

# Properties of artificial bacteriorhodopsin analogs.

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**Retinoids. Historical sketch.**

The relationship between “night-blindness”, or nyctalopia (severe decline of vision in dim light) and certain component in diets of both humans and animals was known back in ancient Egypt. In 1913 McCollum and Davis reported the discovery of a fat-soluble substance in some foods, which stimulated growth of rats and prevented development of “night-blindness” and xerophthalmia, and have called it “factor A”, which was later renamed into “vitamin A”. In 1930 Karrer has established its structure. Today three groups of chemical compounds are united under names vitamin A and retinoids: the derivatives of retinol (vitamin A alcohol, 2), of retinal (vitamin A aldehyde, 3) and of retinoic acid (RA, 4) (Fig. 1).  $\beta$ -Carotene (provitamin A, 1) as well as a number of other carotenoids were identified at the same time, however their transformation pathways into retinoids were found much later.

Today vitamin A (all-*E*-retinol, 2, Fig. 1) is considered the most multifunctional fat-soluble vitamin in the human body. It plays key roles in many physiological processes such as vision, reproduction, embryonic growth and development, immune competence, cell differentiation, cell proliferation and apoptosis, maintenance of epithelial tissue, and brain function. Severe vitamin A deficiency can lead to xerophthalmia and “night blindness”.

Vitamin A comes into the body exclusively with food in the form of retinol esters or from carotenoids split by a number of enzyme systems located in intestines, and is stored as esters in the liver. The role of vitamin A as dietary component required for normal growth and vision was established, vitamin A deficiency (serum vitamin A levels of  $<0.7 \mu\text{mol L}^{-1}$ ) is still prevalent in many developing countries, and considered responsible for child and maternal mortality. The administration of vitamin A alone has been shown to decrease preschool mortality in developing countries by 23–34%. Most of the biological processes linked to retinoids are in fact due to the interaction of several metabolites with retinal based proteins or their nuclear biological receptors. These metabolites are generated *in vivo* by redox changes affecting the functional group (retinal, 3, retinoic acid, 4), the C4-allylic position oxidation or C5-C6-double bond epoxidation, and the conjugated polyene chain and/or by isomerization of some selected double bonds.

Aside from vision, retinoids perform their function in the form of complexes with protein receptors: covalent complexes (retinal based proteins) and noncovalent complexes (nuclear retinoic acid receptors, RAR and RXR). Most of the cellular processes influenced by vitamin A and its analogues are mediated by their binding to (and activating) two families of nuclear receptors as well as to the retinoid metabolizing enzymes. The structural and functional studies of nuclear receptors, and the identification of retinoic acid receptor families, RARs [RAR $\alpha$  (NR1B1), RAR $\beta$  (NR1B2), and RAR $\gamma$  (NR1B3)], and retinoid X receptors, RXRs [RXR $\alpha$  (NR2B1), RXR $\beta$  (NR2B2), and RXR $\gamma$  (NR2B3)], that are activated by all-*E*-retinoic acid (4) and/or its 9*Z*-isomer have significantly deepened our understanding of the molecular mechanisms by which retinoids as ligands of the nuclear receptor superfamily in general confer the ability onto these inducible transcription factors to regulate target gene transcription.

In medicine: all-*E*-retinoic acid/arsenic trioxide combination therapy (together with chemotherapy protocols primarily for post-remission consolidation and maintenance therapy) of acute promyelocytic leukemia (cures more than 90% of patients). As far as RXR ligands (also called rexinoids) are concerned, the U.S. Food and Drug Administration approved bexarotene in 1999 for the treatment of refractory cutaneous T-cell lymphoma, and efforts are ongoing to dissociate activities that induce hypothyroidism and elevated triglyceride levels, presumably by affecting RXR

heterodimer pathways for other nuclear receptors. A limitation of all-*E*-retinoic acid-based therapies is their teratogenicity and hypervitaminosis, the excess intake of vitamin A, may be harmful to the elderly people due to adverse effects of vitamin A toxicity on bone loss [29, 30, 32].

### Retinoid nomenclature and stereochemistry.

Retinoids are referred to as three groups of fat-soluble vitamin A derivatives that differ in the nature of the terminal group. Their molecules consist of the trimethylcyclohexene ring conjugated via four double bonds with the polar terminal group. The numbering of carbon atoms according to IUPAC-IUB recommendations is presented on Fig. 1.

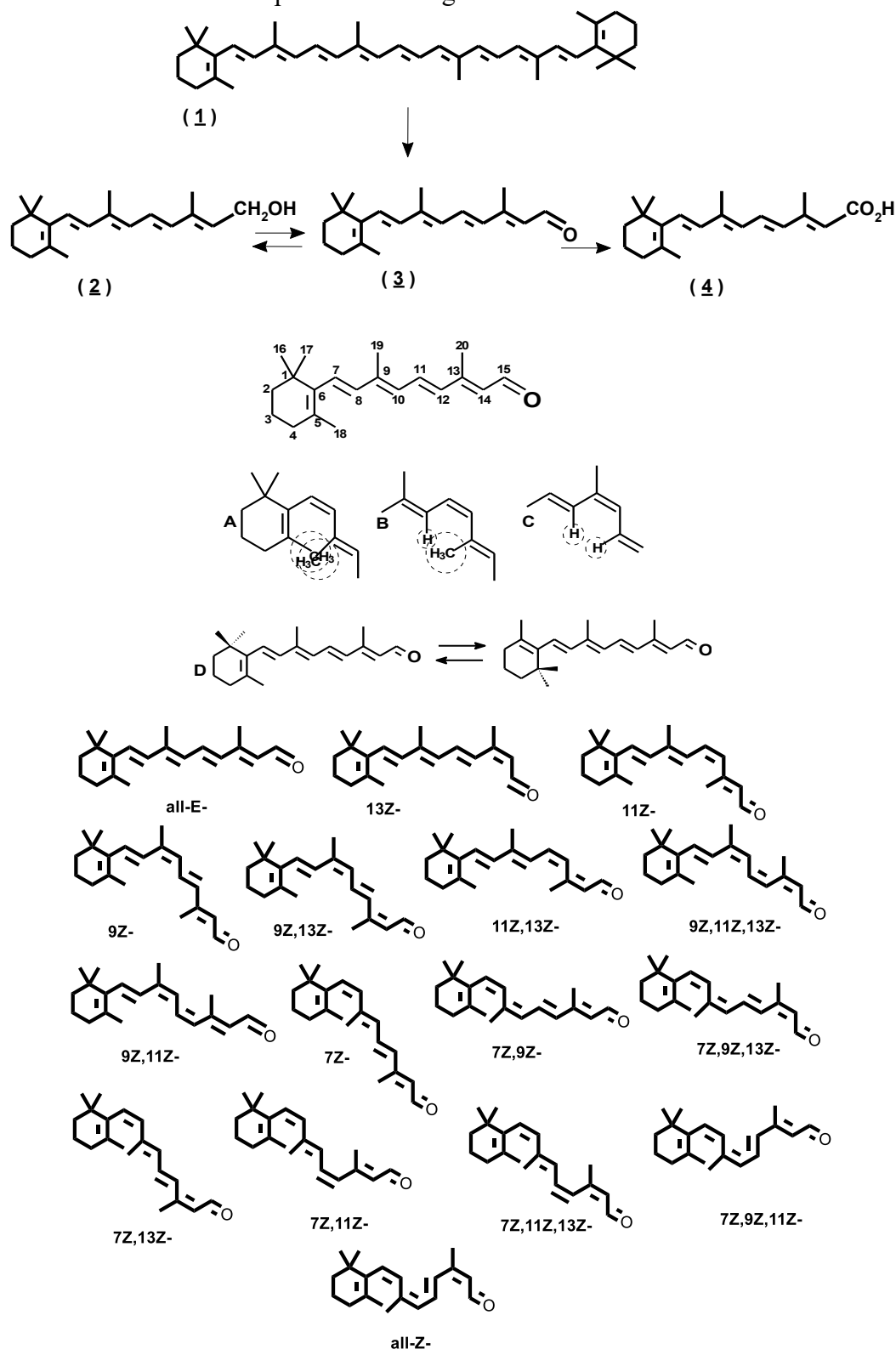


Fig. 1. Retinoid derivatives structures diversity.

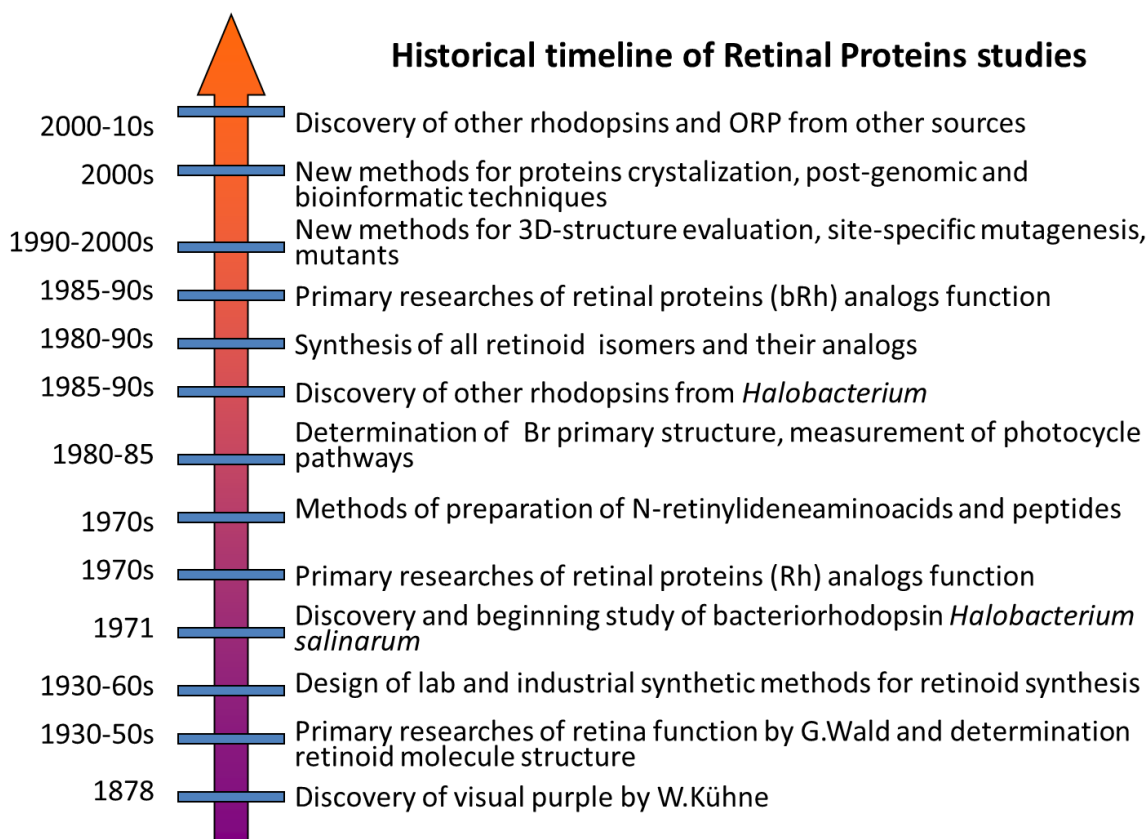
The retinal molecule by its chemical nature contains lipophilic isoprenoid fragment of size C<sub>20</sub> with a system of five conjugated double bonds, one of which is contained inside the trimethylcyclohexene ring, and the remaining four in the side chain ending with a terminal aldehyde group.

Two types of isomerism are characteristic for retinoids: *Z*- and *E*-; *s-trans*- and *s-cis*-. Sixteen geometric retinal isomers are possible in total; their structures are presented in Fig. 1. All isomers may be subdivided into sterically unhindered – all-*E*-; 9*Z*-; 9*Z*,13*Z*- and 13*Z*-, and sterically hindered – the remaining ones. Isomerization to *E*-series, both spontaneous and induced by various physical factors (irradiation, temperature) is characteristic of the latter ones. This phenomenon is due to presence of steric difficulties of overlapping van der Waals radii of interacting groups (H, CH<sub>3</sub>).

### Retinal based Proteins (RBP)

The retinoid isomers play the key role in functioning processes in retinal based proteins — visual pigments; ion-pump bacteriorhodopsin (BRh), halorhodopsin (HRh), sensoric rhodopsins (SRhI, SRhII), tundra-rhodopsin (ESRh), and others, as well as in the retinoic acid nuclear receptors. Upon absorption of light quantum the isomerization of the definite double bond initiates a cascade of events needed for the generation of the physiological or chemical responses. During the evolution process this property of retinoid molecule became the basis for a number of light quantum energy transformation into chemical energy or some physiological response in biological systems, both in higher animals and microorganisms. Retinal based proteins contain a number of defined retinal isomers as part of their chromophoric groups bound via the protonated aldimine bond with the ε-amino group of the Lys residue.

Retinal proteins (Retinal based proteins, RBP) are chromoproteins that function either as sensors or as ion pumps in several species across all domains, Archaea, Eubacteria, and Eukarya. These light-sensitive proteins share a common fold of seven transmembrane (7TM) helices and bind a retinal chromophore through a protonated Schiff base (PSB) with a Lys residue located in helix seven. The absorption maxima of each retinal-based protein are modulated by the ionic environment of the PSB in the binding pocket. Several retinal based proteins with unexpected functions have been discovered and characterized recently.

