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Review Article

A STUDY ON BETA BLOCKERS - A BRIEF REVIEW

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ABSTRACT

Beta blockers are agents or drugs which competitively inhibit the action of catecholamines at the beta adrenergic receptors, which are mainly used to treat variety of clinical conditions like angina, hypertension, asthma, COPD and arrhythmias. These drugs are also useful in several other therapeutic situations including shock, premature labor and opioid withdrawal, and as adjuncts to general anesthetics. These drugs produce their effect by interacting with the beta adrenergic receptors. In the present communication, an effort has been made to compile beta adrenergic receptors and the chemistry, discovery and development, classification and therapeutic applications of beta blockers.

Keywords: Beta blockers, adrenergic receptors, catecholamines and aryloxypropanolamines.

1. INTRODUCTION

1.1 Adrenergic receptors

The ability of a molecule to selectively agonize or antagonize adrenergic receptor made great advances in pharmacotherapeutics. The discovery of adrenergic receptors lead to major development of newer adrenergic agonists as well as antagonist.[1] Adrenergic receptors are 7-transmembrane spanning receptors which mediate both central and peripheral actions of the adrenergic neurotransmitters. Adrenergic receptors are found in nearly all peripheral tissues and on many neurons within the central nervous system.[2] They play an important role in the control of blood pressure, myocardial contractile rate and force, airway reactivity, and a variety of metabolic and central nervous system functions.[3]

In 1948, Raymond P. Ahlquist classified the adrenergic receptors into two major types i.e. α and β, based on their pharmacological characteristics such as rank order of potency of agonists.[4] Subsequently, both α and β types were subdivided into α_1, α_2, β1, β2 and β3subtypes respectively. Further, based on pharmacological and molecular evidences alpha receptor subtypes were classified into α_{1A}, α_{1B}, α_{1D}.

Beta blockers were first developed by Sir James Black in 1962. The structures of these receptors have been studied by x-ray crystallography.[5] In the current article beta blockers are majorly focused with respect to their location, functions mediated, discovery and development, SAR, classification, structures and therapeutic applications.

1.2 Locations and agonistic action of beta adrenergic receptors[6]

The following are the various beta adrenergic receptors found in different physiological locations and their actions mediated by their stimulation with beta adrenergic agonists. (Table 1)

2. DISCOVERY AND DEVELOPMENT OF BETA ADRENERGIC ANTAGONISTS

One of the beta adrenergic agonist drugs, Isoprenaline (Fig. 1), was considered as a lead molecule. It is a beta receptor agonist but has no action on alpha receptors. This lead molecule was studied in depth and suitable structural modifications required for beta adrenergic antagonistic activity were implemented.[3]

The first such modifications carried out included was the replacement of the phenolic hydroxyl groups in isoprenaline with chloro substituents gave

dichloroisoprenaline (Fig. 2), which is a partial agonist.

This promising molecule dichloroisoprenaline gave an insight in next stage of development to convert the beta adrenergic agonistic activity into antagonistic activity. The general methodology to do so was to introduce another aromatic ring into the existing molecule. This resulted in a drastic change in hydrophobic interaction of the molecule with the receptor and also changed the induced fit between the ligand and the binding site. This new fit resulted in binding of ligand to the receptor's binding site but without the activation of the same.

Considering the above fact, the chloro groups were replaced with a benzene ring, to form a rigid naphthalene ring system. This gave pronethalol (Fig. 3), the first beta blocker to be used clinically to treat angina, arrhythmia and hypertension.[5] Though, it exhibited great therapeutic activity, it was soon withdrawn due to its carcinogenic effects.[6]

The further development was a result of the introduction of side chains between the naphthalene ring and the ethanolamine. The discovery of propranolol (Fig. 4) was in fact a result of an accident during the synthesis for which α-naphthol was used in the reaction mixture instead of the β-naphthol and a drug having structure with side chain at C1 of the naphthalene ring rather than the C2 was obtained. Propranolol is a pure antagonist and this molecule is considered to be a bench mark in evaluation of all other beta blockers.

3. CLASSIFICATION OF BETA BLOCKERS

3.1 Beta blocking agents are classified into 3 classes based on selectivity and action:

1 First generation-Non selective in nature and cause no vasodilation
Ex: Propranolol, Nadolol, Pindolol

2 Second generation - cardioselective in nature
Ex: Acebutolol, atenolol

3 Third generation–Non selective agents which cause vasodilation
Ex: Primidolol, Epanolol

3.2 Based on their chemical nucleus Beta blockers can be classified into:

1. Arylethanolamines
Ex: pronetalol, sotalol, labetalol, brefonalol, Bufuralol
2. Aryloxypropanolamines
Ex: Propranolol, esmolol, metoprolol, acebutalol, atenolol

3.3 FDA classes of beta blockers for use in pregnant women [7,8]

A. Category A

Adequate and well-controlled studies have failed to demonstrate a risk to the fetus in the first trimester of pregnancy (and there is no evidence of risk in later trimesters).

No β-blockers is completely safe for using during pregnancy.

B. Category B

Animal reproduction studies have failed to demonstrate a risk to the fetus and there are no adequate and well-controlled studies in pregnant women.

Eg. Pindalol, acebutalol, sotalol

C. Category C

Animal reproduction studies have shown an adverse effect on the fetus and there are no adequate and well controlled studies in humans, but potential benefits may warrant use of the drug in pregnant women despite potential risks.

Eg. Labetalol, Bisoprolol, Timolol, Metoprolol

D. Category D

There is positive evidence of human fetal risk based on adverse reaction data from investigational or marketing experience or studies in humans, but potential benefits may warrant use of the drug in pregnant women despite potential risks.

Eg. Atenolol

4. STRUCTURE ACTIVITY RELATIONSHIP OF ARYLOXYPROPANOLAMINES

Presently, aryloxypropanolamines are the most commonly used beta adrenergic blockers. Though the beta blockers are marketed in the racemic form, typically the activity lies only in one of its isomeric form. In arylethanolamines, the activity was

found to reside in the (R) form, while in case of aryloxypropanolamines, it resides in the (S) form.[9]

Following are the necessary structural requirements for their optimum activity: [4]

- ✓ Presence of branched N-alkyl functional moieties. This fits into the hydrophobic pockets, both branching and extension of this alkyl side chain is essential.
- ✓ Presence of hydroxyl group on the side chain is essential for the hydrogen bonding with receptors.
- ✓ Presence of amino group is essential and it should be secondary in nature, and it is required for the ionic bonding interaction.
- ✓ Presence of oxymethylene bridge is also essential for the drug to bind to the receptor.

However, the following changes are feasible:

- ✓ The aromatic ring system can be heterocyclic in nature.
- ✓ Aryloxy substitution can be at C_2 which gives more potent compounds than those substituted at C_1
- ✓ Variation in lipophilicity can be achieved by introducing suitable substituents.

The following modifications were found to be detrimental and lead to loss of activity:

- ✓ Introduction of substituent on the propyl side chain.
- ✓ Replacement of the ethereal oxygen with S, CH_2 or N-CH_3.

5. MECHANISM OF ACTION OF BETA BLOCKERS [6]

Beta receptors are G protein coupled receptors. Activation of these receptors by the neurotransmitters, results in the production of cAMP by adenyl cyclase. cAMP is a secondary messenger molecule which activates the Protein Kinase A (PKA). The action of PKA is to increase the calcium release which is responsible for the physiological action. Beta blockers act by binding to the beta adrenergic receptors and blocking the action of neurotransmitters. (Fig. 5)

6. BETA ADRENERGIC BLOCKERS[10-25]

Various beta adrenergic blockers, their structures, molecular formula, molar mass and therapeutic uses are discussed here.

The following are the most widely used beta adrenergic blockers: (Table 2).

7. CONCLUSION

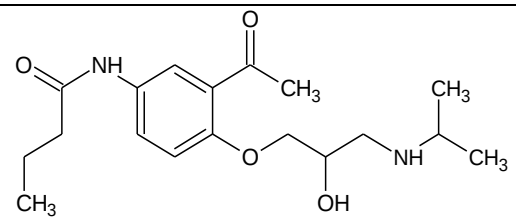
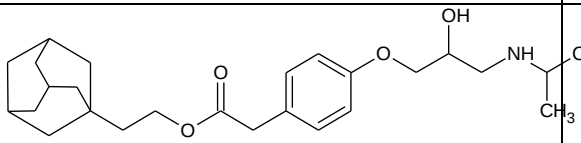
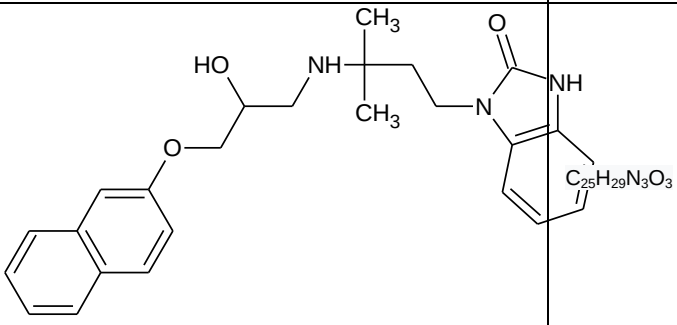
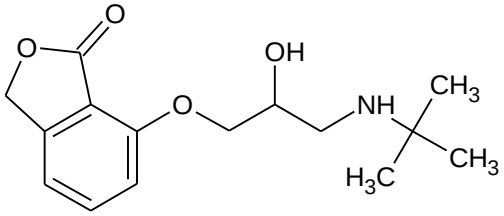
Beta blockers constitute an important class of drugs in the clinical treatment of various disorders like hypertension, angina pectoris, asthma, glaucoma and arrhythmias. Various physical and chemical parameters of beta adrenergic antagonists such as the specificity, solubility, permeability and distribution of the molecule can be modified in order to obtain a drug with preferred characteristics. Study of the nature and type of receptor at the target tissue, and also by analyzing the structure activity relationship helps in obtaining molecules with optimum biological and physiochemical properties.

