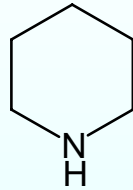
Isonicotinsäurehydrazid
wichtiges Chemotherapeutikum
gegen alle Formen der Tuberculose



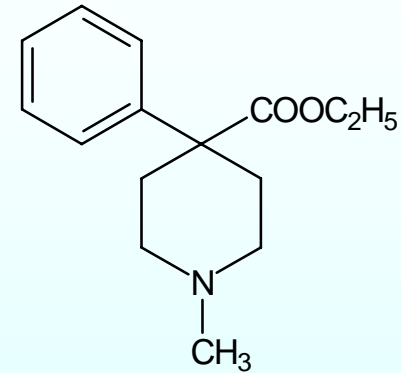
SECHSRINGE



Pyridin



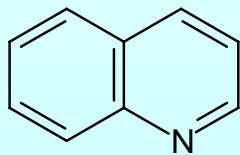
Piperidin



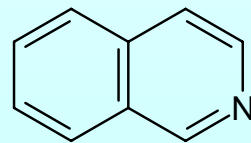
Dolantin

sehr starke analgetische Wirkung

Benzoanellierte Pyridinderivate



Chinolin

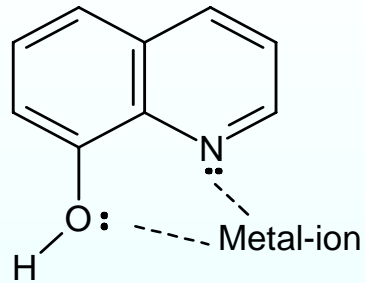


Isochinolin

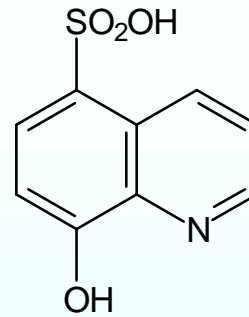
- Heteroaromaten
- schwache Basen
- Vorkommen: in vielen Naturstoffen

SECHSRINGE

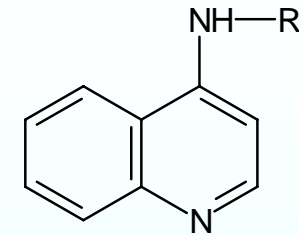
Chinolin-Derivate



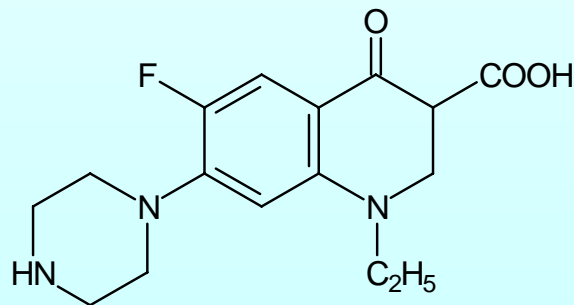
8-Hydroxychinolin
- stabile Innerkomplexe
mit Metall-Kationen