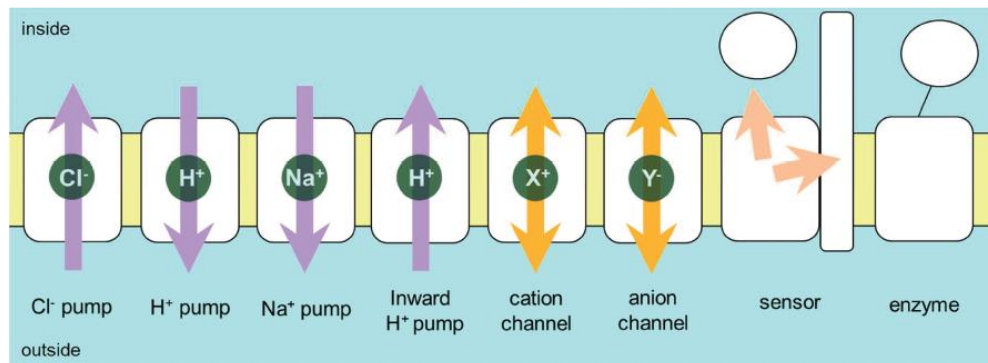


**Fig. 2. Historical timeline of Retinal based proteins studies**

## General features of Retinal based protein structure

Retinal based proteins have the following general features of their structures:

- Protein structure — 7 helical trans-membrane domain fold - (7TM) helices
- Chromophoric group is definite isomer retinal (all-*E*- for the microbial pigments and 11*Z*- for visual pigments) bounded to protein via protonated aldimine bond (Schiff base)
- Their function is closely connected with sun energy conversion into different chemical or physiological response
- Functional mode: light-driven Cl<sup>-</sup> pump, light-driven H<sup>+</sup> pump, light-driven Na<sup>+</sup> pump, inward H<sup>+</sup> pump, light-gated cation channel, light-gated anion channel, light sensor with transmembrane transducer and soluble transducer, and light-activated enzyme.



**Fig. 3. Functions of microbial retinal based proteins - rhodopsins (RHs): light-driven Cl<sup>-</sup> pump, light-driven H<sup>+</sup> pump, light-driven Na<sup>+</sup> pump, light-driven inward H<sup>+</sup> pump, light-gated cation channel, light-gated anion channel, light sensor with transmembrane transducer and soluble transducer, and light-activated enzyme.** Purple or orange arrows indicate uni-directional or bi-directional transport of ions in pumps or channels, respectively [293-294].

The oldest representatives from known retinal based proteins are two visual pigment families – rhodopsins and cone opsins, which responsible for processes dark and color vision. George Wald determined in 1934 that 11*Z*-retinal (Fig. 1) is the chromophore of the visual pigments. Our understanding of the biochemistry and molecular biology of the visual cycle and the retinoid cycle (the conversion of *all-E*-retinal via 11*Z*-retinol to 11*Z*-retinal) has increased enormously in the last years. Other retinal based proteins (microbial rhodopsins) used by microorganisms to control membrane ion homeostasis and phototaxis are based on light-induced photocycles driven by isomerization of the chromophore *all-E*-retinal (3) bound to membrane proteins that are similar to the proteins of the visual cycle.

Retinal based proteins of microorganisms are currently considered to be universal and the most abundant biological light energy transducers. Before the 2000s, only microbial rhodopsins from halophilic archaea have been known (bacteriorhodopsin (BRh) and halorhodopsin (HRh)). A 2000 metagenomic study resulted in the discovery of a rhodopsin gene in marine Proteobacteria that was, accordingly, named proteorhodopsin (PRh). Since 2000, thousands of microbial rhodopsins have been identified, in all three domains of life (bacteria, archaea and eukaryota) as well as in large viruses. The renaissance of rhodopsins as a research field has culminated in the development of optogenetics, the revolutionary method for controlling cell behavior *in vivo* in which microbial rhodopsins play the key role. Several rhodopsins with unexpected functions have been discovered and characterized recently. Among the members of this family are light-driven proton, anion and cation pumps, light-gated anion and cation channels, and photoreceptors. Also, rhodopsins that function as inward proton pumps have been discovered (see, Fig. 2,3) [29, 30, 291-295].

The opsin genes are classified into two groups: Type I opsin genes are found in archaea, eubacteria, fungi, and algae, and Type II opsins are found in animals. Microbial type I opsins, which comprise more than 1000 members, control proton gradients and maintain membrane potential and ionic homeostasis. This group includes the light-driven ion pumps bacteriorhodopsin (BRh), halorhodopsin (HRh) and proteorhodopsin (ESRh) and light-gated ion channels called channel rhodopsins (ChRh). Other microorganisms use opsin-based photoreceptors, such as sensory

rhodopsin (SRh), to modulate flagellar movements in phototaxis. In marine photic ocean zone, the light-activated ion pumps from proteobacteria called proteorhodopsins, PRhs, have been linked to the survival of bacterioplankton. Type II or animal opsins couple to G-protein coupled receptors (GPCR)-dependent signal transduction pathways that affect transmembrane ion currents.

All unicellular organisms use all-*E*-retinal (3) (**Ret**) bound to opsin in rhodopsin-like photoreceptors to capture energy and/or information from light sources and transform it into light-activated ion channels and pumps. Light absorption induces isomerization of the chromophore from all-*E*-retinal (3) to 13*Z*-retinal. In contrast to type II rhodopsin, the activated 13*Z*-retinal chromophore in type I (microbial rhodopsins) remains covalently bound to its opsin protein partner and thermally reverts rapidly to the all-*E*-retinal state without detaching from the protein. The efficiency of light absorption depends on the extinction coefficient of the complexes ( $\epsilon_{\max}$ , typically between 50 000 and 70 000  $M^{-1}cm^{-1}$ ) and the quantum efficiency ( $\Phi$ , typically between 0.3 and 0.7). The turnover time of the photocycle for most light-driven pumps (HRh and BRh) is 10–20 ms [29, 30, 291-295].

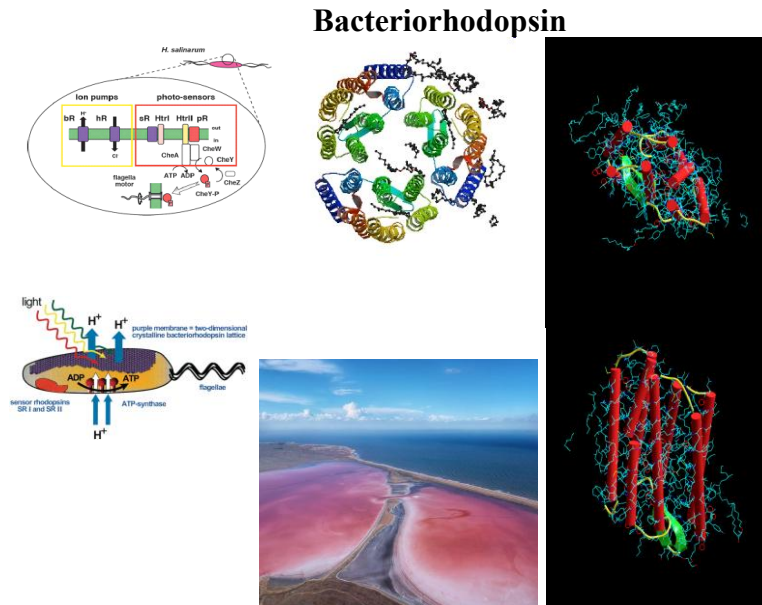


Fig. 4. *Halobacterium salinarum* cell structure (purple membranes and Bacteriorhodopsin)

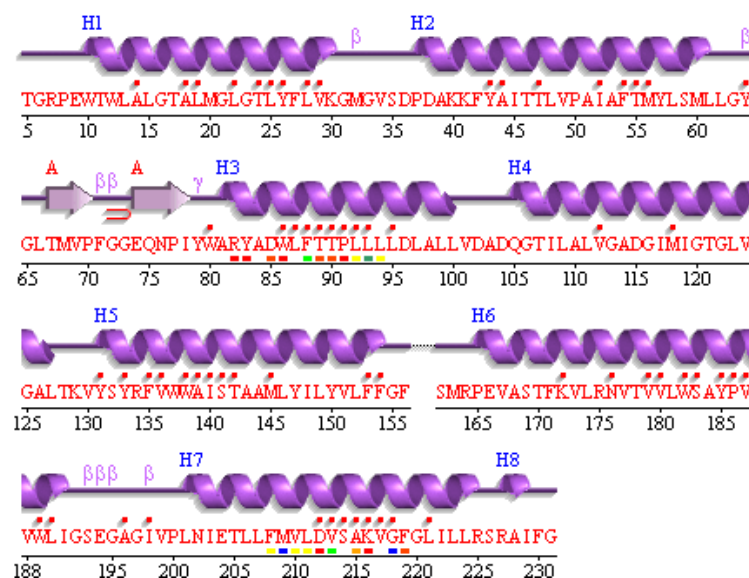
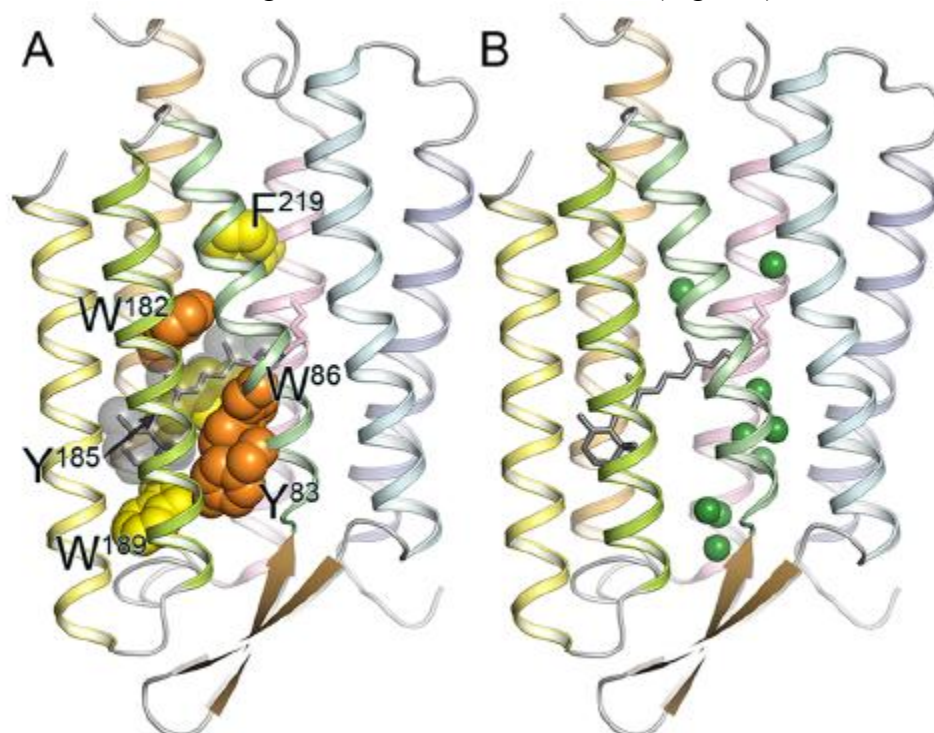


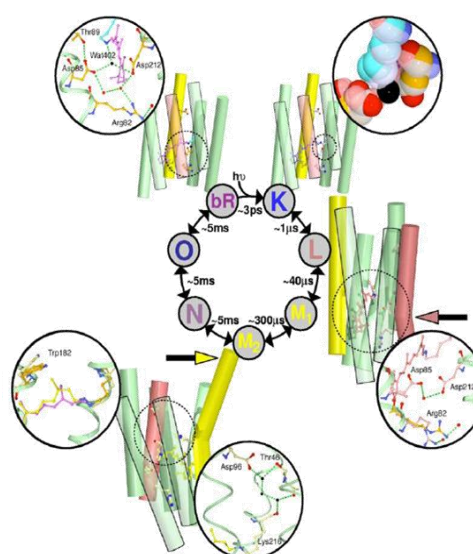
Fig. 5. Bacteriorhodopsin primary amino acid sequence (fragment) and secondary structure (PDB 1m0l).

Bacteriorhodopsin (BRh) from *Halobacterium salinarum*, the first discovered microbial rhodopsin in 1971, [1] is the first membrane protein whose structure was found to be composed of seven helices by electron microscopy, and was also the first membrane protein to have its amino acid sequence determined [2-6]. As the best studied microbial rhodopsin, it serves as a paradigm of a light-driven retinal-binding ion pump and aids in studies of novel rhodopsins.

BRh is the focus of our investigation. This compound is a unique natural photochrome acting as a light-driven proton pump. It is located in special areas of the cells, purple membranes (PM), consisting of BRh trimers embedded in the lipid bilayer. The chromophoric group of this protein is the protonated aldimine of all-*E*- and 13*Z*-isomers of vitamin A aldehyde (retinal). The purple membrane (PM) of *Halobacterium salinarum* is a natural 2D crystal honeycomb lattice of BRh trimers. The BRh protein contains a single polypeptide chain (248 aa) and converts light energy absorbed by the retinal chromophore covalently linked via a Ret-PSB to  $\epsilon$ -amino group of Lys216 in helix 7 into a proton electrochemical gradient across the membrane (Fig. 4-8).



**Fig. 6. (A) Structure of bacteriorhodopsin (BRh), with conserved aromatic residues highlighted (PDB ID: 1QM8). (B) Crystallographically observed internal water molecules of BR (shown as green spheres) [291, 292].** Tyr83, Trp86, and Trp182 are strongly conserved among microbial rhodopsins (orange). Aromatic amino acids are strongly conserved at the position of Tyr185, Trp189, and Phe219 (yellow). In BRh, Trp86, Trp182, Tyr185, and Trp189 constitute the chromophore binding pocket for all-*E*-retinal (gray).