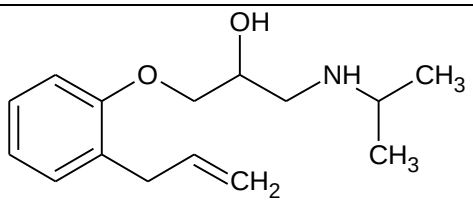
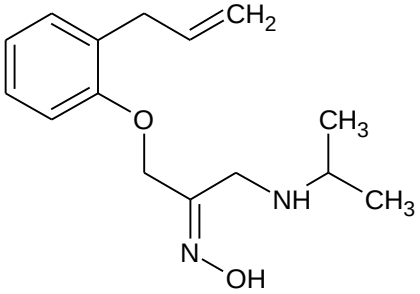
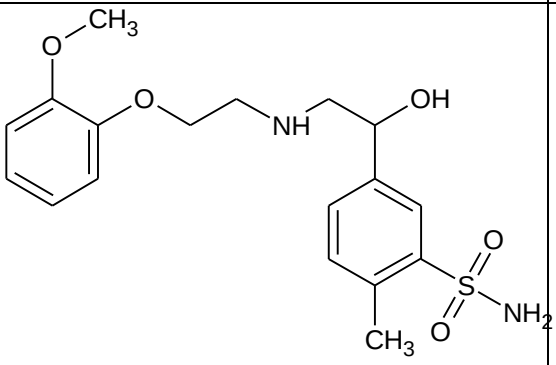
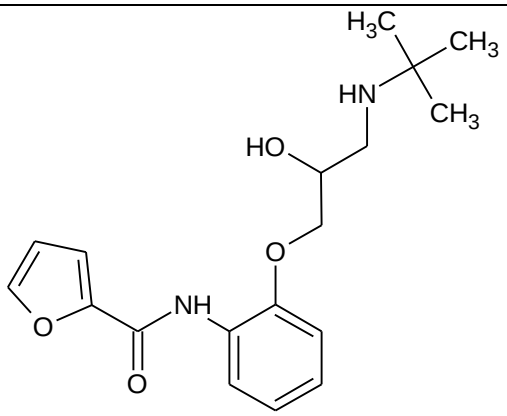
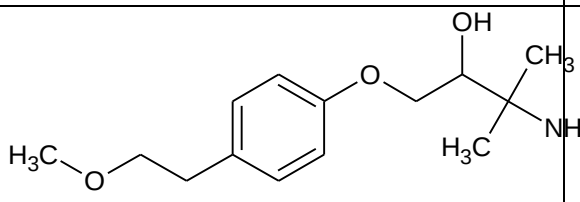
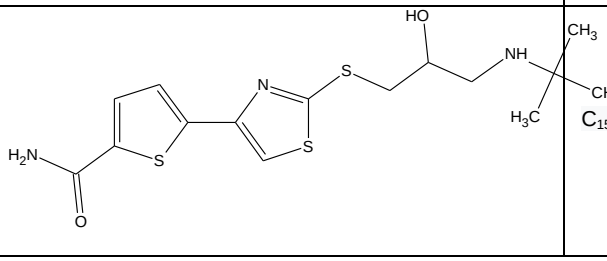
TABLES

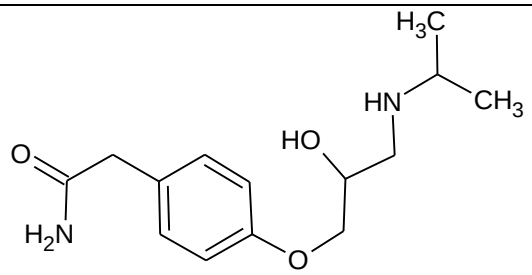
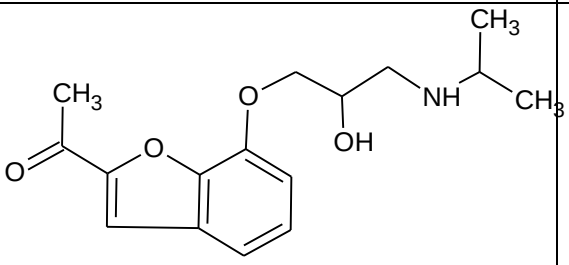
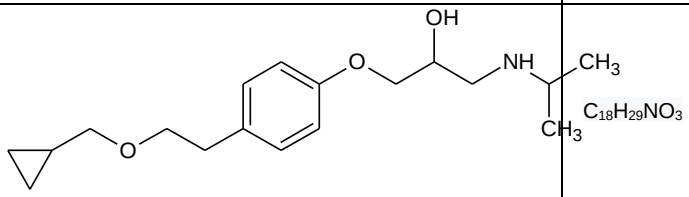
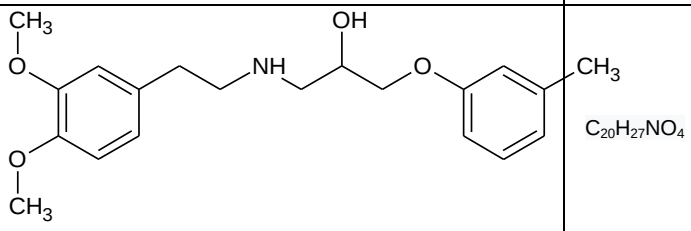
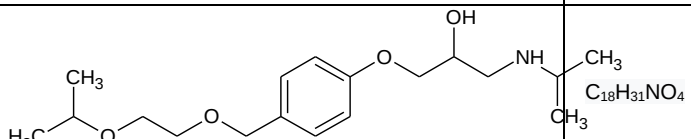
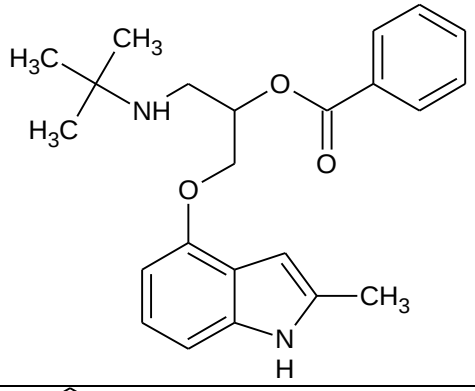
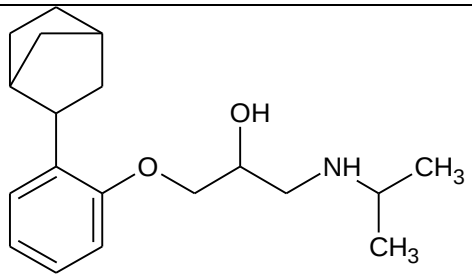
Table 1: locations of beta adrenergic receptors and actions of beta adrenergic agonists

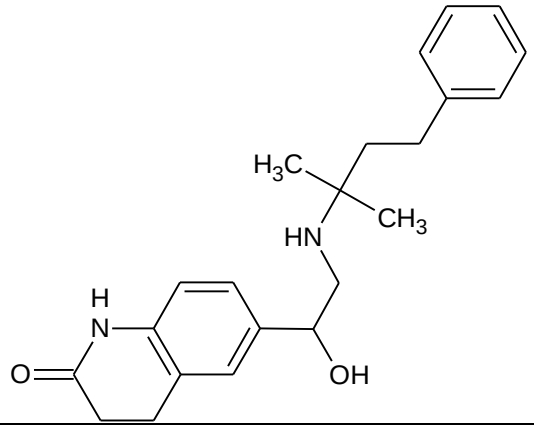
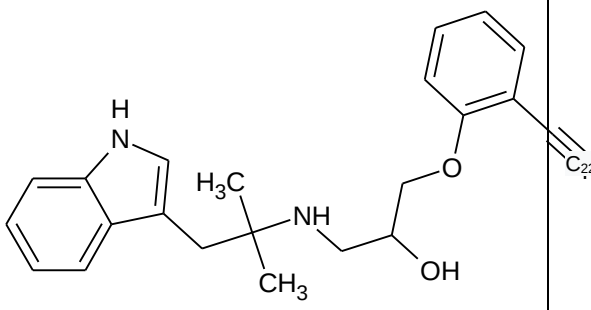
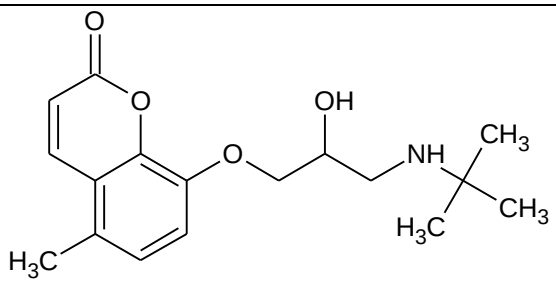
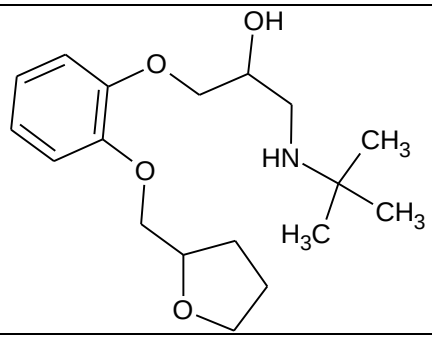
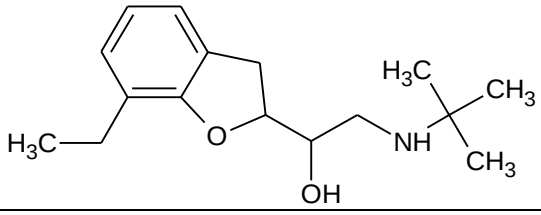
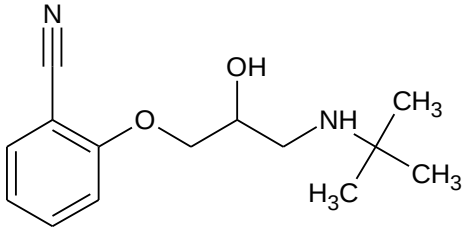
TYPE OF RECEPTOR	LOCATION	PHYSIOLOGICAL EFFECT
β_1	Myocardium	Increase in contractility and heart rate
	Blood vessel	Coronary vasodilation
	Kidney	Increase in renin release
	Fat tissue	Stimulation of lipolysis
β_2	Myocardium	Increase in contractility and heart rate
	Smooth muscles in bronchi	Bronchodilation
	Smooth muscles in blood vessels	Vasodilation
	Smooth muscles in genitourinary tract	Relaxation
	Smooth muscles in large intestine	Relaxation
	Fat tissue	Stimulation of lipolysis
	Liver	Glycogenolysis and glyconeogenesis
	Pancreas	Stimulation of insulin release
	Sympathetic nerve terminals	Stimulation of noradrenaline release
	Skeletal muscles	Less fatigue(due to aerobic respiration) Tremors
	Blood lipids	Low triglycerides and high HDL
	Eye	Increase in intraocular pressure
β_3	Fat tissue	Stimulation of lipolysis and thermogenesis
	Myocardium	Cardiodepression
	Blood vessels	Vasodilation
	Genitourinary smooth muscles	Muscle relaxation