8-Hydroxychinolin-
5-sulfonsäure
Antipyretikum

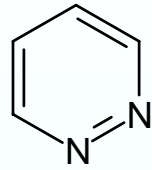


4-Alkylaminochinoline
Antimalaria-Arznei

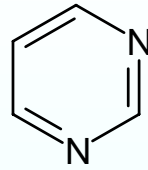


Norfloxacin
DNA-Gyrasehemmer
sehr wirksames Bakterizid

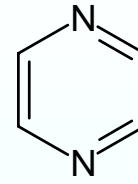
Sechsringe mit zwei Heteroatomen



Pyridazin
1,2-Diazin



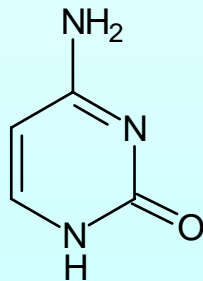
Pyrimidin
1,3-Diazin



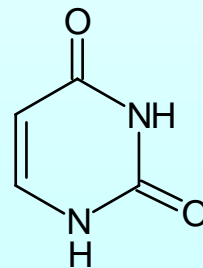
Pyrazin
1,4-Diazin

Pyrimidinderivate

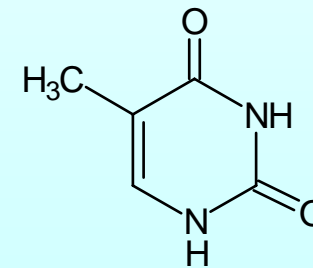
Pyrimidin-Basen aus Nucleinsäuren



Cytosin



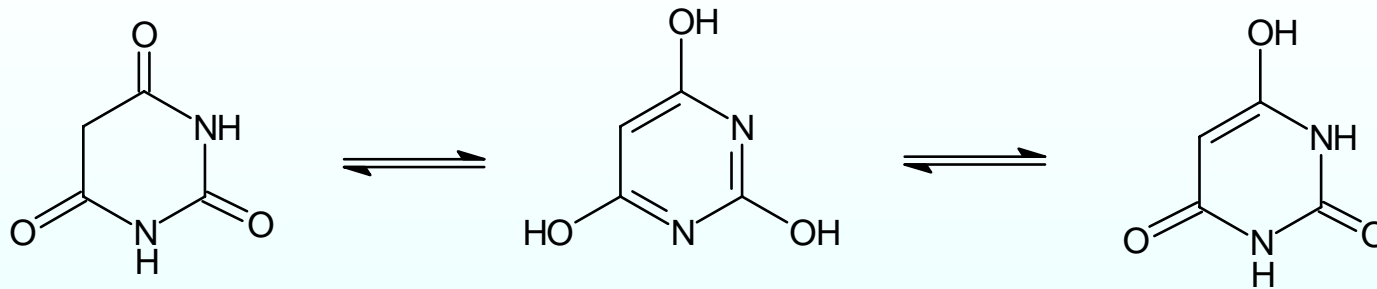
Uracil



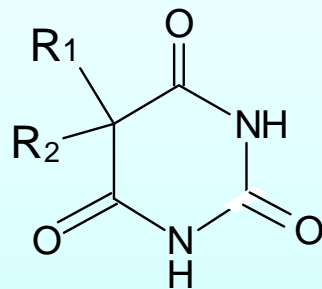
Thymin

Sechsringe mit zwei Heteroatomen

Barbitursäure (tautomere Formen)



5,5-Disubstituierte Derivate der Barbitursäure



R₁

R₂

C₂H₅

C₂H₅

Barbital (Veronal)

C₂H₅

C₆H₅

Phenobarbital (Luminäl)

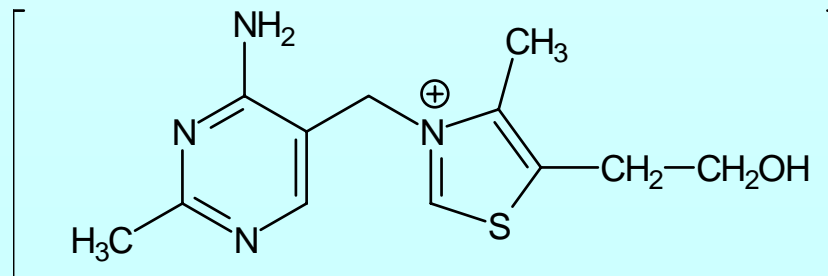
C₂H₅

C₆H₉

Cyclobarbital (Phenodorm)

wichtige Sedativa und Schlafmittel

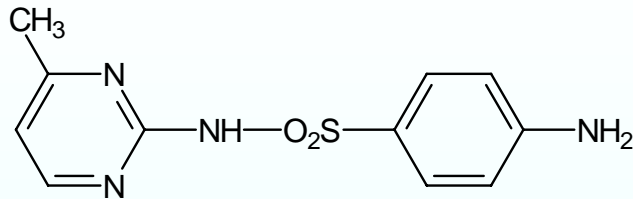
Thiamin (Vitamin B₁)



- Wachstoffsstoff für viele Mikroorganismen
- therapeutisch: bei Neuritiden und Neuralgien

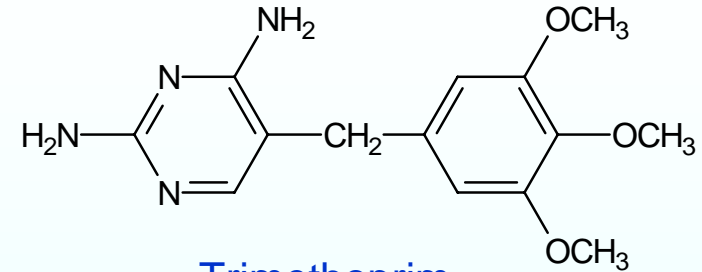
Cl[⊖]