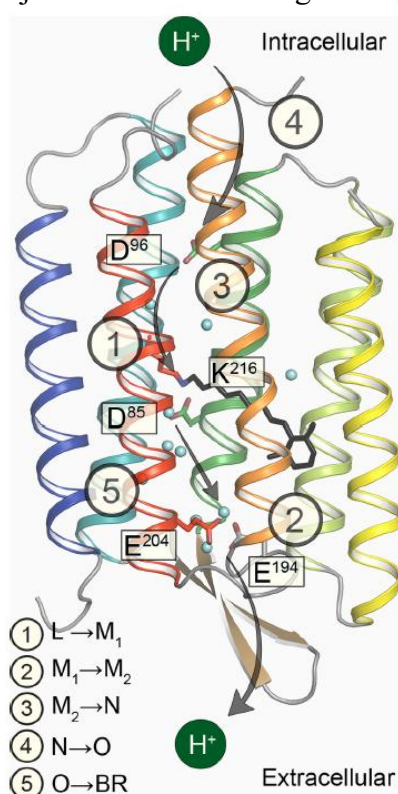


**Fig. 7. Bacteriorhodopsin photocycle [291-294].**

BRh undergoes cyclic photochemical reactions accompanied by the isomerization of the chromophore polyene chain and the deprotonation and reprotonation of the retinal aldimine moiety (Fig. 7, 8). The ground - B-state ( $\lambda_{\max}$  570 nm,  $\epsilon$  63,000 M<sup>-1</sup> cm<sup>-1</sup>) and the M<sub>1,2</sub>-states ( $\lambda_{\max}$  412 nm,

$\epsilon$  45,000 M<sup>-1</sup> cm<sup>-1</sup>,  $\Phi$  0.64) are the key states. Fig. 7 depicts the photocycle of BRh with the species spectroscopically characterized, the wavelength at which each intermediate maximally absorbs light and their lifetimes. Six discrete steps are recognized to account for the isomerizations (from BRh568 to K610 and from N530 to O646), proton transport (from L550 to M<sub>1</sub> 412 and from M<sub>2</sub> 412 to N530), and accessibility changes (from M<sub>1</sub> 412 to M<sub>2</sub> 412 and from O646 to BRh568) of the photocycle. A net transfer of one proton from the cytoplasm to the extracellular side of the membrane is produced under physiological conditions (pH > 7) as a result, and the ground-state configuration containing all-*E*-(Ret-PSB) is recovered. The proton transport sequence comprises transfer of a proton to Asp85, release of a proton from the proton release complex, reprotonation of the Ret-SB by Asp96, uptake of a proton from the cytoplasm to reprotonate Asp96, and the reprotonation of the proton release complex from Asp85, followed by a final proton transfer from Asp85 to Arg82.

The dark-adapted BRh chromophore consists of a mixture of all-*E*-Ret-15-*anti*-PSB and 13*Z*-Ret-15-*syn*-PSB 1:1. The crystal structure of BRh in the dark-adapted state with 13*Z*-Ret-15-*syn*-PSB revealed that the configuration changes due to retinal isomerization affect residues in the vicinity of the Ret-PSB, but most of the aromatic amino acids that surround the chromophore, and the polypeptide backbone of Lys216, undergo small displacements. The photochemistry and photophysics of BRh have been the subject of intense investigations [291-294].



**Fig. 8. Main proton transfer steps in the bacteriorhodopsin photocycle [291-294].**

The proton pathway across the membrane from the cytoplasmic to the extracellular side in BRh is shown in Fig. 8, together with protonatable groups and the order of respective proton transfers. Protonatable groups and bound water molecules important for transport activity are shown as stick representation and blue spheres, respectively (PDB ID: 1C3W). Numbers with arrows represent the sequence of proton transfer reactions, the corresponding transitions between the photointermediates are indicated in the inset. The TM helices are shown in the following colors: A, blue; B, teal; C, green; D, lime green; E, yellow; F, orange; G, red; and the chromophore is depicted as black sticks. ① Proton transfer from the (Ret-PSB) to the primary proton acceptor Asp85; ② proton release to the extracellular medium from the proton-releasing complex; ③ reprotonation of the Ret-SB from the primary proton donor Asp96; ④ reprotonation of Asp96 from the cytoplasmic medium; ⑤ proton transfer from Asp85 to the proton-releasing complex.

The absorption of light by the light-adapted BRh form (which contains the all-*E*-15-*anti*-PSB chromophore) induces an ultrafast photocycle (complete in less than 30 ms), which starts with the isomerization of all-*E*-retinal PSB to the 13*Z*-isomer (with the 15-*anti*-configuration) on the “vibrationally hot” I state followed by a thermal relaxation process involving conformational changes

of the retinal and the protein. Light absorption initiates functions of both microbial and animal rhodopsins, and the wavelength dependence of the absorption efficiency determines the colors of the proteins. The structural features of the protonated Schiff base chromophore and the proton/ion conduction pathway regulate the absorption maxima of the pigments: ChRh,  $\lambda_{\max} \approx 470$  nm; SRhII,  $\lambda_{\max} \approx 487$  nm; BRh,  $\lambda_{\max} \approx 568$  nm; HRhs,  $\lambda_{\max} \approx 580$  nm; SRhI,  $\lambda_{\max} \approx 587$  nm; ESRh,  $\lambda_{\max} \approx 531$  nm.

The length of the  $\pi$ -conjugated polyene chain in the retinal chromophore as well as the protonation of the retinal SB linkage determine the energy gap of the  $\pi$ - $\pi^*$  transition, so that the absorption of most rhodopsins is within the visible region (400–700 nm). While the chromophore molecule is usually the same in all pigments (retinal bound via a (protonated) Schiff base), the absorption maxima differ significantly, implying an active protein control of the energy gap between the ground and excited states of the retinal chromophore.

The mechanism of color tuning has fascinated researchers for a long time, and several factors have been determined to be responsible for it. The protonation state of the chromophore plays a crucial role in color tuning; the unprotonated Ret-SB absorbs in the UV region ( $\lambda_{\max} \sim 360$ – $380$  nm), and this absorption is quite insensitive to the environment in contrast to the Ret-SBH<sup>+</sup> (Ret-PSB), which exhibits a large variation in absorption covering the entire visible light spectrum. Other factors defining the spectral tuning of individual rhodopsins are given by chromophore–protein interactions such as electrostatic interactions with charged and polar amino acids, termed electrostatic tuning and extensively studied, first using retinal analogues, and, later, sitedirected mutagenesis [29, 30, 291-295].

Interactions of retinal with charged, polar, and aromatic amino acids play a role in changing the electronic energy levels, as do hydrogen-bonding interactions and steric contact effects. Strong hydrogen bonds can lead to charge transfer, and steric contacts can lead to a twist of retinal. All these tuning processes in concert shape the absorbance maxima of retinal in microbial and animal rhodopsins. One of the most prominent factors in color tuning is the interaction of retinal with the counterion(s). For microbial rhodopsins, however, the C6–C7 bond is 6-*s-trans*, although the C6–C7 6-*s-cis*-conformer is more stable in solution. As a consequence, an extended conjugation of  $\pi$ -electrons becomes possible from the polyene chain to the  $\beta$ -ionone ring, which presumably contributes to the considerable spectral red-shift observed in microbial rhodopsins. In fact, while absorbance spectra of protonated Schiff bases of all-*E*- and 11*Z*-retinal in MeOH solution are similar ( $\lambda_{\max} \sim 450$  nm), most microbial and animal rhodopsins typically possess  $\lambda_{\max}$  in 520–580 nm and 480–525 nm ranges, respectively, which can in part be explained by the differences in the C6–C7 bond conformation.

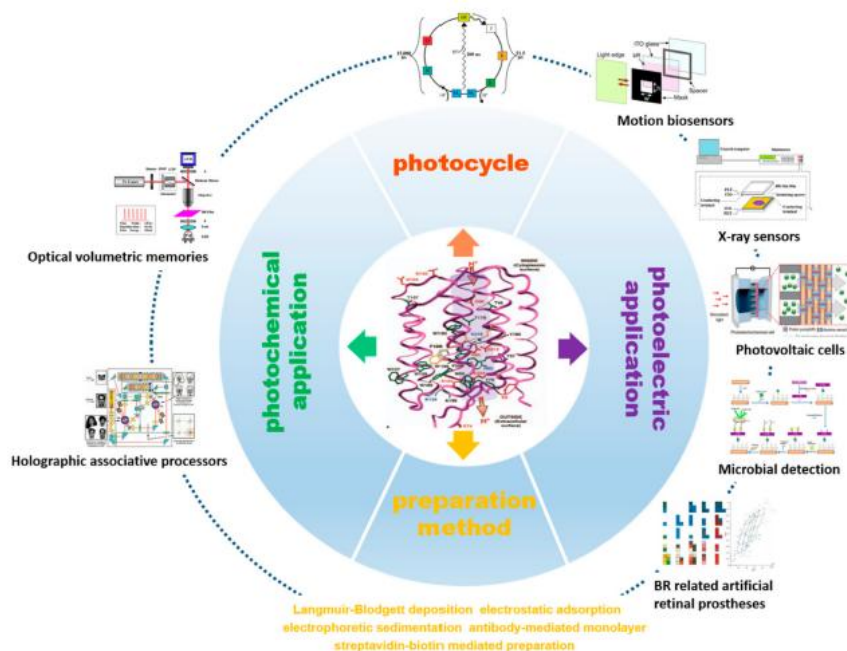
The energy difference between ground ( $S_0$ ) and excited ( $S_1$ ) states of the rhodopsin-like proteins was initially considered to depend upon the planarity of the chromophore (a 6-*s-trans*-conformation and an elongated, almost planar polyene chain for BRh), the distance between the Ret-PSB and the counterion, and the interactions of the chromophore with amino acid residues in the binding pocket (the “two-point” charge model, which suggested the presence of a negative charge close to the hydrophobic ring). The term “opsin shift”, defined as the difference between the protein absorption maximum and that of model retinal *N*-butylamine-PSB hydrochloride in MeOH, was coined to quantify the effect of the apoprotein on the absorption maximum of the retinal chromophore.

Thus, the chromophore molecule modification is a promising approach to the structure-function relationship study in BRh. Analogues of the native chromophore have yielded valuable structural, spectroscopic, and functional insights into the ground-state structure of the chromophore in the complex before X-ray structures became available, and continue to provide information on the nature of the photocycle intermediates. Produced by chemical synthesis, retinal analogues have been obtained with alterations on the polyene side-chain by substitution (demethylations, change of methyl positions), saturation of double bonds, incorporation of substituents (halogens, alkyl groups) and additional rings to lock conformations and/or configurations, and modifications on the trimethylcyclohexenyl ring.

The uniqueness of BRh – a natural photocontrollable photosynthetic system – for nanobiophotonics is defined by its following properties:

- 1) BRh is the most simple and surprisingly stable proton pump;
- 2) availability in high quantities, simplicity of isolation with relatively low cost;

- 3) stability in intensive light, oxygen, wide range of temperatures ( $-196 - 70^{\circ}\text{C}$ ), pH values (0–11), concentrations of salts, water-glycerol media;
- 4) the “primary act” after photon absorption ( $\text{B} \rightarrow \text{J}$ ) is an extremely fast process (0.5 ps);
- 5) high quantum yield ( $\Phi$  0.64);
- 6) possibility of making “dry” films as well as integrating BRh into polymer matrices of various compositions;
- 7) application possibilities both in optical and electronic devices, using either varying optical or electrical component of the response.



**Fig. 9. An overview of BRh-based bioelectronic devices showing the photocycle, preparation method, and photochemical and photoelectric applications**

Fig. 9 shows the roadmap of BRh-based bioelectronics applications since the discovery of BRh protein which reveals the development of BRh application [296-299].

In 1972, the “Rhodopsin program” was created in the USSR under the leadership of Academician Yu.A. Ovchinnikov. Its main goals were to develop methods for determining the structure of light-sensitive RBPs: bacteriorhodopsin (BRh) and the visual pigment rhodopsin (Rh), and to comprehensively study their functions. The first participants in the program were teams from four laboratories: the laboratory of Academician Yu.A. Ovchinnikov himself at the Institute of Bioorganic Chemistry of the USSR Academy of Sciences, Academician V.P. Skulachev at the A.N. Belozersky Institute of Physicochemical Biology of the M.V. Lomonosov Moscow State University, L.P. Kayushin at the Institute of Biophysics of the USSR Academy of Sciences in Pushchino, and Academician M.A. Ostrovsky at the Institute of Chemical Physics of the USSR Academy of Sciences.

The main goals and objectives of the “Rhodopsin project”

1. Selection of target proteins from available RBPs: MRhs or Rh visual pigments;
2. Development and research of methods for culturing/isolating RBPs from producer biomass or from animal models; obtaining mutants and developing methods for creating recombinant RBP producers;
3. Determination of RBP structural parameters: amino acid composition, primary and tertiary polypeptide sequences, the binding site of the retinal molecule to the polypeptide chain, the isomeric composition of the chromophore group, production of 3D crystal preparations suitable for X-ray diffraction analysis, and obtaining and decoding high-resolution 3D structures of RBPs using X-ray diffraction and other methods;
4. Determination of the functional properties and characteristics of target proteins: study of the photochemistry and electrogenesis of MRhs and their analogs; study of the biophysical and physiological aspects of visual pigment function; signal transduction pathways from visual rhodopsin to the brain, etc.

5. Development of methods for obtaining RBP models: a) mutants with single- and multi-point amino acid substitutions along the MRhs polypeptide chain; b) MRhs derivatives modified along the polypeptide chain with various types of reporter groups; c) model MRhs analogs with a modified chromophore group; d) aldimines of retinal analogs with various amino components: amino acids and/or polypeptides;

6. Search for practical applications of MRhs in various fields.

An excellent review of the results of the “Rhodopsin project” was recently published for its 50th anniversary [305].

Our research team participated in the implementation of the “Rhodopsin project” in close collaboration with a number of other scientific organizations and universities (M.M. Shemyakin and Yu.A. Ovchinnikov Institute of Bioorganic Chemistry of the RAS; A.N. Belozersky Institute of Physicochemical Biology of the M.V. Lomonosov Moscow State University; Photochemistry Center of the RAS, M.V. Lomonosov Moscow Institute of Fine Chemical Technologies (MITKHT); Institute of Biophysics of the RAS, etc.).

The main areas of our group's research included: 1) the development and practical implementation of an integrated approach to the study of structure-function relationships in RBP through chemical modification of functionally significant elements of the retinoid molecule structure.

The overall objective was to provide other groups participating in the project with sets of reference compounds—individual retinoid isomers, their derivatives and analogs, as well as MR analogs—necessary for structural studies of RBPs.