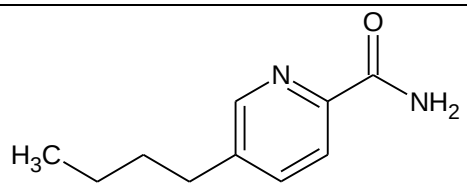
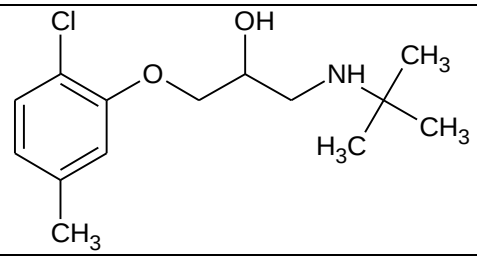
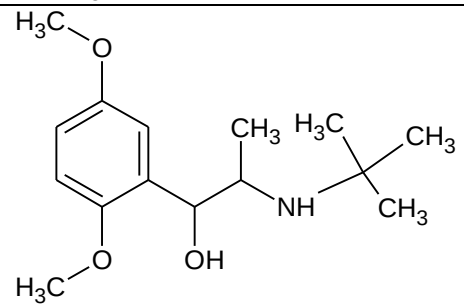
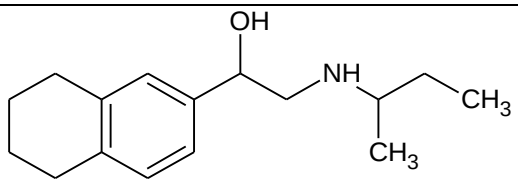
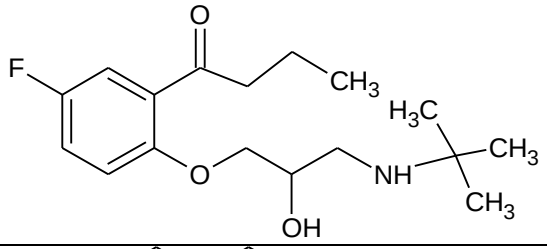
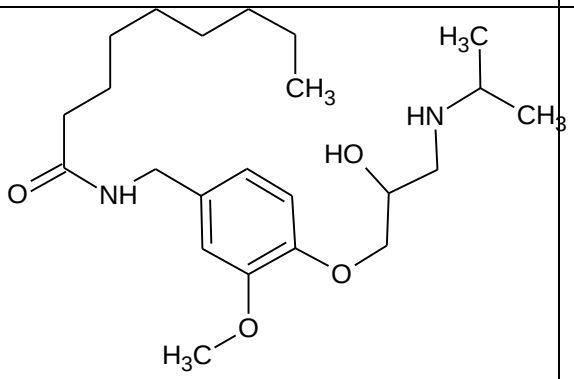
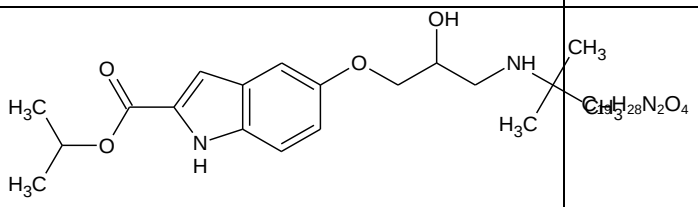
Table 2: List of beta blockers and their properties and uses

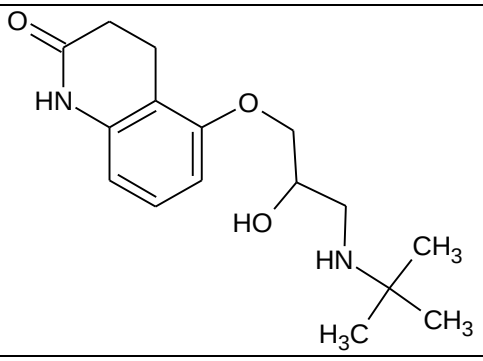
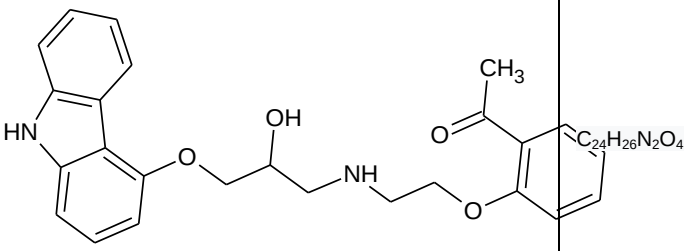
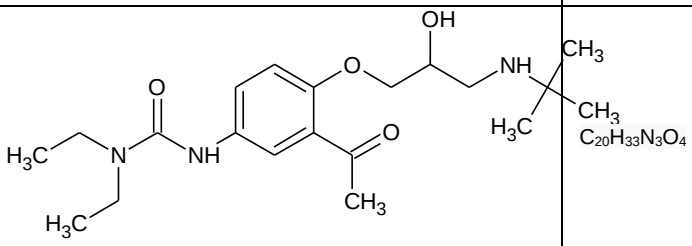
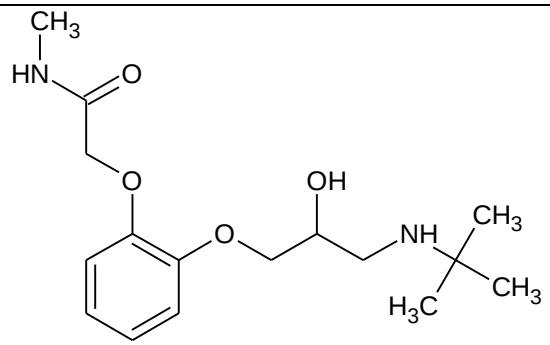
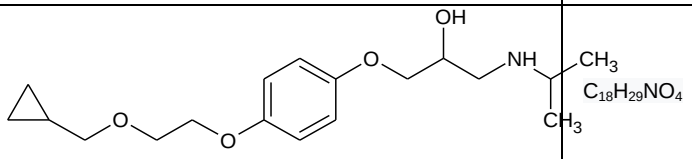
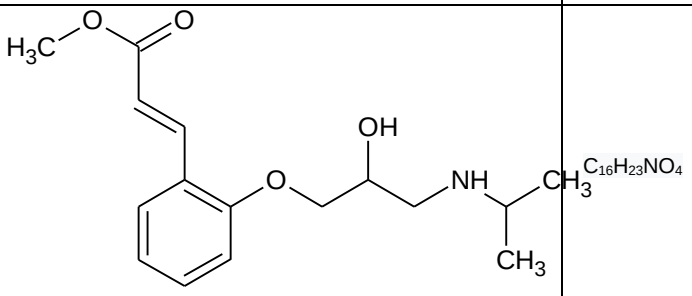
Sl. No.	Compound Name	Structure	Molecular Formula	Molecular Mass	Therapeutic uses
1	Acebutalol		$C_{18}H_{28}N_2O_4$	336.426 g/mol	Hypertension and arrhythmia
2	Adaprolol		$C_{26}H_{39}NO_4$	429.59 g/mol	Glaucoma
3	Adimolol		$C_{25}H_{29}N_3O_3$	419.52 g/mol	Antihypertensive
4	Alfurolol		$C_{15}H_{21}NO_4$	279.33 g/mol	-