Sechsringe mit zwei Heteroatomen



Sulphamerazin

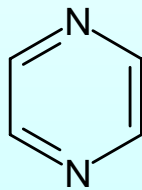
- wichtiger Vertreter der Sulfonamid-Chemotherapeutika



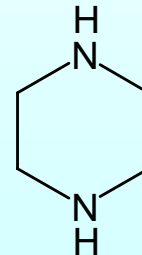
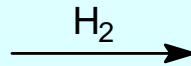
Trimethoprim

verwendet in Kombination mit Sulfon-
Amiden, das den bakteriellen Stoffwechsel
hemmt

Pyrazingruppe



Pyrazin
 $pK_B = 13,4$

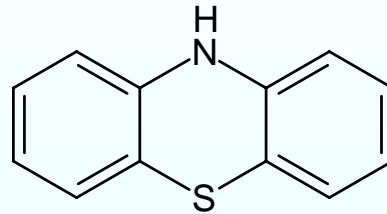


Piperazin
 $pK_B = 4,05$

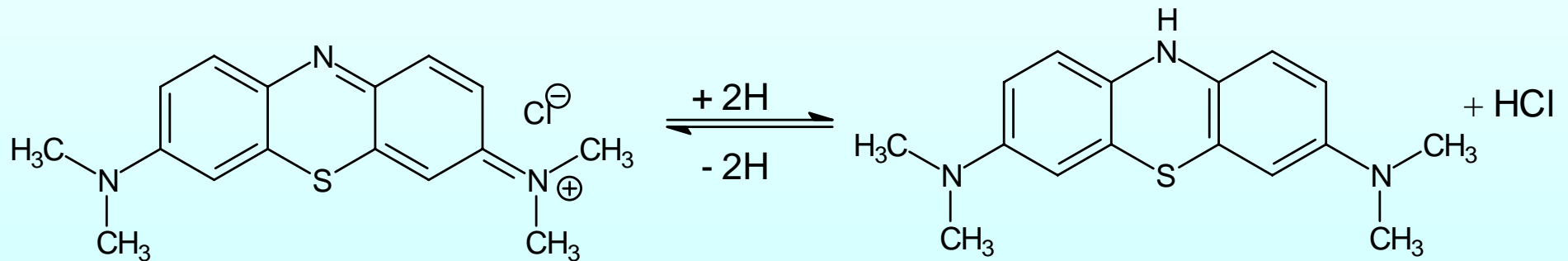
Anthelmintikum (Wurmmittel),
wirksam gegen Oxyuriasis, Ascariasis