1. Developing synthetic routes for retinal isomers and analogs and methods for their isolation, producing sample compounds;

2. Studying the interaction of MRh family apoproteins with the obtained retinal analogs;

3. Synthesizing model compounds—aldimines of retinal analogs.

To implement this, it was necessary to solve the following set of problems:

1. Searching for and creating new synthetic approaches to various modifications of the retinoid molecule and methods for their separation, producing samples in quantities sufficient to support the entire cycle of subsequent experiments;

2. Studying the physicochemical properties and spectral characteristics of the synthesized compounds;

3. Studying the interaction of MR family apoproteins with the obtained retinal analogs;

4. Synthesis of model compounds—aldimine retinal analogs;

5. Studying the effects of various modifications of the chromophore groups of bacteriorhodopsin (BRh) from the purple membranes of *H. salinarum* and proteorhodopsin (ESRh) from *Exiguobacterium sibiricum* on their photochemical properties and proton transport, and modeling the spatial constraints of the chromophore binding site in these proteins;

6. Creation of the "Properties of artificial bacteriorhodopsin analogs" database, version 3.0.

### **Basic directions in the retinal molecule modification strategy**

In the USSR and later in Russia, the chemistry and biochemistry of retinoids were limited to a few scientific schools and laboratories at several research institutes and universities. The foundation for this research area was laid by Professor N.A. Preobrazhensky's work in the 1950s and 1960s at the M.V. Lomonosov Moscow Institute of Fine Chemical Technologies (MITKHT). This work was closely linked to the vitamin industry, implemented at the Belgorod Vitamin Plant, and aimed at developing and improving the domestic vitamin industry.

The development of Professor N.A. Preobrazhensky's scientific legacy in the synthesis of vitamin A and its derivatives led to the formation of two scientific schools: 1) at the Department of Biotechnology at the MITKHT and 2) at the Laboratory of Polyene Compounds at the Scientific Production Association "Vitamins" (Professor G.I. Samokhvalov). After 1965, this topic was further developed at the Department of Biotechnology of the MITKHT in the works of the co-workers of prof. N.A. Preobrazhensky: Academician of the RAS V.I. Shvets, professors E.N. Zvonkova, A.A. Khodonov, associated professors B.I. Mitzner, E.N. Karnaukhova and others (now from the Department of Biotechnology and Industrial Pharmacy of the Russian Technical University - MIREA). Among other achievements in this area, it is necessary to note a series of works devoted to

the synthesis of retinoids and their analogues, carried out under the supervision of prof. S.M. Makin at the Department of Organic Chemistry of the MITKHT in the 1970s - 1996s.

After the mid-1990s, it was successfully continued at Lab. 0501 of the N.M. Emanuel Institute of Biochemical Physics of the RAS (under the direction of Corresponding Member of the RAS, Professor S.D. Varfolomeev and Professor A.A. Khodonov). This laboratory conducted comprehensive, systematic research aimed at developing a synthetic methodology for obtaining retinoids of various structures, as well as analyzing the effects of modifications of individual structural elements of the retinoid molecule on the functioning of various retinoid-protein complexes. Below, we present our own results obtained by the authors during a series of structural and functional studies of BRh and other MRs within the "Rhodopsin" program.

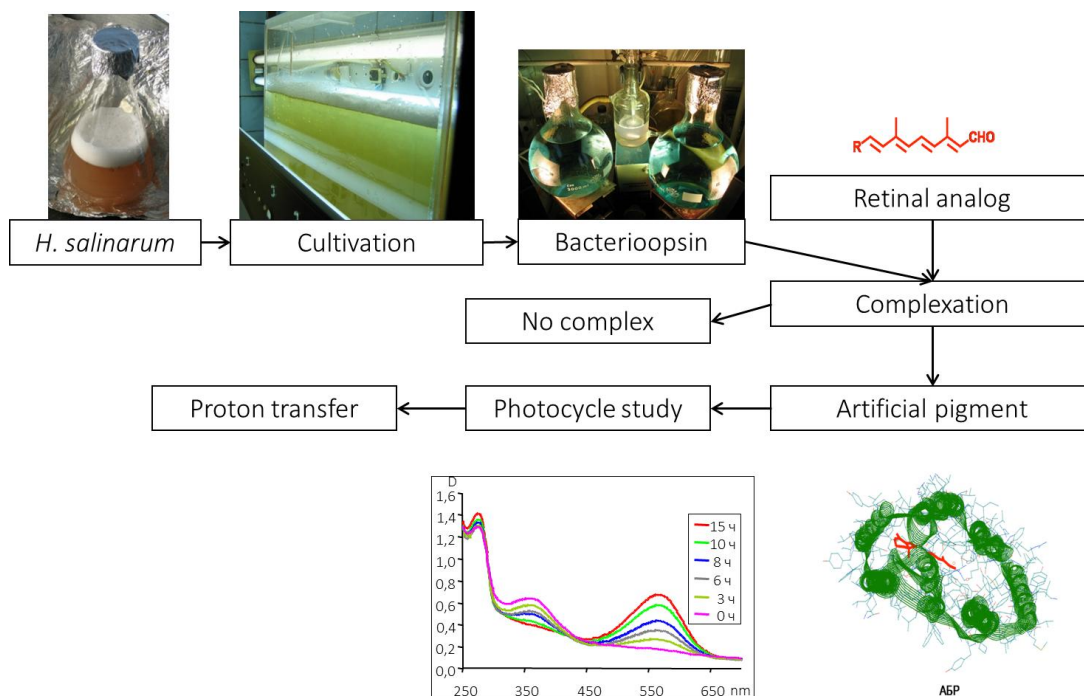
During the course of the research cycle implemented within the framework of the "Rhodopsin program", we developed new methods for synthesizing retinoids with virtually any given structure, including those containing various types of reporter groups isotopic, fluorescent, spin, affinity, photoaffinity and electron-electron-dense labels, as well as fluorine atoms) [297-304].

BRh is one of the first successful examples of biological photochromic material designed by the nature. One promising area of research on the retinal protein structure function relationship involves the replacement of the natural chromophore by analogs and the comprehensive study of the hybrid products. The photochemical properties of analogs BRh (ABR) can be controlled using the following approaches: 1) the substitution of one or more amino acid residues in certain positions of the BRh molecule by genetic engineering methods (using BRh mutant strains with slower photocycles); 2) the use of natural BRh incorporated into a polymer matrix, oriented Langmuir-Blodgett films, or oriented layers immobilized on a solid support; 3) the use of environmental conditions (low temperature, electric fields, humidity, pH level); 4) a combination of the above-mentioned approaches. General directions of the BRh chromophore structure modification are depicted in Figs. 10, 11. The comparative analysis of our and other researchers' data has shown, that by diversification of the chromophore structure, it is possible directly to change  $\lambda_{\max}$  in the spectra of the BRh analogs in the rather wide interval (from 412 to 830 nm), though not all of these pigments are capable for cyclic photochemical reactions.

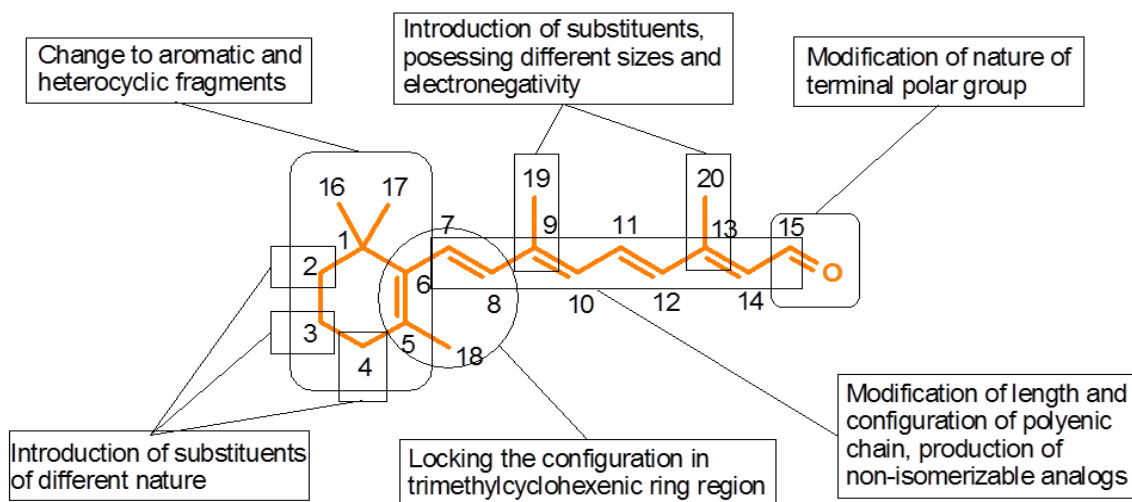
We have previously developed a common procedure for structure function studies of retinal proteins. The preparation of BRh analogs (ABR) and the testing scheme are shown in the Fig. 9. Several approaches to the preparation of ABR have been developed earlier based on the addition of polyenals to:

- 1) growing cells of retinal-deficient *H. salinarum* strains (for example, JW5);
- 2) to "white" membranes or membrane vesicles obtained from the retinal-deficient strains;
- 3) to so-called apomembranes containing bacterioopsin (BO) generated from purple membranes by hydroxylaminolysis at pH 7.0 and 0-5°C under intense illumination. We used the third approach in our investigations with an additional procedure for the removal of retinal oxime based on the treatment of BO with a saturated solution of  $\beta$ -cyclodextrin. Then a comprehensive study of the artificial pigments: the kinetic peculiarities of the formation of BRh analogs, the spectral properties ( $\lambda_{\max}$ , the presence and type of the photochemical cycle, quantum yield, the adaptation to the light and darkness) and the efficiency of the proton transport were undertaken.

The synthesized retinal analogs were tested in recombination with bacterioopsin (BO), from apomembranes *H. salinarum* (strain ET1001). Apomembranes obtained from purple membranes by hydroxylaminolysis at pH 7.0 and 0 - 5°C and intensive illumination. Resynthesis of pigments conducted by addition of a methanol solution of analog to a suspension apomembranes in a buffer (protein concentration - 2 mg/ml, 21°C, pH 6.0, 5 mM MES). It was found, that the formation of pigments takes place from several min till 1 month period. It should be noted that position of the ABR  $\lambda_{\max}$  located from 412 to 830 nm.



**Fig. 10. Technology of the Bacteriorhodopsin analogs production.**



**Fig. 11. Basic directions in the retinal molecule modification strategy**

**All retinal molecule modification variants were divided in next charts:**

- A. Natural chromophore — retinal and its isomers
- B. Terminal polar group modification
- C. Polyenic chain modification
- D. Alteration of the bond types and its disposition in the chromophore polyenic chain
- E. Alteration of the polyenic chain length and bond disposition and terminal group types
- F. Alteration or locking of the bond configuration. Non-isomerizable analogs
- G. Alteration of the trimethylcyclohexenic ring. Ring modification
- H. Alteration of the trimethylcyclohexenic ring. Replacement ring to aromatic or heterocyclic fragments
- I. Alteration of the trimethylcyclohexenic ring. Acyclic analogs
- J. Miscellaneous modifications
- K. Labelled BRh derivatives (radioactive, photo-affinic, fluorophoric, heavy-atom, paramagnetic (SL), ionophoric and photochromic probes)

This year will be 55-year anniversary from discovery of the bacteriorhodopsin by D. Oesterhelt and W. Stoekenius [1].

Below we are presenting the next generation of database “Properties of artificial bacteriorhodopsin analogs. Version 3, 2026. From 1975 to 2025”, which combined information from our and literature data sources with duration period 1975 - 2025. The comparative analysis of our database, including the information on spectral characteristics and proton transport efficiency of the interaction products about 447 polyenic compounds with BO has shown, that by diversifying the chromophore nature, it is possible to directly change  $\lambda_{\max}$  in ABR spectra in a rather wide interval (from 412 to 830 nm), though not all these pigments are capable to cyclic photochemical reactions.

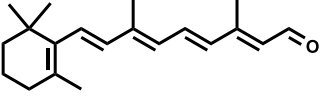
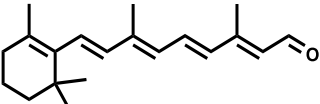
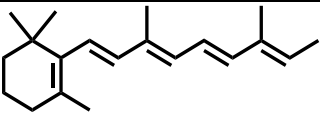
In the frames of defined type modification relationship between  $\lambda_{\max}$  position in dependence of chromophore nature could be described by linear regression equations in axes (Y) -  $\lambda_{\max}$ SB or (SBH<sup>+</sup>, P<sup>LA</sup>) / (X) -  $\lambda_{\max}$ (CHO). These relationships could be used for the prognosis of the spectral properties of ABR from new retinal derivatives and BO [297-304].

This work was partly supported by RFBR (projects № 09-03-00565, 16-04-01254, 20-03-00139).