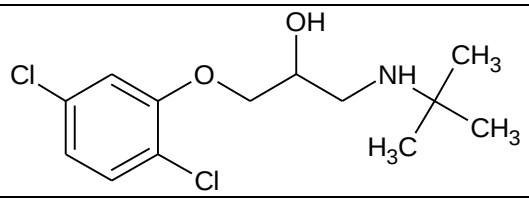
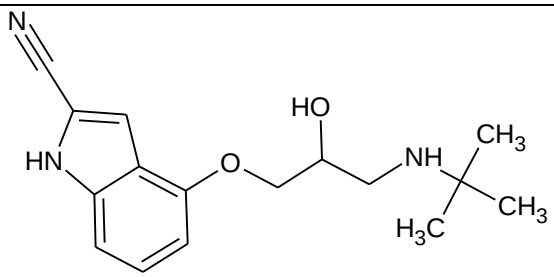
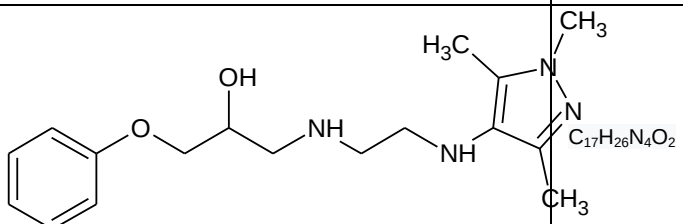
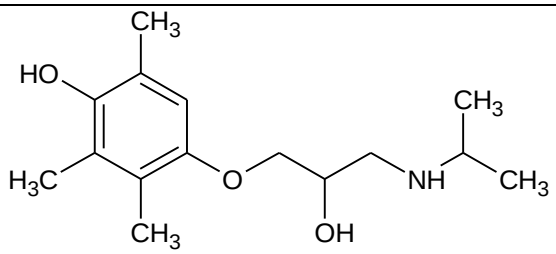
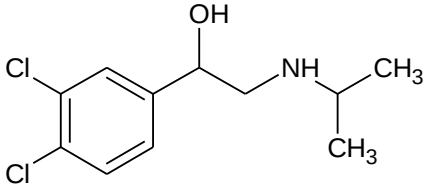
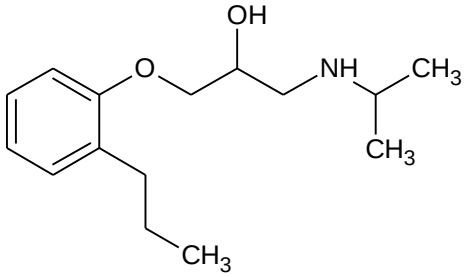
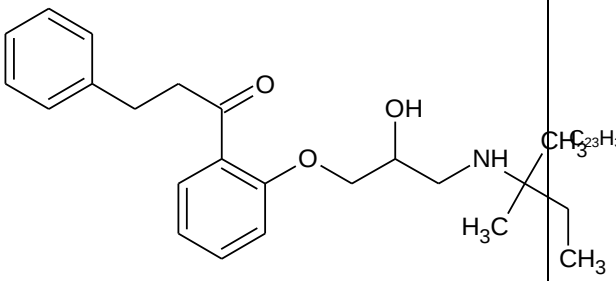
5	Alprenolol		$C_{15}H_{23}NO_2$	249.34 g/mol	Antihypertensive, in edema, ventricular tachycardia and atrial fibrillation
6	Alprenoxime		$C_{15}H_{22}N_2O_2$	262.35 g/mol	It is a prodrug to alprenolol.Antihypertensive, in edema, ventricular tachycardia and atrial fibrillation
7	Amosulalol		$C_{18}H_{24}N_2O_5S$	380.45 g/mol	Antihypertensive prior to operations in patients with pheochromocytoma
8	Ancarolol		$C_{18}H_{24}N_2O_4$	332.39 g/mol	Antihypertensive
9	Arnolol		$C_{14}H_{23}NO_3$	253.34 g/mol	-
10	Arotinolol		$C_{15}H_{21}N_3O_2S_3$	371.54 g/mol	Treatment of high blood pressure and essential tremor.

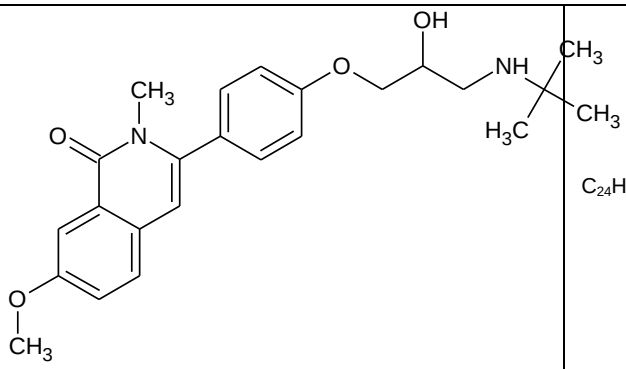
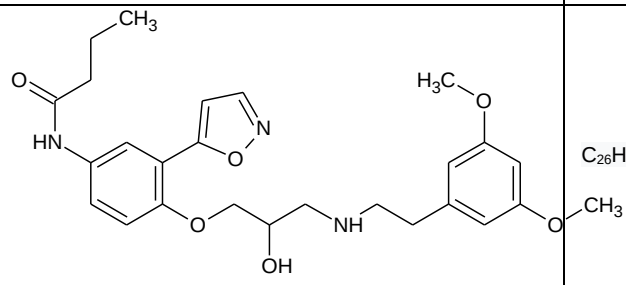
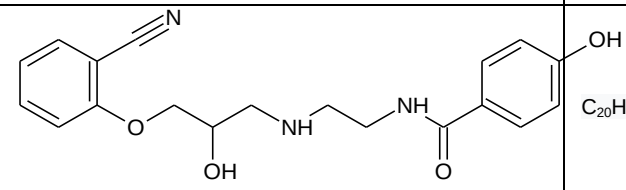
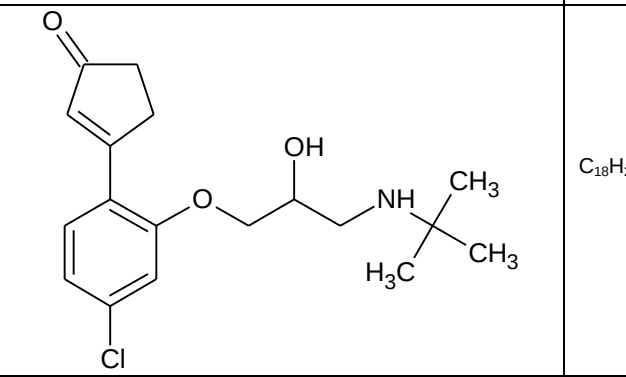
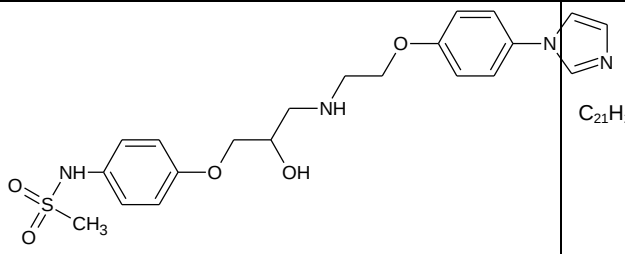
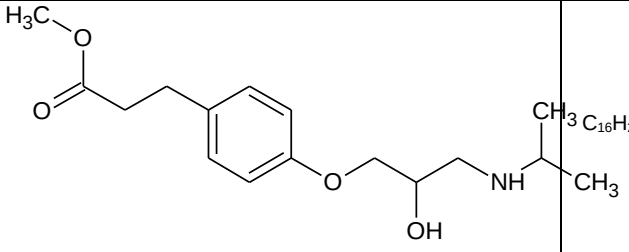
11	Atenolol		$C_{14}H_{22}N_2O_3$	266.336 g/mol	Used primarily in cardiovascular diseases. Treatment for hypertension
12	Befunolol		$C_{16}H_{21}NO_4$	291.342 g/mol	Management of open-angle glaucoma.
13	Betaxolol		$C_{18}H_{29}NO_3$	307.428 g/mol	Treatment of hypertension and glaucoma
14	Bevantolol		$C_{20}H_{27}NO_4$	345.43 g/mol	Treatment of angina and hypertension
15	Bisoprolol		$C_{18}H_{31}NO_4$	325.443 g/mol	High blood pressure, chest pain from not enough blood flow to the heart, and heart failure
16	Bopindolol		$C_{23}H_{28}N_2O_3$	380.48 g/mol	Angina pectoris, Hypertension
17	Bornaprolol		$C_{19}H_{29}NO_2$	303.45 g/mol	Antihypertensive

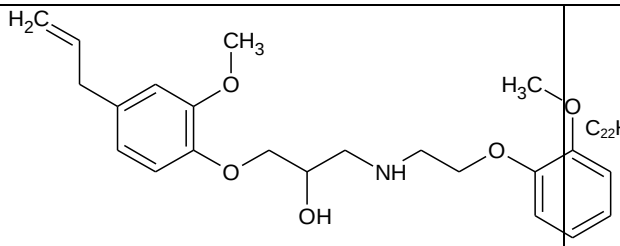
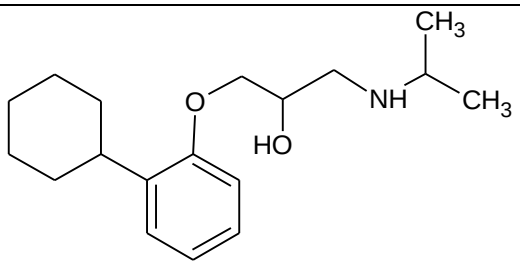
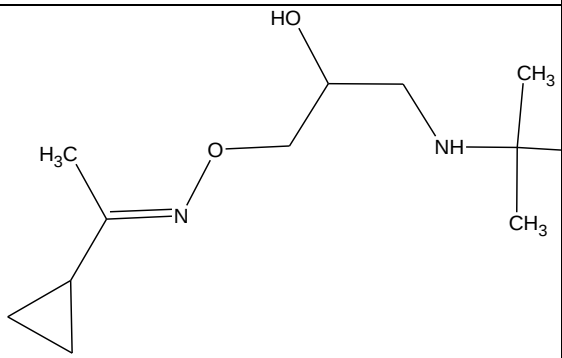
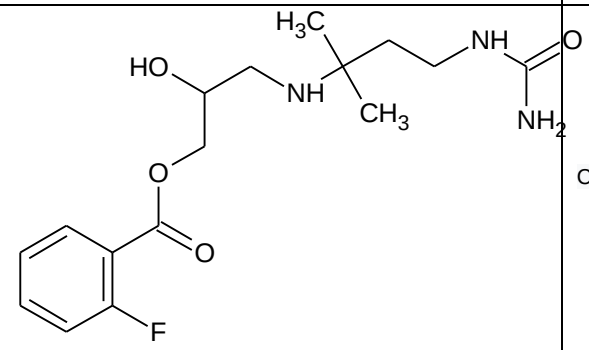
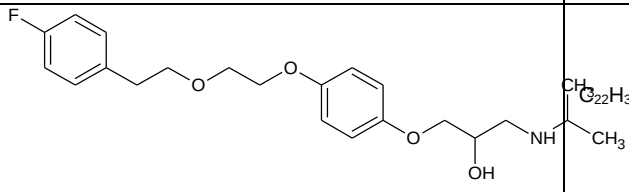
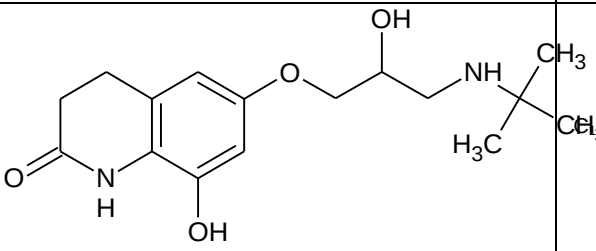
18	Brefonalol		$C_{22}H_{28}N_2O_2$	352.48 g/mol	-
19	Bucindolol		$C_{22}H_{25}N_3O_2$	363.45 g/mol	-
20	Bucumolol		$C_{17}H_{23}NO_4$	305.37 g/mol	Antihypertensive
21	Bufetolol		$C_{18}H_{29}NO_4$	323.43 g/mol	Antiarrhythmic
22	Bufuralol		$C_{16}H_{23}NO_2$	261.37 g/mol	Peripheral vasodilating, antianginal and antihypertensive
23	Bunitrolol		$C_{14}H_{20}N_2O_2$	248.33 g/mol	Antianginal and antiarrhythmic