Sechsringe mit zwei Heteroatomen

Phenothiazine



Phenothiazin

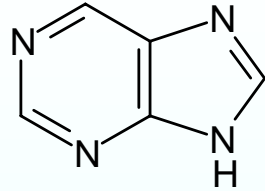


Methylenblau
Verwendung: Farbstoff in der
Pathologie und Bakteriologie

reduzierte Form
farblos

Sechsringe mit zwei Heteroatomen

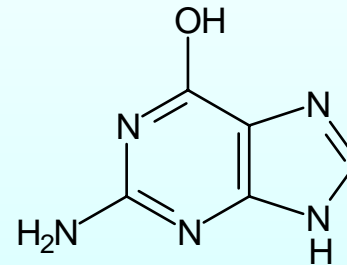
Purine



Purin-Basen aus DNS

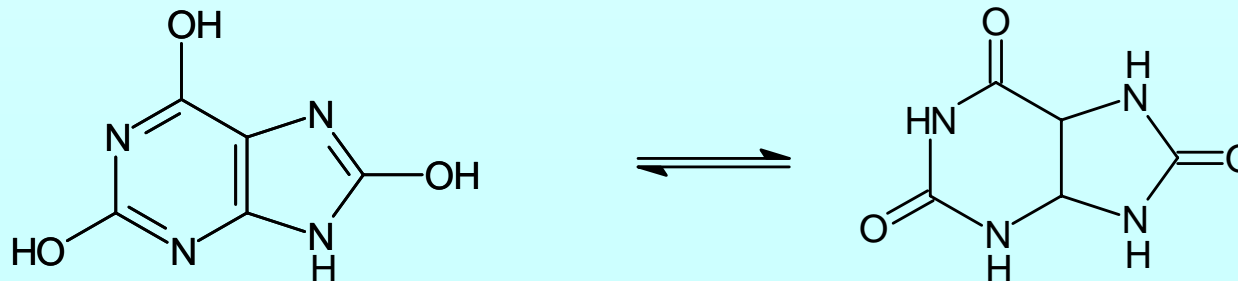


Adenin



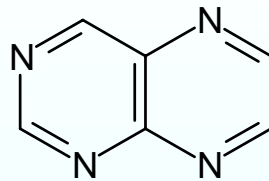
Guanin

Harnsäure



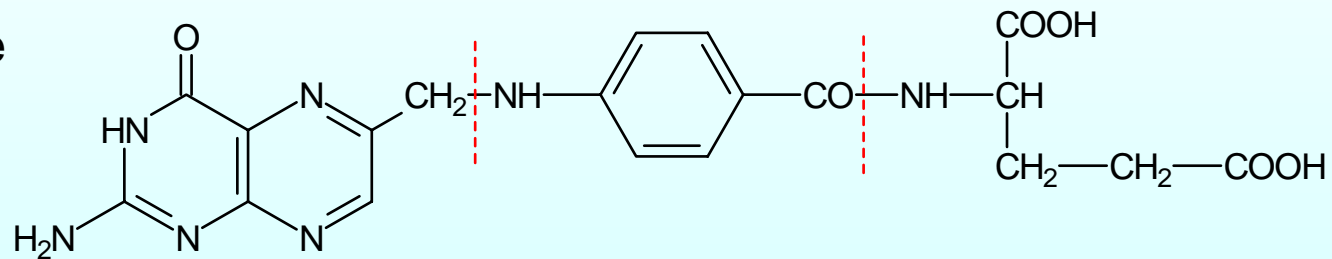
Sechsringe mit zwei Heteroatomen

Pterine



Pteridin

Folsäure



Pterin

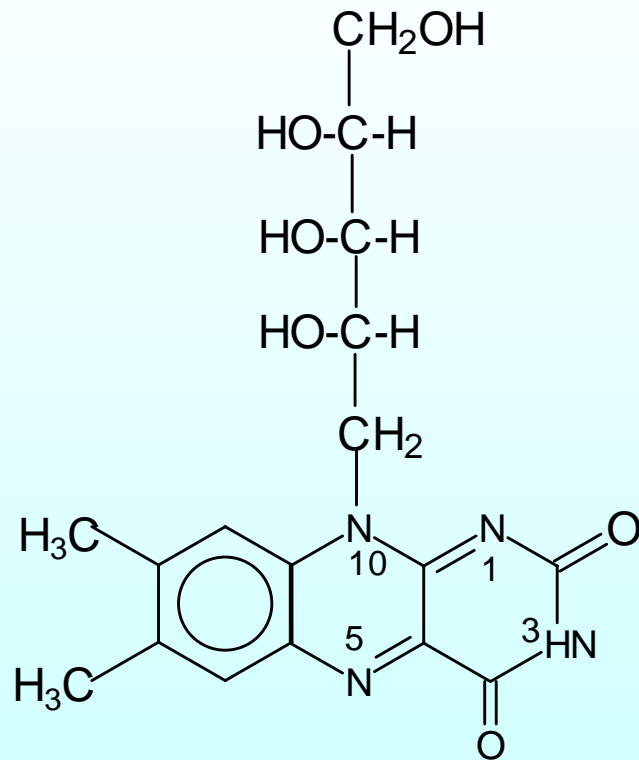
p-Aminobenzoesäure

L-Glutaminsäure

- Biosfactor für die Leukocyten,
- beeinflusst die Blutbildung
- medizinische Anwendung: bei der Behandlung der perniziösen Anämie

Sechsringe mit zwei Heteroatomen

Riboflavin (Vitamin B₂)



- isoliert aus Eiweiß and Wolke
(70 mg aus 1000 L Milch (!))
- Wachstumsfaktor für Tiere und Mikroorganismen
- beteiligt an biologischen Redoxvorgängen