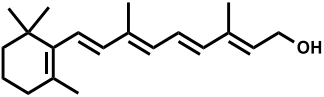
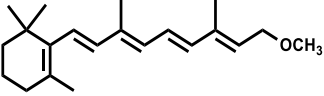
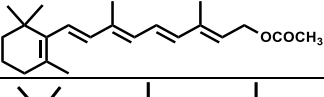
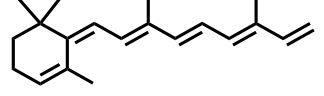
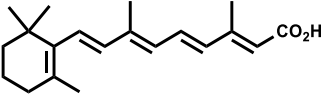
For contacts:

**E-mail:** [khodonov@gmail.com](mailto:khodonov@gmail.com), [nbelikov86@gmail.com](mailto:nbelikov86@gmail.com)

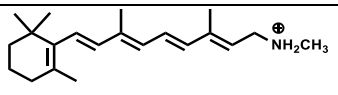
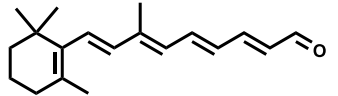
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh cm <sup>-1</sup>	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
<b>A. Natural chromophore — retinal and its isomers</b>																			
1.		all-E-	381	360	440		558		568	+	412	100	50/50	4810					<a href="#">132</a>
		all-E-	380	360	437				568	+	412	100	100/0	5120					<a href="#">17</a>
		all-E-	380				400, 430/ 460												
		all-E-			440				568				<2 13Z-						<a href="#">Biochem</a>
		13Z-	375				548	555	568			0	34/66						<a href="#">17(25)</a> , <a href="#">5353-</a> <a href="#">5359</a> <a href="#">Eur. J.</a>
		11Z-	254, 290sh 377			400							0/100						<a href="#">Biochem</a>
		9Z-				388 390/ 470													<a href="#">1977</a> , <a href="#">76, 499-</a> <a href="#">511</a>
		9Z,13Z-			465														<a href="#">JACS</a> , <a href="#">1996</a> , <a href="#">118(45)</a> , <a href="#">11299-</a> <a href="#">11300</a>
	all-E-					570 605 565											in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">BiophysJ</a> <a href="#">1989</a> <a href="#">56(6)</a> , <a href="#">1259-</a> <a href="#">1265</a>	
	 6-s-trans conformer	all-E-	381				568						3900					<a href="#">JACS</a> , <a href="#">1986</a> , <a href="#">108(11)</a> <a href="#">3104-</a> <a href="#">3105</a>	
<b>B. Terminal polar group modification</b>																			
2.		all-E-				332	NO											str. R <sub>1</sub> M <sub>1</sub>	<a href="#">Biochem</a> <a href="#">1978</a> , <a href="#">17(25)</a> , <a href="#">5353-</a> <a href="#">5359</a>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					NO									str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">Biochem Soc. Trans. 1976, 4(4), 556-559</a>		
3.		all-E- 13Z- 11Z- 9Z- all-E-	325			344sh 357, 376	NO									str. R <sub>1</sub> M <sub>1</sub>	<a href="#">Biochem 1978, 17(25), 5353-5359</a>		
4.		all-E-				336, 357sh 376sh	NO									str. R <sub>1</sub> M <sub>1</sub>	<a href="#">Biochem 1978, 17(25), 5353-5359</a>		
5.		all-E-					NO									str. R <sub>1</sub> M <sub>1</sub>	<a href="#">2</a>		
6.		all-E-					NO									str. R <sub>1</sub> M <sub>1</sub>	<a href="#">Biochem 1978, 17(25), 5353-5359</a>		
7.		all-E-					NO  NO									str. R <sub>1</sub> M <sub>1</sub>  str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">2</a>  <a href="#">Biochem Soc. Trans. 1976,</a>		

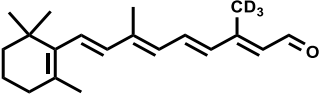
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
8.		all-E-					NO	NO										4(4), 556-559 Biochem 1978, 17(25), 5353-5359	
<b>C. Polyenic chain modification</b>																			
9.		all-E-	377	362	439		565		565	+		+		5080				str.353P, pH 6.5, 20°C $\tau_{\text{rec}}$ 13Z 0.5h $\tau_{\text{rec}}$ all-E- 2 days $\tau_{\text{Mdecay}}$ decelerated There 2 long-waved intermediates 13Z-(ABR) $\tau_{\text{form}(1)}$ <200 ns; $\tau_{\text{form}(2)}$ ~ms; Photoelectrical responses are smaller in amplitudes and drastically differ in form and kinetics from natural BRh cycle. No L-D adaptation	Bioorgan Khim. 1988, 14(3), 434-436 Biophysic (Rus), 1989, 34(4), 623-626 Bioorgan Khim. 1989, 15(11), 1484-1497 Archiv. Biochem. Biophys. 1990, 279(2), 225-231 Biolog. Membr. 1998, 12(1), 121-123. Tetrahedron L. 1980, 21(4), 347-350 Biochem 1988, 27(9), 3497-
		all-E-	380 <sup>b</sup>				565		565			1-3	21/69 15/85 15/85					White membranes, str. JW5, 21°C. "M"-like intermediate has two species in 1.5 : 1 ratio. In cycle all-E "M" <sup>420</sup> ABR $\tau_{1/2M\text{form}}$ 25/400 $\mu\text{s}$ , $\tau_{1/2M\text{decay}}$ 20/1700 ms, In cycle 13Z-(ABR	
		13Z-					565						8/92						
		11Z-					565						10/80/10 all-E /13Z/						

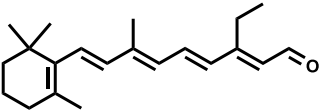
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh cm <sup>-1</sup>	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		9Z- 7Z-					NO 495				11Z					85%) I <sup>610</sup> $\tau_{form}$ <4 $\mu$ s, $\tau_{decay}$ 250ms Photophosphorilation rate 1.1% from control BRh	<a href="#">3502</a> <a href="#">Biochem</a> <a href="#">1983.</a> <a href="#">22(11).</a> <a href="#">2637-</a> <a href="#">2644</a>		
		all-E-	366°						+	+	16					White membranes, str. JW5, (ABR)- <sup>&lt;5ns</sup> >K <sub>0.4s</sub> >(ABR)	<a href="#">Biochem</a> <a href="#">1987.</a> <a href="#">26(3).</a> <a href="#">751-758</a>		
		all-E-	365°			430	560									str. R <sub>1</sub> S <sub>9</sub> , 22°C. all-E-430 nm species ABR stable in dark	<a href="#">Recl.</a> <a href="#">1983.</a> <a href="#">102(1).</a> <a href="#">42- 46</a> <a href="#">Recl.</a> <a href="#">198r3.</a> <a href="#">102(1).</a> <a href="#">46 -51</a>		
		13Z-				430	560				0	0/100							
		11Z-				430	560				0								
		9Z- 7Z-				NO NO	NO NO												
		all-E-					554 595 595									in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys.</a> <a href="#">J., 1989.</a> <a href="#">56.</a> <a href="#">1259-</a> <a href="#">1265</a>		
		all-E-						565	+							Photochemistry of 13- desmethyl ABR Resonance Raman spectra of ABR	<a href="#">J. Phys.</a> <a href="#">Chem. B</a> <a href="#">2005.</a> <a href="#">109(33).</a> <a href="#">16142-</a> <a href="#">16152.</a> <a href="#">J. Phys.</a> <a href="#">Chem.</a> <a href="#">1990.</a> <a href="#">94(12).</a> <a href="#">4920-</a> <a href="#">4926</a>		
		all-E-						569 567	+	410	<20 WT	15/85		stable		native WT  transform WT	<a href="#">The</a> <a href="#">Biology</a> <a href="#">ChemInt</a>		

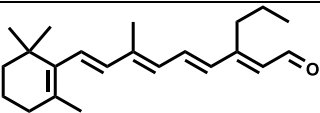
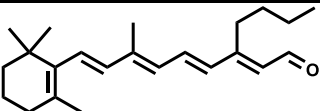
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
							566			0 R82A							R82A str. IV-8 pK <sub>a</sub> R82A 8.1 $\tau_{\text{Mdecay}}$ 3 s "O" 600nm, arises from the 13-cis cycle and is long lived.  Raman spectra Schiff base (-C=NH-) stretching frequency. 1642 $\text{cm}^{-1}$  ABR quantum-chem calculations  str. S9 ABR cycle was tested by picosecond transient spectroscopy (PTA). "J" "K"  Holographic properties of ABR film in gelatin matrix were investigated.	<a href="#">urface</a> <a href="#">1999 ch</a> <a href="#">15 431-</a> <a href="#">444</a>  <a href="#">Photoche</a> <a href="#">mPhotob</a> <a href="#">iol 1985</a> <a href="#">41(5)</a> <a href="#">563-567</a>  <a href="#">Biophys</a> <a href="#">1985</a> <a href="#">47(3)</a> <a href="#">349-355</a>  <a href="#">Chem.</a> <a href="#">Phys.</a> <a href="#">Lett.</a> <a href="#">1992.</a> <a href="#">190(3-</a> <a href="#">4), 298-</a> <a href="#">304.</a>  <a href="#">Optical</a> <a href="#">Rev.</a> <a href="#">2001,</a> <a href="#">8(5),</a> <a href="#">368-372.</a>  <a href="#">Biochem</a> <a href="#">istry,</a> <a href="#">1994, V,</a> <a href="#">33 No 41,</a> <a href="#">P. 12439</a> <a href="#">- 12450.</a>
		all-E-					560			410								
		13Z-					565				15/85							
10.		all-E-	381	360	440		565		565	+		+++	5030 5030				str.353P, pH 6.5 $\tau_{\text{rec}}$ 0.5 h, 20°C	<a href="#">Bioorgan</a> <a href="#">Khim.</a> <a href="#">1988,</a> <a href="#">14(3),</a> <a href="#">434-436</a>

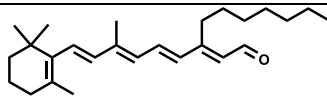
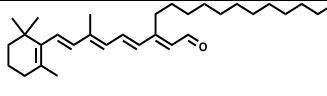
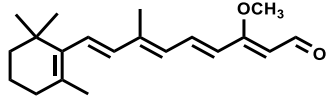
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Bioorgan. Khim. 1989. 15(11), 1484-1497.</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2), 225-231</a>  <a href="#">Bioorgan. Chem. 1991. 19(1), 18-28</a>	
11.		all-E-	383	365	446		567			+	+	++		4790			str.353P, pH 6.5 $\tau_{\text{rec}}$ 0.5 h 20°C ABR cycle similar to BRh (M, O). L-D adaptation decelerated	<a href="#">Bioorgan. Khim. 1988. 14(3), 434-436</a> <a href="#">Bioorgan. Khim. 1989. 15(11), 1484-1497.</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2), 225-231</a>	
		all-E-	379 <sup>b</sup>				559 $\epsilon$ 60000	556		+	420	70	67/33 67/33				White membranes, str. JW5, 21°C. ABR cycle similar to BRh (M, O). (ABR) <sup>559</sup> . ->K->L->M->(ABR) $\tau_{\text{Kform}} < 5 \text{ ns}$ , $\tau_{\text{Kdecay}} 0.55 \mu\text{s}$ ; $\tau_{1/2 \text{ Mform}} 20 \mu\text{s}$ , $\tau_{1/2 \text{ Mdecay}} 1.2 \text{ ms}$ ,	<a href="#">Biochem. 1987. 26(3), 751-758</a> <a href="#">Biochem. 1988. 27(9),</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					558 WT 550 T90A			+	+	26			$\tau_{1/2\text{destr}}$ 4.1 h $\tau_{1/2\text{destr}}$ 3.7 h		CD ABR 567 (+)/ 625 (-) WT T90A and T90A-13E- CD RET showed similar M intermediate ABR 559 (+)/ 605 (-) T90 A  ABR quantum-chem calculations	<a href="#">3497-3502</a> <a href="#">Eur. J. Biochem</a> <a href="#">1988</a> <a href="#">176</a> <a href="#">641-648</a>  <a href="#">PLoS One</a> <a href="#">2012</a> <a href="#">7(8)</a> <a href="#">e42447</a>  <a href="#">BiophysJ</a> <a href="#">1985</a> <a href="#">47(3)</a> <a href="#">349-355</a>	
12.		all-E-	380 <sup>b</sup>				545		537	+	+	40					White membranes, str. JW5, 21°C. ABR cycle similar to BRh. (ABR) <sup>559</sup> →K→>L→>M→>(ABR) $\tau_{1/2 \text{ Mdecay}}$ 5 ms	<a href="#">Biochem</a> <a href="#">1988</a> <a href="#">27(9)</a> <a href="#">3497-3502</a>	
13.		all-E-	382	358	439		540			+		+		4260			str.353P, pH 6.5 $\tau_{\text{rec}}$ 3h 20°C	<a href="#">Bioorgan</a> <a href="#">Khim.</a> <a href="#">1988</a> <a href="#">14(3)</a> <a href="#">434-436</a> <a href="#">Bioorgan</a> <a href="#">Khim.</a> <a href="#">1989</a> <a href="#">15(1)</a> <a href="#">1484</a> <a href="#">1497</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Archiv. Biochem. Biophys. 1990, 279(2), 225-231</a>	
14.		all-E- 13Z-	380 376	357 363	439 444		531 527			+		+		3950 3550				str. 353P, 20°C pH 6.5, $\tau_{\text{rec}}$ 3 days <a href="#">29</a>	
15.		all-E- 13Z-	381 375	361 364	443 442		543 547			+		+		4160 4340				str. 353P, 20°C pH 6.5, $\tau_{\text{rec}}$ 6 days <a href="#">29</a>	
16.		13Z-	360 <sup>b</sup>	346 <sup>b</sup>	360 <sup>b</sup>		460, 515 $\epsilon$ 40000		460, 515	+		2	30/70 9Z,13Z- /13Z-	6040 8360				White membranes, str. JW5, 21°C. $\tau_{\text{rec}}$ 20h, ABR cycle K <sup>570</sup> -decayed in biphasic mode. (ABR): $\tau_{1\text{decay}}$ 0.5 $\mu\text{s}$ (67%-13Z-) and $\tau_{2\text{decay}}$ 5 $\mu\text{s}$ (33%-9Z,13Z). $\tau_{\text{rec}}$ ABR 40 h is slower by a factor of 40 compared to 13-ethyl BRh. ABR 515nm photoreversion of its blue-shifted form - 460 nm.  in water. pH 7.0 pH 2.5 pH 0.5 changed to 450 nm after 60 s.  ABR quantum-chem calculations	

[Archiv. Biochem. Biophys. 1990, 279\(2\), 225-231](#)

[29](#)

[29](#)

[Biochem. 1987, 26\(3\), 751-758](#)  
[Tetrahedron Lett. 1982, 23\(36\), 3673-3676](#)  
[Liebigs Ann. Chem. 1988, \(7\), 705-715](#)  
[Eur. J. Biochem. 1988, 176, 641-648](#)

[Biophys. J., 1989, 56, 1259-1265](#)

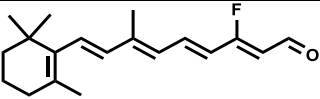
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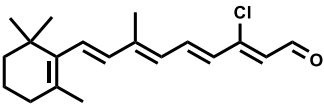
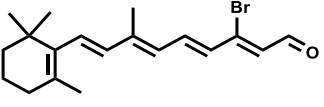
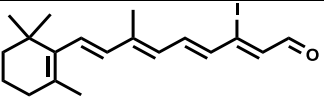
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-		367	467		625		+	430			5400			are substantially modified: 13-CF <sub>3</sub> ABR, pKa (SB ABR) 8.2. Data of ABR titrations.	<a href="#">Biochem 1995 34(37):12066-12074</a>	
		all-E					625 JW5 625 L-07									10 mM Hepes buffer, pH 6.5 at 25°C for 1 h. pKa (SBH <sup>+</sup> ) 1.8, pKa (SB ABR) 8.2	<a href="#">PNAS 1986, 83:3262-3266</a>	
		13Z-					618									13-CF <sub>3</sub> -retinal ABR to growing JW5 and D96N (chromophore deficient strain L-07) cells, has low pK shifts to 9.1/8.1 Flash photolysis data.	<a href="#">Biochem 1998 37(22):8227-8232</a>	
																ABR quantum-chem calculations	<a href="#">BiophysJ 1985 47(3):349-355</a>	
																Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH <sub>4</sub>	<a href="#">JBiolChem 2000 275(28):21010-21016</a>	
																str. R <sub>1</sub> M <sub>1</sub> pH 7.0, 25°C 10 mM HEPES buffer X-ray photoelectron spectroscopy.	<a href="#">JPhysSoc Japan 1984 53(10)</a>	