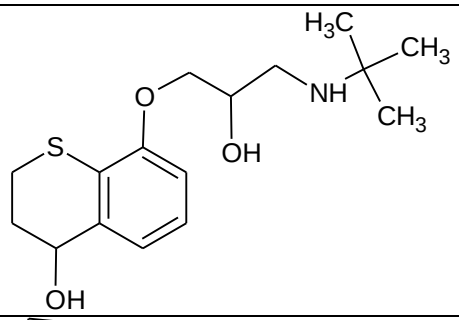
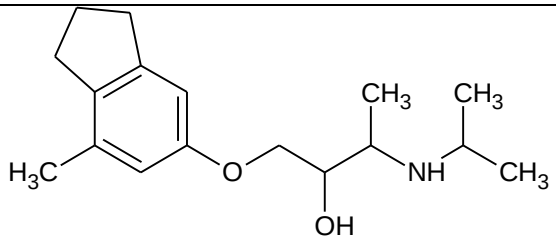
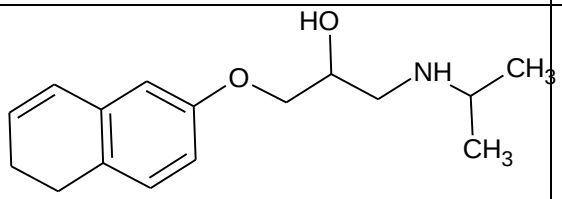
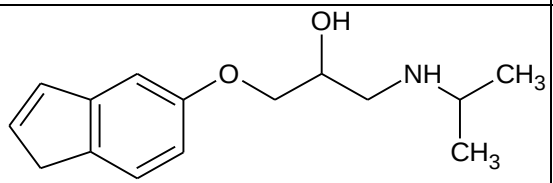
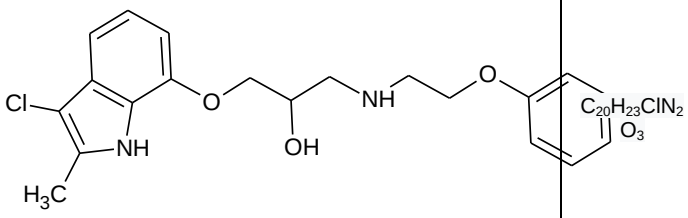
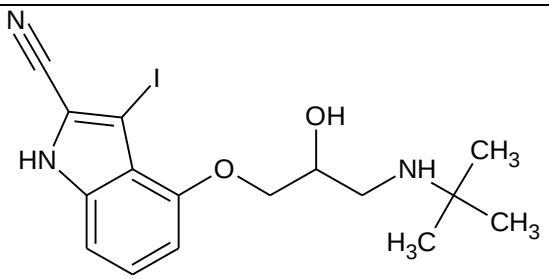
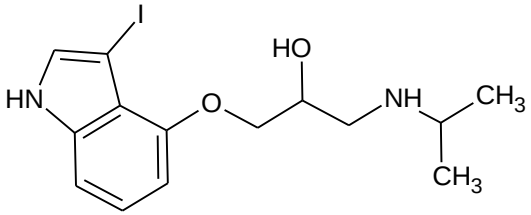
24	Bupicomide		$C_{10}H_{14}N_2O$	178.24 g/mol	Antihypertensive
25	Bupranolol		$C_{14}H_{22}ClNO_2$	271.78298 g/mol	Treat hypertension and tachycardia
26	Butaxamine		$C_{15}H_{25}NO_3$	267.364 g/mol	-
27	Butidrine		$C_{16}H_{25}NO$	247.38 g/mol	Local anesthetic
28	Butofilolol		$C_{17}H_{26}FNO_3$	311.392 g/mol	Treatment of essential hypertension
29	Capsinolol		$C_{23}H_{40}N_2O_4$	408.58 g/mol	In tachycardia
30	Carpindolol		$C_{19}H_{28}N_2O_4$	348.44 g/mol	-

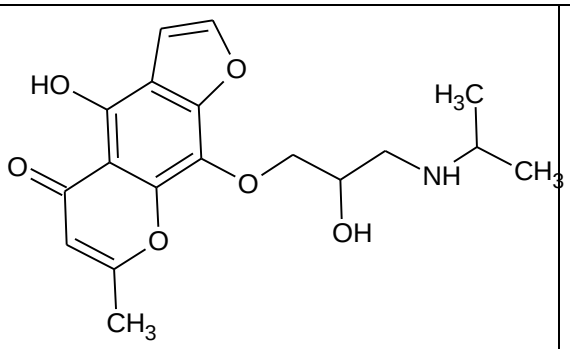
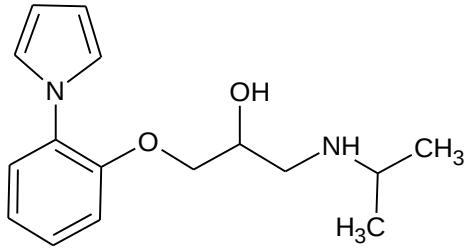
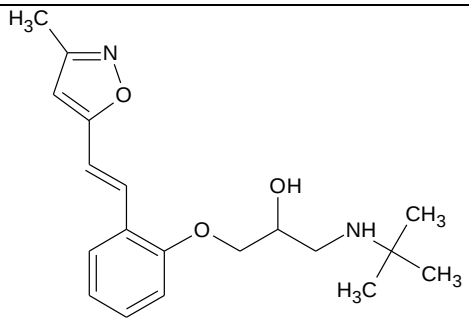
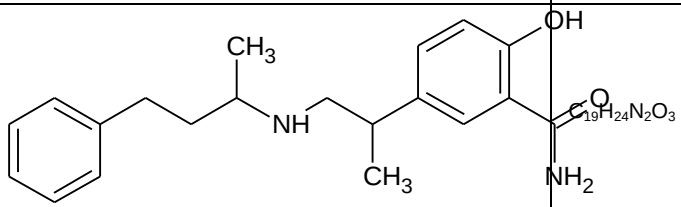
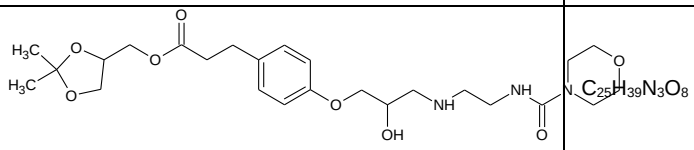
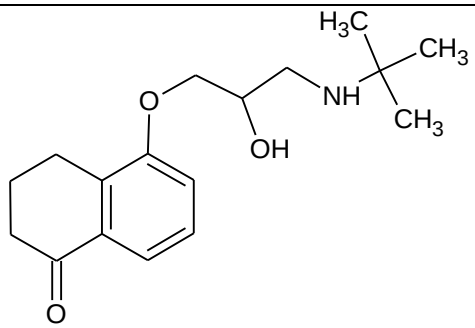
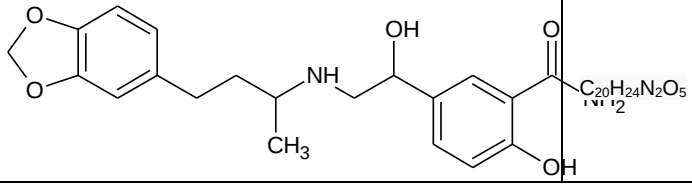
31	Carteolol		$C_{16}H_{24}N_2O_3$	292.373 g/mol	Glaucoma (open -angle type) or other eye diseases (such as ocular hypertension), antihypertensive, antiarrhythmic, antianginal.
32	Carvedilol		$C_{24}H_{26}N_2O_4$	406.474 g/mol	Used for treating mild to severe congestiv e heart failure (CHF), lef t ventricular dysfunction (LV D) following heart attack and for treating high blood pressure.
33	Celiprolol		$C_{20}H_{33}N_3O_4$	379.49 g/mol	Treatment of high blood pressure and treatment of vascular Ehlers–Danlos syndrome.
34	Cetamolol		$C_{16}H_{26}N_2O_4$	310.39 g/mo l	-
35	Cicloprolol		$C_{18}H_{29}NO_4$	323.43 g/mo l	In tachycardia
36	Cinamolol		$C_{16}H_{23}NO_4$	293.36 g/mol	-