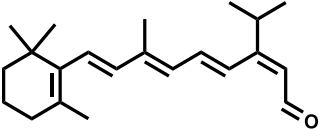
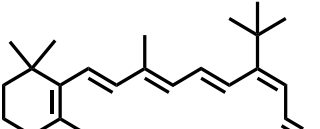
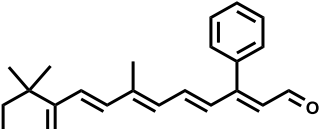
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E					625											<a href="#">3321-3323</a> <a href="#">FEBSL 1989 250(2) 179-182</a>
		all-E					624						5390					<a href="#">Mol. Cryst. Liq. Cryst. 2000, 345, 317-322</a>
		all-E					625		+	420								10 mM PIPES buffer, pH 7, pK ~ 8.4, dehydration of the sample leads to appearance of a fraction of an M-like ABR form with deprotonated SB.
		all-E																<a href="#">Biochem. 2005, V. 44 No 23, P. 8479-8485.</a>
19.		all-E-	382	362	446		548						4170				str. S9	<a href="#">J. Org. Chem. 1997, 62(2), 310-319</a>
		all-E-					566											<a href="#">Seibutsu Butsuri 2001, 41(suppl), S62</a>

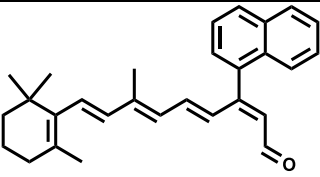
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
20.		all-E-					597				90/10					$\tau_{\text{decay}}$ 10.3 ms	<a href="#">Seibutsu Butsuri 2001.41(suppl.) S62</a>	
21.		all-E-	388 $\epsilon$ 23800		465		595		595	+			4700 4700		stable $\tau_{\text{rep}} > 24\text{h}$ dark, 25°C, pH 7.0	CD ABR 560 (+) 632 (-)	$\tau_{\text{rec}}$ 20 h, 25°C, pH 7.0. 30min D $\rightleftharpoons$ L 30 h	<a href="#">JACS. 1980. 102(27). 7947-7949 MIE. V. 88 Part I. 1982. 178-180.</a>
		all-E-							596	+		+++ JW 2N			stable		str. ET1001, JW 2N pH 7.0, 22°C, BO washed by BSA ABR cycle compared to BRh, but various rate constants are altered. X-ray data.	<a href="#">Photochem Photobiol 91 54(6) 873-879</a>
		all-E-					598				+		97/3				$\tau_{\text{decay}}$ 6.1 ms	<a href="#">Seibutsu Butsuri 2001.41(suppl.) S62</a>
22.		all-E-			470°	440/ 500		598 $\epsilon$ 58000	598	+	100 pH 6.8 60 pH 6.5	97/3 97/3	4600			CD ABR 555 (+) 635 (-)	ABR photointermediates $\tau_{\text{form}}$ $\tau_{\text{decay}}$ slightly faster than the native BRh "O" 690nm X-ray data	<a href="#">Biophys. J. 2002. 83(6). 3460-3469</a>
		9Z-					NO											
		all-E-					598						97/3				$\tau_{\text{decay}}$ 2.7 ms	<a href="#">Seibutsu Butsuri 2001.41(suppl.) S62</a>

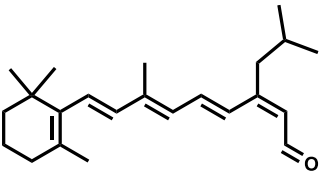
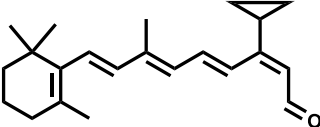
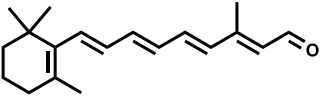
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		suppl.), S62	
23.		13Z-	373	347	427		545		550	+	+			5070 5240				str. 353P, pH 6.5 $\tau_{\text{rec}}$ 6h, 20°C ABR cycle compared to BRh. L-D adaptation decelerated.	<a href="#">Bioorgan. Khim. 1988. 14(3). 434-436</a> <a href="#">Bioorgan. Khim. 1989. 15(11). 1484-1497</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2). 225-231</a>
24.		13Z-	325, 360				500			+								str. 353P, pH 6.5 $\tau_{\text{rec}}$ 48h 40°C At 20°C ABR doesn't formed during 10 days. BO washed by cyclodextrine solution. ABR cycle efficiency drastically degraded.	<a href="#">Bioorgan. Khim. 1988. 14(3). 434-436</a> <a href="#">Bioorgan. Khim. 1989. 15(11). 1484-1497</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2). 225-231</a>
25.		all-E-	382	370	455		572		564	+	+			4500 4250				str. 353P, pH 6.5 $\tau_{\text{rec}}$ 3h 20°C No long-wave intermediates were determined in the time scales $\tau_{\text{form}} > 10\mu\text{s}$ $\tau_{\text{Mdecay}} \sim \text{s}$ .	<a href="#">Bioorgan. Khim. 1988. 14(3). 434-436</a> <a href="#">Bioorgan. Khim. 1989.</a>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					572			+	415		4500					<a href="#">15(11)</a> , <a href="#">1484-1497</a> , <a href="#">Archiv. Biochem. Biophys.</a> 1990, <a href="#">279(2)</a> , <a href="#">225-231</a> <a href="#">Sensors Actuator s. B.</a> 1997, <a href="#">39(1-3)</a> , <a href="#">218-221</a> , <a href="#">Mol. Cryst. Liq. Cryst.</a> 2000, <a href="#">345</a> , <a href="#">317-322</a>	
26.		13Z-	392	372	461		587		581	+			4660 4480				str. 353P, pH 6.5 $\tau_{\text{rec}}$ 5 days 20°C BO washed by cyclodextrine solution. ABR cycle efficiency drastically degraded	<a href="#">Bioorgan. Khim.</a> 1988, <a href="#">14(3)</a> , <a href="#">434-436</a> <a href="#">Bioorgan. Khim.</a> 1989, <a href="#">15(11)</a> , <a href="#">1484-1497</a> , <a href="#">Archiv. Biochem. Biophys.</a> 1990, <a href="#">279(2)</a> , <a href="#">225-231</a>	

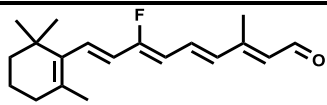
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
27.		13Z-	379	355	435		500						2990				str. 353P, pH 6.5 $\tau_{rec}$ 3h 20°C	<a href="#">Bioorgan. Khim. 1988. 14(3). 434-436</a> <a href="#">Bioorgan. Khim. 1989. 15(11). 1484-1497</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2). 225-231</a>	
28.		13Z-	382	346	426		555			+			5460				str. 353P, pH 6.5 $\tau_{rec}$ 3 h 20°C	<a href="#">Bioorgan. Khim. 1988. 14(3). 434-436</a> <a href="#">Bioorgan. Khim. 1989. 15(11). 1484-1497</a> <a href="#">Archiv. Biochem. Biophys. 1990. 279(2). 225-231</a>	
29.		all-E- 13Z- 11Z- 9Z- 7Z- all-E-	360°   357°			430 430 430 NO NO	530 530 NO NO NO		540	+     +		37	+/ +/    44/56				str. R1S9, 22°C in distilled water.	<a href="#">Recl. 1983. 102(1). 42-46</a> <a href="#">Recl. 1983. 102(1). 46-51</a>	

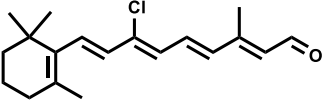
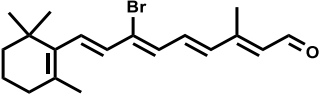
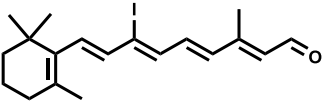
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-70/30	OS BRh cm <sup>-1</sup>	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-					532										70 mM potassium phosphate, pH 6.5.	<a href="#">Biochem 1983, 22(11), 2637-2644</a>
		all-E-					530			+		68					str. S9	<a href="#">Biochem Biophys. Res. Commun. 1977, 78(2), 669-675</a>
		all-E-					540			+	410	<20 WT		stable			str. L33 W182F W189F mutants FTIR data ABR cycle exhibits great delay in the L→M conversion Trp182 interacts with the Ret side chain through the 9-methyl group Ret native WT transform WT	<a href="#">Biochem 1995, 34(2), 577-582</a> <a href="#">The Biology of Chemistry</a>
							540										R82A str. IV-8 "O" 600 nm	<a href="#">Interface 1999 ch 15 431-444</a>
							537										ABR cycle at 80, 170, and 213 K. ABR cycle is slowed down about 250-fold. Low-temperature FT-IR difference spectra.	<a href="#">Biochem 1995, 34(41), 13502-13510</a>
																	ABR cycle "M" at 410 nm and "O" 660 nm. Time-	<a href="#">Biochem 1996, 35(33)</a>

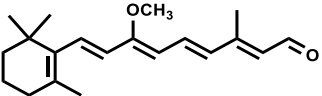
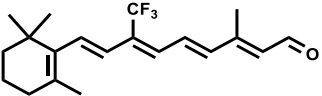
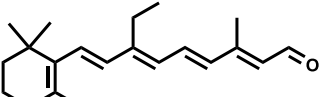
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-	376 <sup>b</sup> $\epsilon$ 39000					535 $\epsilon$ 43850	542 $\epsilon$ 43570			37/63  71/29	4284  4486			resolved UV-Vis and FT-IR difference spectra of WT BRh and mutant W182F. The steric interaction between W182 and the 9-methyl group of the retinal.  compared the proton uptake and release of WT and two mutant BRh D96N, D85N in ABR films or L-B layers on ATO.	10807-10814  Bioelectrochem 2000, 51(1), 27-33 Bioelectrochem Biosci 1997, 44(1), 37-43  Ockenfels A. Ph.D. thesis, Duisburg: 2000	
30.		all-E-	369 <sup>a</sup>	357 <sup>a</sup>	426 <sup>a</sup>				530				4610				Synlett, 1995, (12), 1247-1248	
		all-E	368	355	428		518						4060			str. S9  9-demethyl-9-haloretinal	J. Org. Chem. 1997, 62(2), 310-319  Eur. J. Org. Chem., 2004, P. 2166 -	

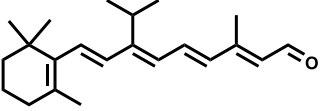
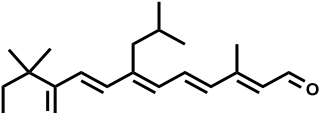
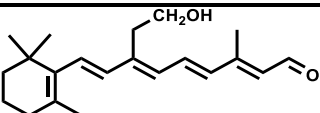
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
31.		all-E-																2175
32.		all-E-  all-E-	372 $\epsilon$ 39300		430			535  543	545  543	+  +			4570 4910		stable  stable	CD- L- ABR 512 (+)/ 590 (-) CD D- ABR 505 (+)/ 585 (-)	$\tau_{\text{rec}}$ 6 h, 25°C pH 7.0, H <sub>2</sub> O  15min D <====> L 50 h  str. ET1001 JW2N BO washed by BSA ABR cycle compared to BRh, but rate constants are altered. X-ray data	<a href="#">Eur. J. Org. Chem., 2004, P. 2166 - 2175</a>  <a href="#">JACS. 1980. 102(27), 7947 - 7949</a> <a href="#">MIE, V. 88 Part I, 1982. 178-180.</a> <a href="#">PhotochemPhotobiol 1981. 33(4) 483-488</a>  <a href="#">Photochem. Photo. biol. 1991. 54(6), 873-879.</a>  <a href="#">Eur. J. Org. Chem., 2004, P. 2166 - 2175</a>
33.		all-E-																<a href="#">Eur. J. Org. Chem., 2004, P. 2166 - 2175</a>

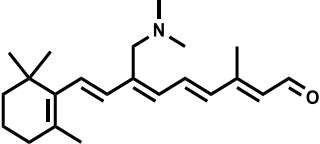
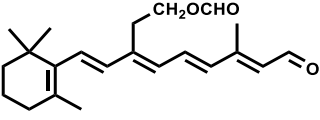
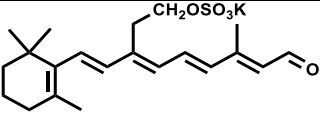
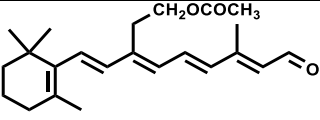
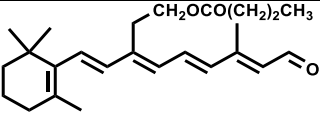
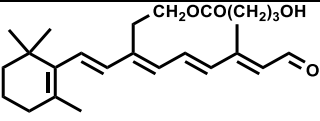
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
34.		9Z-	380 <sup>b</sup>				410/ 560		410/ 560								$\tau_{\text{rec}}$ 50 h 20°C ABR 415 nm after 300 min of $h\nu$ → ABR 560 nm. 560 nm reconvert thermally in 415 nm after 15h in dark	<a href="#">Liebigs Ann. Chem. 1988. (7), 705-715.</a> <a href="#">Eur. J. Biochem 1988. 176. 641-648</a>
35.		all-E-		347	399		520					5900					<a href="#">Photochem Photobiol. 1993. 58(5), 701-705</a>  <a href="#">JACS. 1982. 104(18), 4979-4981</a>  <a href="#">Tetrahedron Lett. 1985. 26(24), 2881-2884</a>	<a href="#">JACS 2002. 124(40), 11844-11845</a>
		all-E-					520									Second harmonic generation signal ABR		
36.		all-E-		364	440		573					5300					Kinetics were measured at 22°C in 10 mM sodium	<a href="#">Retinal Proteins 1987. 205-216</a>  <a href="#">PNAS 1997. 94(10)</a>

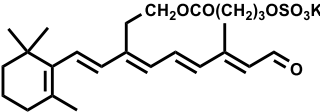
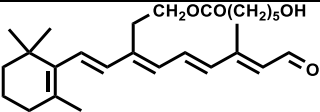
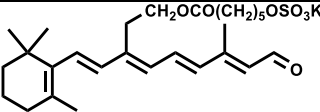
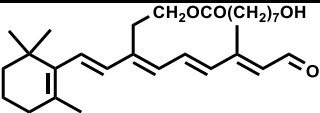
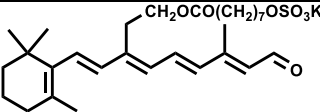
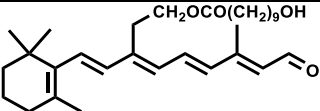
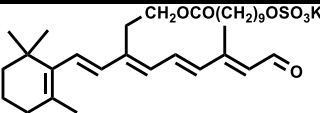
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	376 <sup>b</sup> $\epsilon$ 39000					545 $\epsilon$ 32900	559 $\epsilon$ 31400			42/58  75/25	4379  4838				phosphate buffer at pH 7.0 Addition of bulk at the C9 position of Retinal does not accelerate the cycle of ABR Leu93 →Ala mutant.  str. JW5, 20°C in distilled water ABR cycle data. pH Titration ABR pKa <sub>1</sub> ~ 4.5 pKa <sub>2</sub> ~ 8.5	<a href="#">5028-5033</a>  <a href="#">Ockenfels A. Ph.D. thesis, Duisburg : 2000</a>	
37.		all-E-	376 <sup>b</sup> $\epsilon$ 30400					481 $\epsilon$ 16700	479 $\epsilon$ 16800			56/7.5  50/18	2041  1954				str. JW5, 20°C in distilled water ABR cycle data. pH Titration ABR pKa <sub>1</sub> ~ 3.0 pKa <sub>2</sub> ~ 8.0	<a href="#">Ockenfels A. Ph.D. thesis, Duisburg : 2000</a>	
38.		all-E-		355	435		450						750				Kinetics were measured at 22°C in 10 mM sodium phosphate buffer at pH 7.0 Addition of bulk at the C9 position of Retinal does not accelerate the cycle of ABR Leu93 →Ala mutant.	<a href="#">Retinal Proteins 1987, 205-216</a>  <a href="#">PNAS 1997, 94(10), 5028-5033</a>	
39.		all-E-					560			+		40 JW2N					pH 7.0, 25°C 10 mM HEPES buffer, smooth formation	<a href="#">JACS, 1989, 111(13), 4997-4998.</a>	
		all-E-		351	430		571						5700						

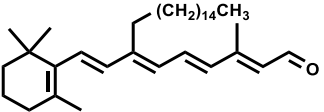
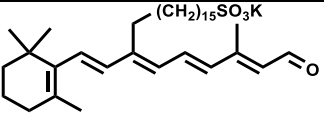
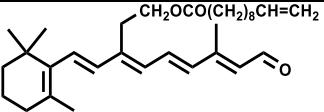
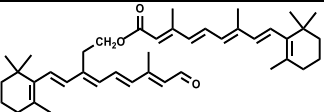
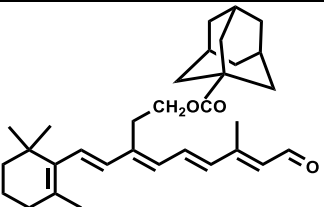
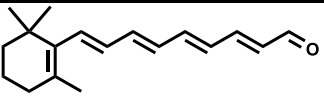
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Retinal Proteins 1987. 205-216</a>	
40.		all-E-		360	447		449						0					<a href="#">Retinal Proteins 1987. 205-216</a>	
41.		all-E-					452										HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS. 1989. 111(13). 4997-4998.</a>	
42.		all-E-					NO										HEPES buffer, pH 7.0, 25°C in dark no ABR after 16-24 h	<a href="#">JACS. 1989. 111(13). 4997-4998.</a>	
43.		all-E-					452										HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS. 1989. 111(13). 4997-4998.</a>	
44.		all-E-					452			+		12 JW2N					HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS. 1989. 111(13). 4997-4998.</a>	
45.		all-E-					452						0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{rep}} > 24\text{h}$ dark, 25°C pH 7.0		HEPES buffer, pH 7.0, 25°C in dark smooth formation	<a href="#">JACS. 1989. 111(13). 4997-4998.</a>		

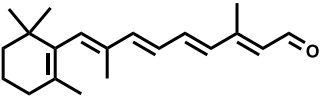
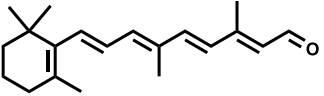
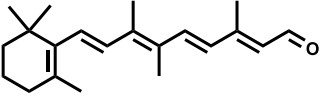
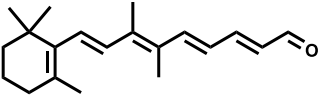
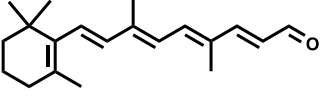
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
46.		all-E-					NO										HEPES buffer, in dark no ABR after 16-24 h.	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>	
47.		all-E-					452						0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{repl}} > 24\text{h}$ dark, 25°C pH 7.0		HEPES buffer, pH 7.0, 25°C in dark smooth formation	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
48.		all-E-					NO										in dark no ABR after 16-24 h	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>	
49.		all-E-					452						0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{repl}} > 24\text{h}$ dark, 25°C pH 7.0		HEPES buffer, pH 7.0, 25°C in dark smooth formation	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
50.		all-E-					475										HEPES buffer, pH 7.0, 25°C in dark $\tau_{\text{form}} \geq 6\text{h}$ .	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>	
51.		all-E-					452				7 JW2N		0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{repl}} > 24\text{h}$ dark, 25°C pH 7.0		HEPES buffer, pH 7.0, 25°C in dark smooth formation	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
52.		all-E-					475				12 JW2N		0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{repl}} > 24\text{h}$ dark, 25°C pH 7.0		HEPES buffer, pH 7.0, 25°C in dark immediately formation	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		

### Properties of artificial bacteriorhodopsin analogs

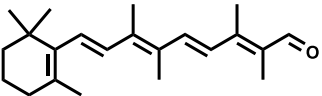
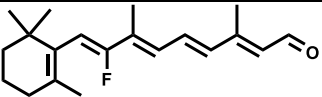
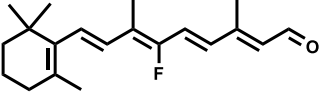
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
53.		all-E-					450	452						0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min		HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>	
54.		all-E-					475						0.1 M light 450nm $\tau_{1/2\text{destr}}$ 5-10 min	stable $\tau_{\text{rep}} > 24\text{h}$ dark, 25°C pH 7.0	HEPES buffer, pH 7.0, 25°C in dark immediately formation	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
55.		all-E-					452			10 JW2N					HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
56.		all-E-					450								HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
57.		all-E-					452			7 JW2N					HEPES buffer, pH 7.0, 25°C in dark	<a href="#">JACS.</a> <a href="#">1989.</a> <a href="#">111(13).</a> <a href="#">4997.</a> <a href="#">4998.</a>		
58.		all-E- 13Z- 11Z- 9Z- all-E-	356°   356°			430 430 430 430	530 530 530 530		530 530 530 530		37					str. R1S9, 22°C	<a href="#">Recl.</a> <a href="#">1983.</a> <a href="#">102(1).</a> <a href="#">42-46</a> <a href="#">Recl.</a> <a href="#">1983.</a> <a href="#">102(1).</a> <a href="#">46-51</a>	
							539 538		+    		<20 WT			<25% in 2h pH 7.5		native WT transform WT	<a href="#">The</a> <a href="#">Biology</a> <a href="#">Chemistr</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
								539			0 R82A			moderate degradation		R82A str. IV-8, pH 8.8 "M" WT quite small Only long-lived 600-nm species was found	<a href="#">Y. Interface 1999 ch 15-431-444</a>	
59.		all-E-	360	346	424	440	?								immediately replaced	str. S9 $\tau_{rec}$ 6 days 20°C	<a href="#">JACS 1995 117(31) 8220-8231</a>	
60.		all-E-	380	354	432		540						4630		immediately replaced	str. S9 $\tau_{rec}$ 6 days 20°C	<a href="#">JACS 1995 117(31) 8220-8231</a>	
61.		all-E-  all-E-								NO	NO					ABR pigment shows no light-induced absorbance changes over the time scale of 0.1 ms to 1.0 s. Raman spectra Schiff base (-C=NH-) stretching frequency. 1643 $cm^{-1}$  str. JW5, 20°C in distilled water ABR cycle data. pH Titration ABR pKa <sub>1</sub> ~ 5.7 pKa <sub>2</sub> ~ 8.8	<a href="#">Photochem Photobiol 1985 41(5) 563-567</a>  <a href="#">Ockenfels A. Ph.D. thesis. Duisburg: 2000</a>	
62.		all-E-	384 <sup>b</sup> $\epsilon$ 38100					485 $\epsilon$ 10500	467 $\epsilon$ 17920			35/17  4/32 9Z-59%	1803  1008			str. JW5, 20°C in distilled water ABR cycle data. pH Titration ABR pKa <sub>1</sub> ~ 5.7 pKa <sub>2</sub> ~ 8.8	<a href="#">Ockenfels A. Ph.D. thesis. Duisburg: 2000</a>	
63.		all-E-	382	368	444	420	?								immediately replaced	str. S9	<a href="#">JACS 1995 117(31) 8220-8231</a>	



### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
67.		all-E-		~ 360			433			NO							str. R1 form unprotonated SB. Raman spectra Schiff base (-C=N-) stretching frequency 1623 $\text{cm}^{-1}$	<a href="#">Photochem Photobiol</a> 1985, 41(5), 563-567	
68.		all-E-		351	418		530					5000 5000						<a href="#">Photochem Photobiol</a> , 1993, 58(5), 701-705	
		all-E-			427		530		530			4550 4550					str. R1	<a href="#">Biochem</a> 1990, 29(25), 5948-5953	
		all-E-															8-F mutant D96N and str. S9 Effects of fluorination of the retinal polyenic chain on the influence protein-lipid interaction	<a href="#">Eur. Biophys. J.</a> , 2001, 29(8), 628-640	
69.		all-E-		364	438		562					5000						<a href="#">Photochem Photobiol</a> , 1993, 58(5), 701-705	
		all-E-				442		431, 565		+	410	+	4930 4670					str. R1. "O" -650 nm	<a href="#">Biochem</a> 1990, 29(25), 5948-5953
		13Z-						557									10-F mutant D96N and str. S9 Effects of fluorination of the retinal polyenic chain on the influence	<a href="#">Eur. Biophys. J.</a> , 2001, 29(8), 628-640	





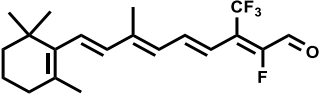
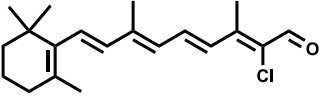
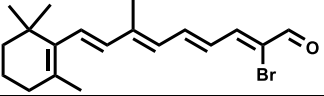
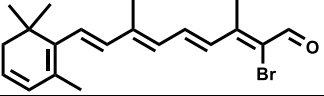
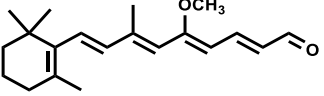
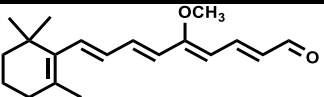
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E- 13Z-					588 587									ESR data. ABR reduced by NABH <sub>4</sub>  Dynamic holography recording using 14-F-ABR in gelatin films.  str. WT ET-1000 and D96N pH 6, 25°C, ABR from all- <i>trans</i> - and 13- <i>cis</i> -14-F-retinal analogs. $\tau_{\text{rec}}$ 1h from WT ET-1000 or D96N BRh and no red tail band was formed! After 560 nm light in 5 min illumination, pH 7, 10°C, ABR640-650 nm band appear for both the 14-F WT and D96N ABR. The photocurrent transients generated by yellow light in 14-F-WT and 14-F-D96N unoriented films on tin-oxide electrodes were measured.  Spectral and kinetic transformations were studied in gelatin films made with 14-F WT 14-F D96N ABR  Photoinduced transformation in gelatin films made with 14-F ABR, both WT and D96N mutant, were studied. Spectral	<a href="#">Photochem Photobiol 2005, 81(4), 920-923</a>  <a href="#">BBA 1998, 1371(2), 371-381</a>  <a href="#">Bio Systems 2001, 59(1), 53-60</a>  <a href="#">Appl. Biochem. Biotechnol. 2005, 120(2), 121-132</a>	

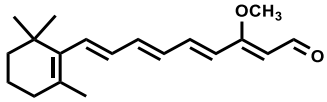
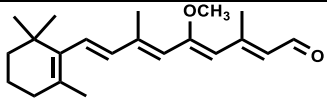
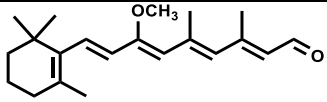
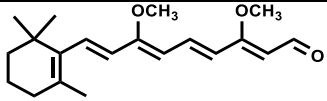
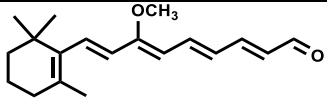
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	394 <sup>a</sup>		455		587 680sh					4800 7100				and kinetic peculiarities for these two types of samples were compared over a wide range of relative humidity (9–92%).  Spectral and kinetic characteristics were measured for gelatin films based on 14-F ABR, both wild-type (WT) and D96N mutant, to study the peculiarities of photo-induced transformation of the samples.	<a href="#">JBiomaterSciPolym</a> <a href="#">2008</a> <a href="#">19(12)</a> <a href="#">1585-</a> <a href="#">1595</a>		
																14-F mutant D96N and str. S9 Effects of fluorination of the retinal polyenic chain on the influence protein-lipid interaction	<a href="#">Eur. Biophys. J.</a> , 2001, <a href="#">29(8)</a> <a href="#">628–640</a>		
																effect of high pressure on ABR, BRh mutant D96N and fluoroABR	<a href="#">EurBiophysJ.</a> <a href="#">2002</a> <a href="#">31(7)</a> <a href="#">539-548</a>		
																pK ~ 9.3	<a href="#">Biochem.</a> , 2005, <a href="#">V. 44 №</a> <a href="#">23. P.</a>		