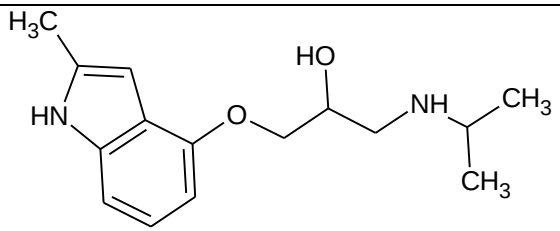
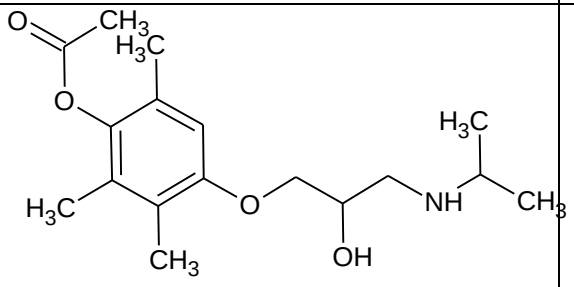
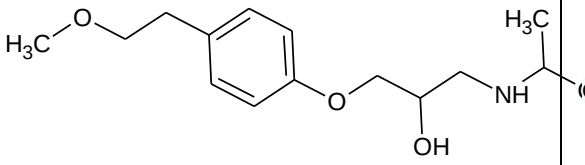
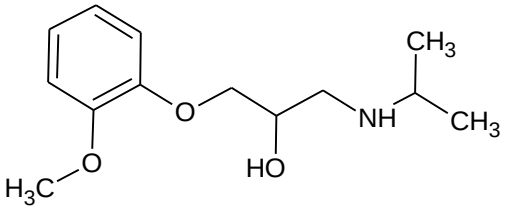
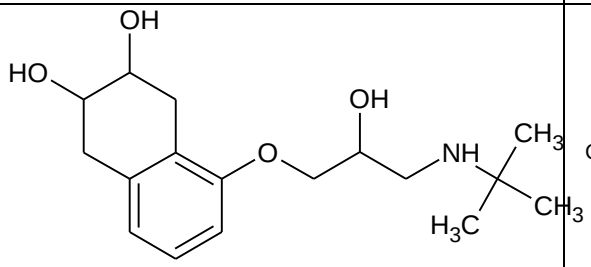
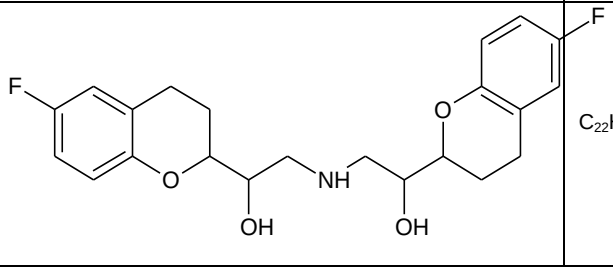
37	Cloranolol		$C_{13}H_{19}Cl_2NO_2$	292.20 g/mol	Antiarrhythmic
38	Cyanopindolol		$C_{16}H_{21}N_3O_2$	287.36 g/mol	-
39	Dalbraminol		$C_{17}H_{26}N_4O_2$	318.41 g/mol	-
40	Desacetylmetipranolol		$C_{15}H_{25}NO_3$	267.37 g·mol^{-1}	Active metabolite of metipronolol
41	Dichloroisoprenaline		$C_{11}H_{15}Cl_2NO$	248.15 g/mol	-
42	Dihydroalprenolol		$C_{15}H_{25}NO_2$	251.37 g/mol	Alprenolol derivative
43	Diprafenone		$C_{23}H_{31}NO_3$	369.51 g/mol	New class I C antiarrhythmic agent

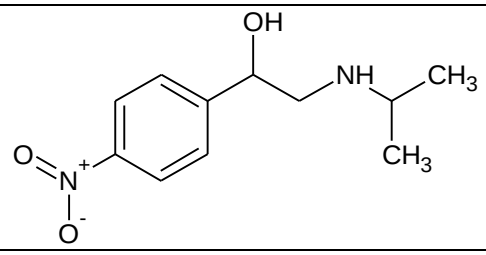
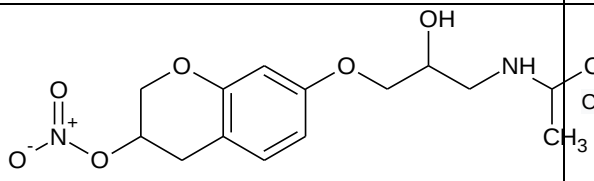
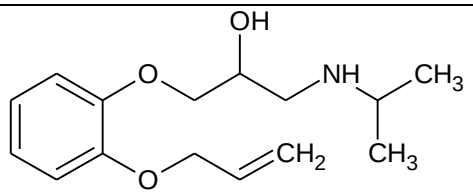
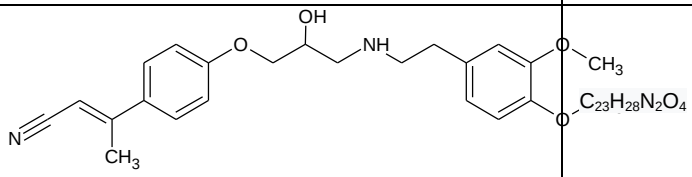
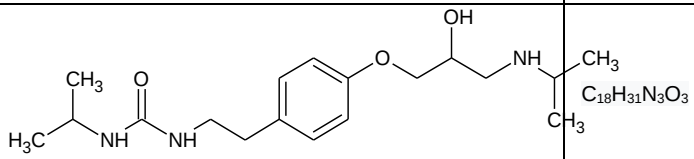
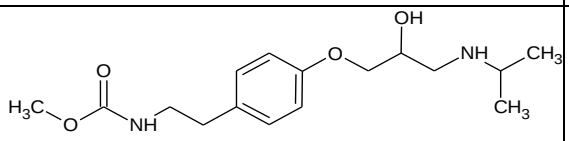
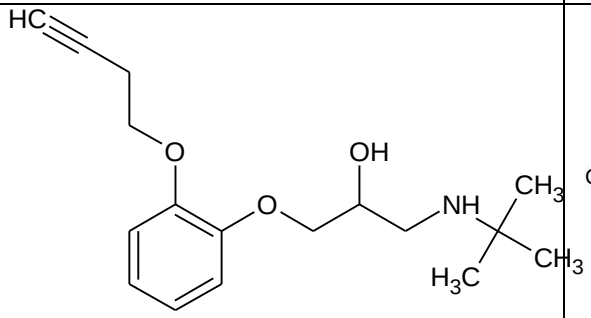
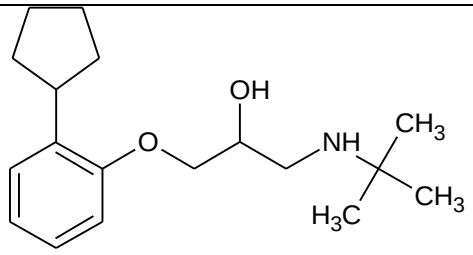
44	Draquinolol		$C_{24}H_{30}N_2O_4$	410.51 g/mol	-
45	Ecastolol		$C_{26}H_{33}N_3O_6$	483.56 g/mol	-
46	Epanolol		$C_{20}H_{23}N_3O_4$	369.41432 g/mol	New antianginal
47	Ericolol		$C_{18}H_{24}ClNO_3$	337.84 g/mol	Antihypertensive, antianginal and antiarrhythmic
48	Ersentilide		$C_{21}H_{26}N_4O_5S$	446.52 g/mol	Antifibrillatory
49	Esmolol		$C_{16}H_{25}NO_4$	295.374 g/mol	Class II antiarrhythmic

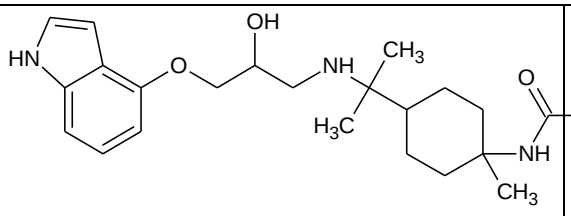
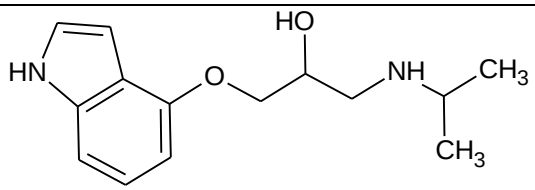
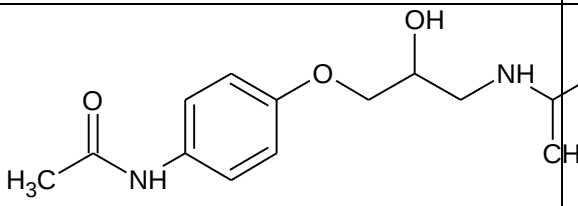
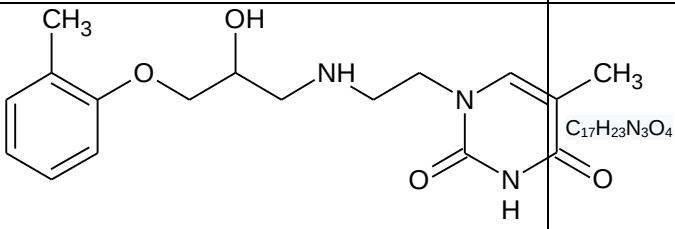
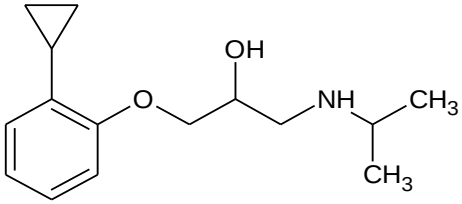
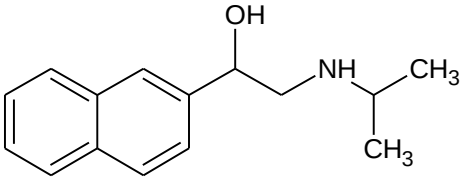
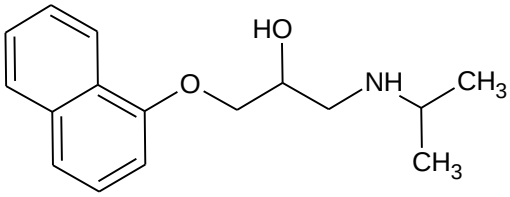
50	Eugenodilol		$C_{22}H_{29}NO_5$	387.47 g/mol	-
51	Exaprolol		$C_{18}H_{29}NO_2$	291.44 g/mol	-
52	Falintolol		$C_{12}H_{24}N_2O_2$	228.34 g/mol	Treatment of glaucoma
53	Flestolol		$C_{15}H_{22}FN_3O_4$	327.36 g/mol	In angina and atrial fibrillation
54	Flusoxolol		$C_{22}H_{30}FNO_4$	391.48 g/mol	Antihypertensive, antianginal and antiarrhythmic
55	Hydroxycarteolol		$C_{12}H_{24}N_2O_4$	308.37 g/mol	Active metabolite of carteolol

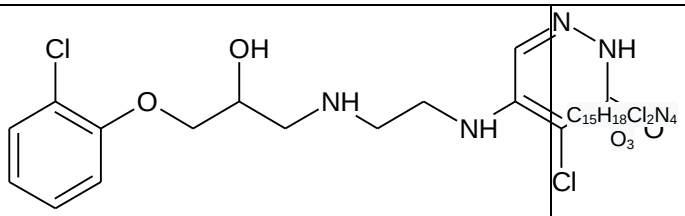
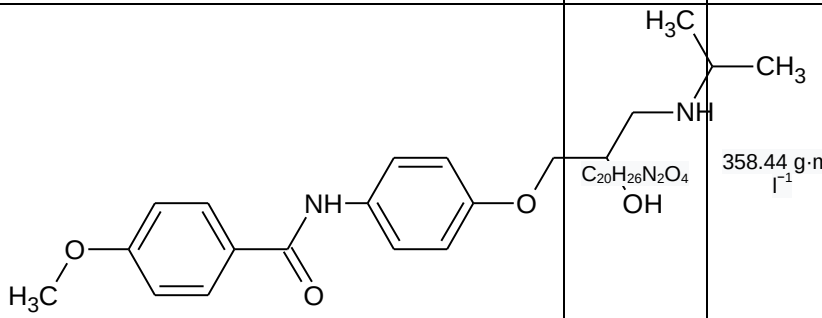
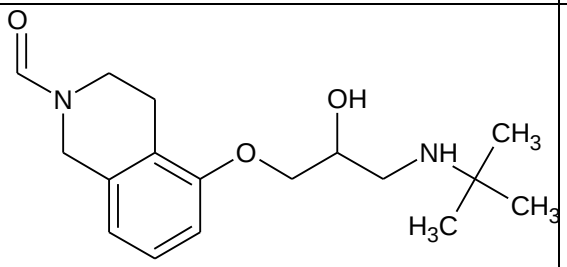
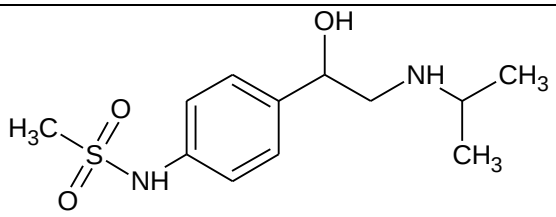
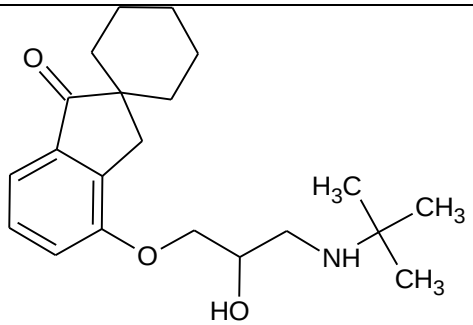
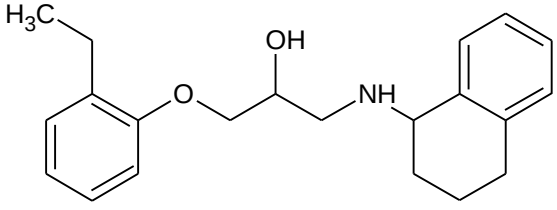
56	Hydroxytertatolol		$C_{16}H_{25}NO_3S$	311.44 g/mol	-
57	ICI-118,551		$C_{17}H_{27}NO_2$	277.402 g/mol	-
58	Idropranolol		$C_{16}H_{23}NO_2$	261.36 g/mol	-
59	Indenolol		$C_{15}H_{21}NO_2$	247.34 g/mol	Antiarrhythmic
60	Indopanolol		$C_{20}H_{23}ClN_2O_3$	374.86 g/mol	-
61	Iodocyanopindolol		$C_{16}H_{20}IN_3O_2$	413.25 g/mol	Used in mapping the distribution of beta adrenoreceptors in the body
62	Iodopindolol		$C_{14}H_{19}IN_2O_2$	374.22 g/mol	Used in mapping the distribution of beta adrenoreceptors in the body

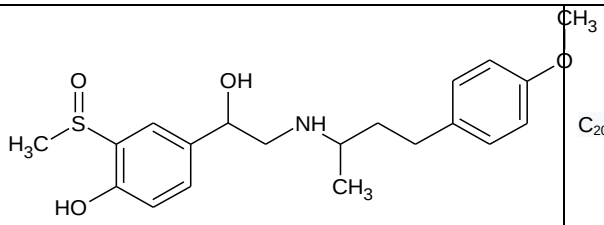
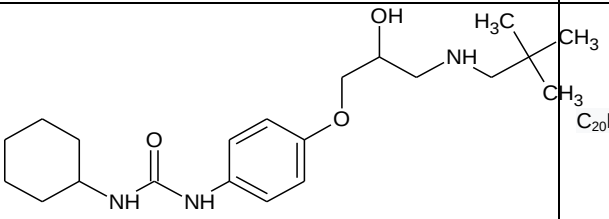
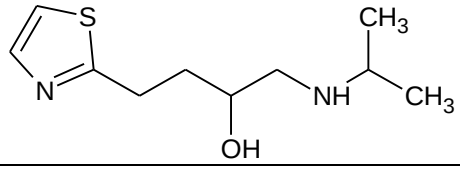
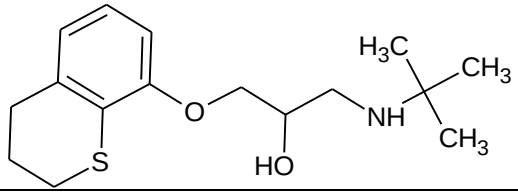
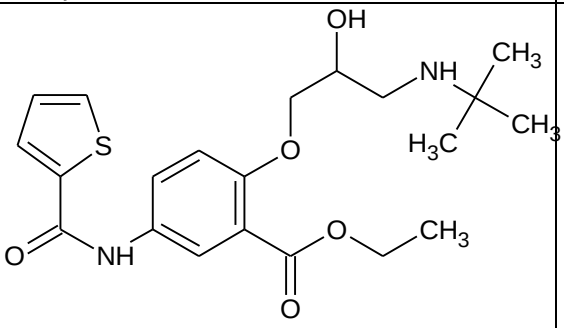
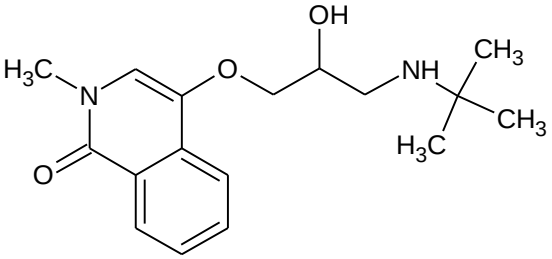
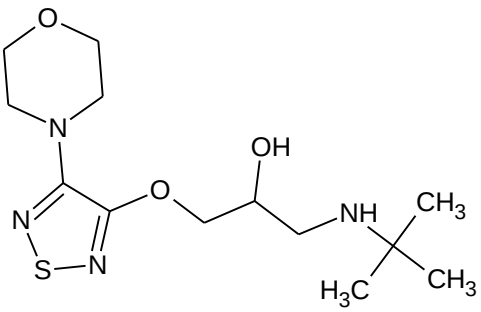
63	Iprocrolol		$C_{18}H_{23}NO_6$	349.38 g/mol	Antiarrhythmic
64	Isamoltane		$C_{16}H_{22}N_2O_2$	274.357 g/mol	Used in scientific research. It acts as an antagonist at the β-adrenergic, 5-HT_{1A}, and 5-HT_{1B} receptors.
65	Isoxaprolol		$C_{19}H_{26}N_2O_3$	330.42 g/mol	Antiarrhythmic and antihypertensive
66	Labetalol		$C_{19}H_{24}N_2O_3$	328.406 g/mol	Antihypertensive
67	Landiolol		$C_{25}H_{39}N_3O_8$	509.59 g/mol	Antiarrhythmic agent
68	Levobunolol		$C_{17}H_{25}NO_3$	291.385 g/mol	Topically to manage glaucoma
69	Medroxalol		$C_{20}H_{24}N_2O_5$	372.415 g/mol	Vasodilator

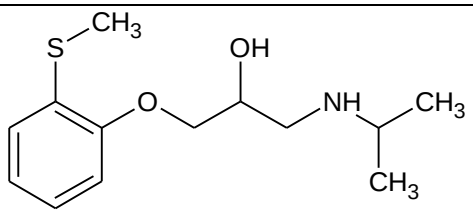
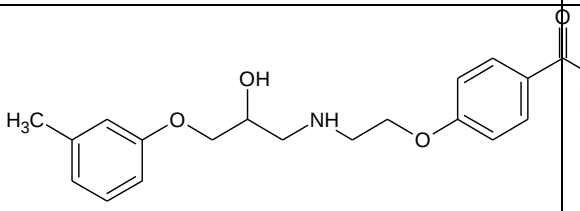
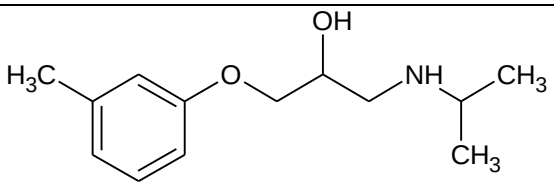
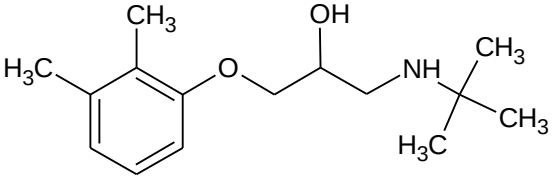
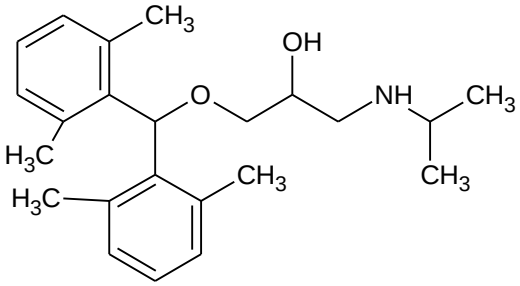
70	Mepindolol		$C_{15}H_{22}N_2O_2$	262.35 g·mol^{-1}	To treat glaucoma
71	Metipranolol		$C_{17}H_{27}NO_4$	309.401 g/mol	To treat glaucoma
72	Metoprolol		$C_{15}H_{25}NO_3$	267.37 g·mol^{-1}	To treat high blood pressure, chest pain due to poor blood flow to the heart, and arrhythmia. Treatment of post myocardial infarction patients and also in migraine.
73	Moprolol		$C_{13}H_{21}NO_3$	239.32 g·mol^{-1}	To treat hypertension, anxiety, and glaucoma
74	Nadolol		$C_{17}H_{27}NO_4$	309.401 g/mol	Treatment of high blood pressure and chest pain. Additionally, in the treatment of atrial fibrillation, migraine headaches, and complications of cirrhosis.
75	Nebivolol		$C_{22}H_{25}F_2NO_4$	405.435 g/mol	Treatment of hypertension and left ventricular failure.

76	Nifenalol		$C_{11}H_{16}N_2O_3$	224.26 g·mol^{-1}	Treatment of angina
77	Nipradilol		$C_{15}H_{22}N_2O_6$	326.35 g·mol^{-1}	In treatment of glaucoma
78	Oxprenolol		$C_{15}H_{23}NO_3$	265.348	Treatment of angina pectoris, abnormal heart r hythms and high blood pressure.
79	Pacrinolol		$C_{23}H_{28}N_2O_4$	396.49 g·mol^{-1}	Long acting antihypertensive.
80	Pafenolol		$C_{18}H_{31}N_3O_3$	337.46 g·mol^{-1}	Antihypertensive
81	Pamatolol		$C_{16}H_{26}N_2O_4$	310.39 g·mol^{-1}	Antihypertensive drug
82	Pargolol		$C_{16}H_{23}NO_3$	277.36 g·mol^{-1}	-
83	Penbutolol		$C_{18}H_{29}NO_2$	291.428 g/mol	Treatment of high blood pressure

84	Pindobind		$C_{23}H_{34}BrN_3O_3$	480.45 g·mol^{-1}	CNS depressant drug in animals
85	Pindolol		$C_{14}H_{20}N_2O_2$	248.321 g/mol	Treatment of hypertension and angina pectoris
86	Practolol		$C_{14}H_{22}N_2O_3$	266.336 g/mol	Emergency treatment of cardiac arrhythmias. Practolol is no longer used as it is highly toxic
87	Primidolol		$C_{17}H_{23}N_3O_4$	333.39 g·mol^{-1}	Antihypertensive
88	Procinolol		$C_{15}H_{23}NO_2$	249.35 g·mol^{-1}	Antiarrhythmic
89	Pronethalol		$C_{15}H_{19}NO$	229.32 g/mol	Never used clinically due to carcinogenicity
90	Propranolol		$C_{16}H_{21}NO_2$	259.34 g/mol	To treat hypertension, arrhythmia, thyrotoxicosis, capillary hemangiomas, performance anxiety, essential tremors, to prevent migraine headaches, further heart problems in those with angina or previous heart attacks

91	Ridazolol		$C_{15}H_{18}Cl_2N_4O_3$	373.23 g·mol^{-1}	-
92	Ronactolol		$C_{20}H_{26}N_2O_4$	358.44 g·mol^{-1}	-
93	Soquinolol		$C_{17}H_{26}N_2O_3$	306.41 g·mol^{-1}	-
94	Sotalol		$C_{12}H_{20}N_2O_3S$	272.3624 g/mol	Class III antiarrhythmic drug
95	Spirendolol		$C_{21}H_{31}NO_3$	345.48 g·mol^{-1}	In control of essential tremors
96	SR 59230A		$C_{21}H_{27}NO_2$	325.45 g·mol^{-1}	-

97	Sulfinalol		$C_{20}H_{27}NO_4S$	377.50 g·mol^{-1}	Antihypertensive
98	Talinolol		$C_{20}H_{33}N_3O_3$	363.50 g·mol^{-1}	-
99	Tazolol		$C_9H_{16}N_2O_2S$	216.30 g·mol^{-1}	Treatment of heart disease.
100	Tertatolol		$C_{16}H_{25}NO_2S$	295.44 g/mol	Antihypertensive
101	Tienoxolol [		$C_{21}H_{28}N_2O_5S$	420.52 g·mol^{-1}	Diuretic
102	Tilisolol		$C_{17}H_{24}N_2O_3$	304.38 g/mol	Vasodilator
103	Timolol		$C_{13}H_{24}N_4O_3S$	316.421 g/mol	Antihypertensive ,treatment of chest pain due to insufficient blood flow to the heart, also used to prevent further complications after a heart attack, and migraines prevention.

104	Tiprenolol		$C_{13}H_{21}NO_2S$	255.38 g·mol^{-1}	-
105	Tolamolol		$C_{19}H_{24}N_2O_4$	344.41 g·mol^{-1}	-
106	Toliprolol		$C_{13}H_{21}NO_2$	223.32 g·mol^{-1}	-
107	Xibenolol		$C_{15}H_{25}NO_2$	251.36 g/mol	-
108	Xipranolol		$C_{23}H_{33}NO_2$	355.51 g/mol	Antiarrythmic

FIGURES

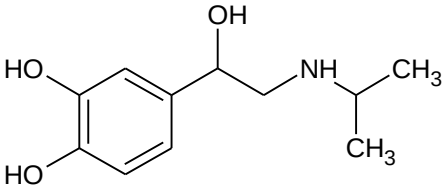


Fig. 1: Chemical structure of isoprenaline

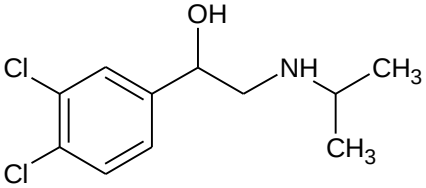


Fig. 2: Chemical structure of dichloroisoprenaline

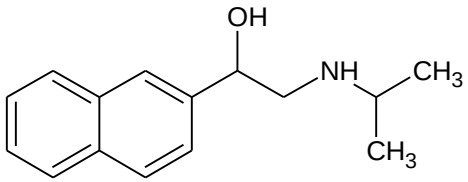


Fig. 3: Chemical structure of pronethalol

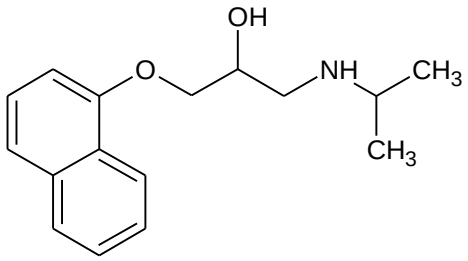


Fig. 4: Chemical structure of propranolol

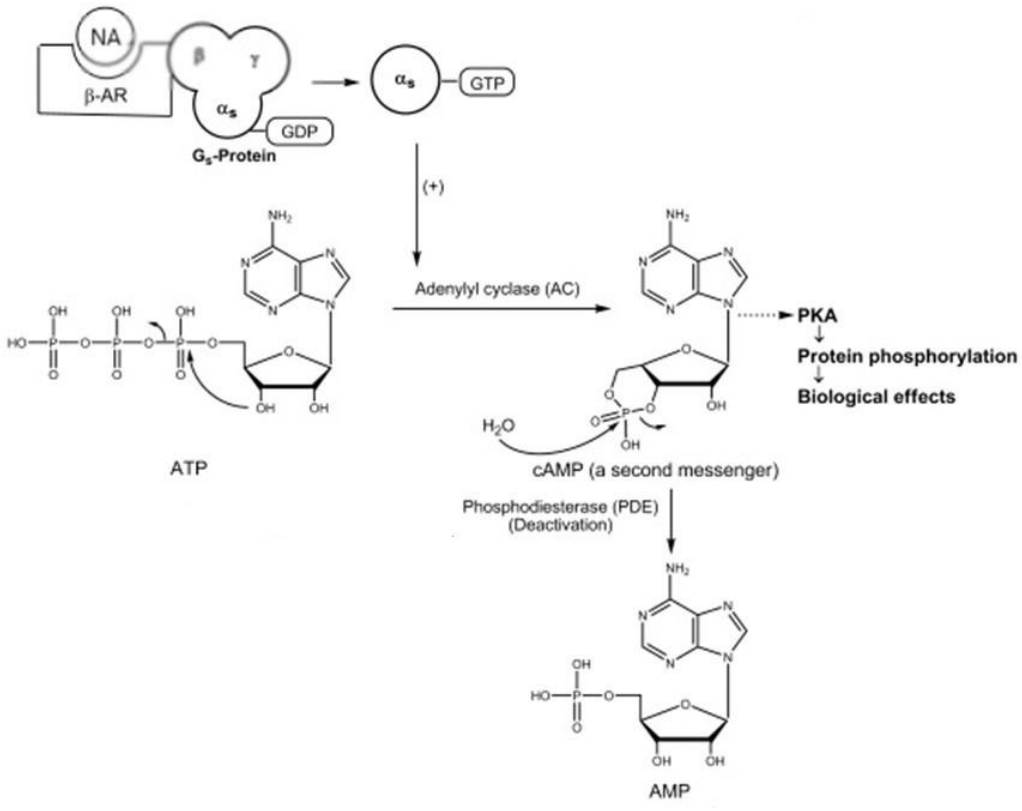


Fig. 5: Mechanism of action of nor adrenaline on beta adrenergic receptors.[11]

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