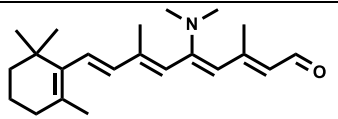
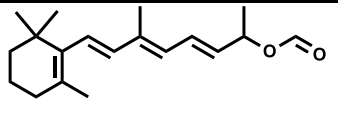
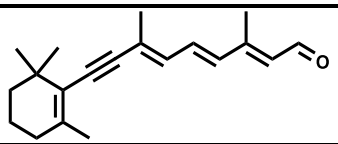
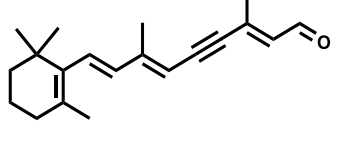
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		8479 – 8485.	
77.		all-E-		371	426		NO											Photochem Photobiol. 1993, 58(5), 701-705	
78.		all-E- 13Z- all-E-					440-475, 691 430 691 472/691		691		after 5 days 61/39 after 5 days 55/45		500 7200			str. JW2N pH 6.0 25°C $\tau_{\text{rec}}$ ABR440-475 1 h $\tau_{\text{rec}}$ ABR691 5 days ~ 5% ABR691 after 5 days		Biochem 1990, 29(25), 5948-5953  Photochem Photobiol. 2001, 74(6), 837-845	
79.		all-E-					NO											10	
80.		all-E-				+	NO											29	
81.		11Z-	364				532											Eur. J. Biochem 1988, 176, 641-648	
82.		11Z-	366				534											Eur. J. Biochem 1988, 176, 641-648	

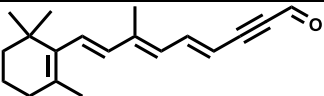
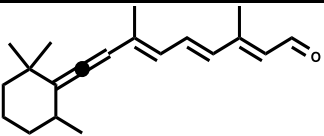
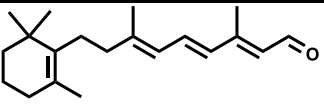
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
83.		13Z-	347				490											<a href="#">Eur. J. Biochem</a> 1988, 176, 641-648
84.		all-E-															Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH <sub>4</sub>	<a href="#">JBiolChem</a> m 2000 275(28) 21010-21016
85.		all-E-															Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH <sub>4</sub>	<a href="#">JBiolChem</a> m 2000 275(28) 21010-21016
86.		9Z,13Z-	352				500											<a href="#">Eur. J. Biochem</a> 1988, 176, 641-648
87.		9Z-	376				490 in H <sub>2</sub> O 510 in cells			10						str. JW2N	<a href="#">Eur. J. Biochem</a> 1988, 176, 641-648	

### Properties of artificial bacteriorhodopsin analogs

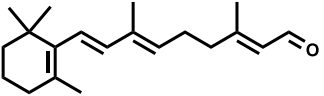
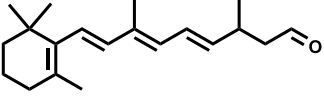
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
88.		all-E-															Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH <sub>4</sub>	<a href="#">JBiolChem 2000 275(28):21010-21016</a>
89.		all-E-	291 <sup>c</sup> $\epsilon$ 34100 293 <sup>a</sup>			331 $\epsilon$ 29000	NO										No covalent binding. Possible interaction between C18 fragment and some groups in protein microenvironment. $\tau_{\text{rec}}$ 6 min. Iminoester formation? If PM instead BO $\lambda_{\max}$ 302 nm	<a href="#">Photochem. Photobiol. 1992. 55(5):745-752.</a>
<b>D. Alteration of the bond types and its disposition in the chromophore polyenic chain</b>																		
90.		all-E- 13Z-				440 532 515			+		45	70-90%E					H <sup>+</sup> pumping in str. JW-5 cells	<a href="#">JACS. 1984. 106(19):5654-5659</a>
91.		all-E- 13Z- 9Z- 9Z,13Z- 7Z- 7Z,9Z-	290sh 364 $\epsilon$ 26100 288sh 358 $\epsilon$ 20300	343 347	418 417	539 519 495			+	~410			5370 4710					<a href="#">Bioorgan. Khim. (Rus). 1989. 15(3):307-312</a> <a href="#">Biolog. Membranes (Rus). 1994. 11(5):575-576</a> <a href="#">Molecular Biol. (Rus).</a>

### Properties of artificial bacteriorhodopsin analogs

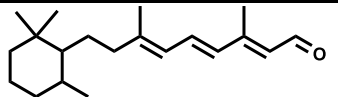
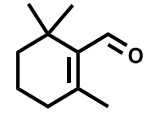
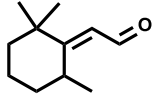
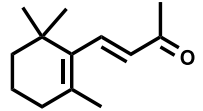
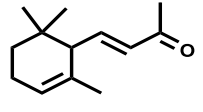
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			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		7Z,13Z-				NO												1995, 29(6), 1398-1407 Mol. Cryst. Liq. Cryst. 2000, 345, 317-322	
92.		all-E-				NO												10	
93.		all-E-				+				+ 10-15								Pure Appl. Chem., 1986, 58(6), 719-724	
94.		all-E-	342		392		440						2780					Biophys. J. 1986, 49, 479-483	
		all-E-			390		442	442	440		77/23 51/49		3000 2900			50 mM Hepes, pH 7.0		Photochem Photobiol 1991 54(6) 969-976	
		all-E-					400											11	
		all-E-	338		385		400						1000					JACS. 1980, 102(27), 7945-7947	
		all-E-			385			400				1000						Photochem Photobiol 1981 33(4)	



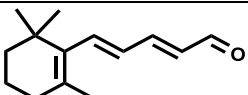
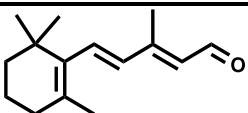
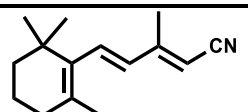
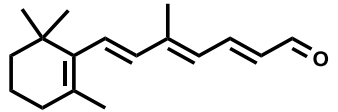
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					+	343			NO		1910				phosphate buffer, pH 7.0.	<a href="#">JACS. 1980. 102(27). 7945-7947</a> <a href="#">Pure Appl. Chem. 1986. 58(6). 719-724</a> <a href="#">Biophys. J. 1984 45 272a</a>	
96.		all-E-	236		270		+										$\lambda_{\max}$ ABR overlap with the absorption of the protein.	<a href="#">Photochem Photobiol 1981 33(4) 483-488</a> <a href="#">JACS. 1980. 102(27). 7945-7947</a>	
97.		all-E-	289 <sup>a</sup>					328					4110				in 20 mM Tris/HCl and 4 M NaCl at pH 7.0. ABR <sup>328</sup> with distinct vibrational fine structure. $\tau_{\text{rec}}$ 45 min Mutagenesis studies and two photon spectroscopy studies argue against a discrete charge in the binding site but not against the local electrostatic fields, which would fulfill the conditions of the original point charge model. 270-fold	<a href="#">JBiolChem. 1995. 270(50). 29668-29670</a>	

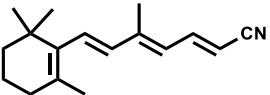
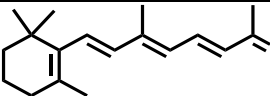
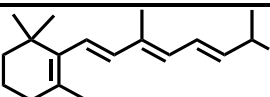
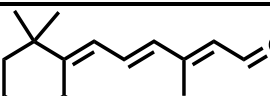
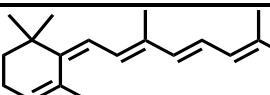
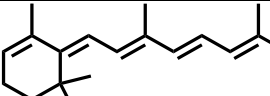
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	inhibition of the native retinal Incorporation in ABR.	
98.		all-E-	339		392		435						2520					<a href="#">Biophys. J. 1986. 49. 479-483</a> <a href="#">Pure Appl. Chem., 1986. 58(6). 719-724</a>
		all-E-			382		438	438	436		61/39 40/60		3350 3200				50 mM Hepes, pH 7.0.	<a href="#">PhotochemPhotobiol 1991 54(6) 969-976</a>
<b>E. Alteration of the polyenic chain length and bond disposition and terminal group types</b>																		
99.						NO	NO										str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem 1981. 117(2). 353-369</a>
100.		E-	225 <sup>c</sup>			NO	NO		NO								In 50 mM sodium phosphate buffer pH 7.2. 24 h	<a href="#">Biochem 1986. 25(8). 2022-2027.</a> <a href="#">IS</a>
101.		E-	222, 292 <sup>b</sup>			NO	NO		NO								str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem 1981. 117(2). 353-369</a>
102.		E-	232 <sup>b</sup>			NO	NO		NO								str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem 1981. 117(2). 353-369</a>

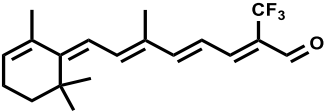
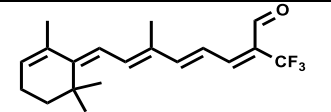
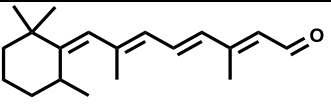
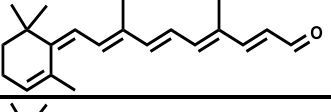
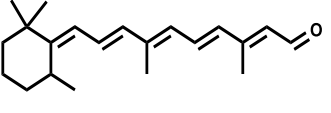
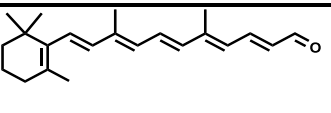
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
103.		all-E- 9Z-	264, 330 <sup>b</sup> 266, 320 <sup>b</sup>			346 344	NO NO									str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369		
104.		all-E- 9Z- all-E- 9Z- all-E- 9Z-	264, 330 <sup>b</sup> 326 <sup>a</sup> 323 <sup>a</sup> 280 278			350 352 364 362 360 359	NO     		NO				unstable, destroyed very rapidly		364+ 362+	str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369  <a href="#">Bioorgan. Khim. (Rus)</a> , 1981, 7(8), 1169-1194  <a href="#">Photochem. Photo. biol.</a> , 1981, 33(4), 495-499		
105.		all-E-	252, 306 <sup>b</sup>			324	NO									str. R <sub>1</sub> M <sub>1</sub> 5°C	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369		
106.		all-E- 9Z- all-E- 11Z- 9Z-	350 <sup>b</sup> 322 <sup>b</sup> 340 <sup>a</sup> $\epsilon$ 33200 323 <sup>a</sup> 336 <sup>a</sup> $\epsilon$ 29000			420 380 413 $\epsilon$ 40000 400 402 $\epsilon$ 30000							unstable  unstable  unstable			str. R <sub>1</sub> M <sub>1</sub> 5°C  str. R <sub>1</sub>	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369  <a href="#">Photochem. Photo. biol.</a> , 1981, 33(4), 495-499		


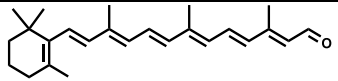


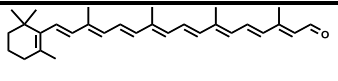

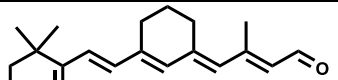

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	340 <sup>a</sup>					413	415	NO	NO								
107.		all-E-	328 <sup>b</sup>			366	NO										str. R <sub>1</sub> M <sub>1</sub> , 5°C	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369	
108.		all-E- 9Z- all-E-	352 <sup>b</sup> 302, 344			414 344 +	NO										str. R <sub>1</sub> M <sub>1</sub> , 5°C	<a href="#">Eur. J. Biochem</a> 1981, 117(2), 353-369 <a href="#">FEBS Lett.</a> 1979, 97(1), 15-19	
109.		all-E-	284 <sup>c</sup> $\epsilon$ 33000, 284 <sup>a</sup>			328	NO								328 nm peak moves to 300 nm, when all-E-Ret added			<a href="#">Photochem. Photobiol.</a> 1992, 55(5), 745-752	
110.		E- 2Z-	320 <sup>c</sup> 318 <sup>c</sup>				416 414		420 420	NO NO		NO		stable stable	stable stable		In 50 mM sodium phosphate buffer pH 7.2. 24 h	<a href="#">Biochem</a> 1986, 25(8), 2022-2027	
111.		6Z-	378 <sup>c</sup>			409	514sh							stable hv			stable under illumination. Isomerisation to E-isomer $\tau_{\text{rec}}$ 14 days	<a href="#">Tetrahedron Lett.</a> 1991, 32(17), 1933-1936	
112.		all-E-	378 <sup>c</sup>			449	542							stable hv			stable under illumination. $\tau_{\text{rec}}$ 11 days	<a href="#">Tetrahedron Lett.</a> 1991, 32(17), 1933-1936	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
113.		Z-	400 <sup>c</sup>				579							unstable hv		destroyed under illumination. $\tau_{\text{rec}}$ 1 day	<a href="#">1933-1936</a> <a href="#">Tetrahedron Lett., 1991, 32(17), 1933-1936</a>	
114.		E-	400 <sup>c</sup>				NO										<a href="#">Tetrahedron Lett., 1991, 32(17), 1933-1936</a>	
115.		E- 2Z- all-E-	334 <sup>c</sup> 332 <sup>c</sup> 334 <sup>a</sup>				458 455 458		463 463 463	+  +	355-360  357	+  +		stable $\tau_{1/2\text{destr}}$ 70 min  easy replaced		In 50 mM sodium phosphate buffer pH 7.2. 24 h $\tau_{1/2\text{rec}}$ 25 min low yield. $\tau_{1/2\text{Mdecay}}$ 11ms.	<a href="#">Biochem 1986, 25(8), 2022-2027</a> <a href="#">13</a>	
116.		all-E-					528		535								<a href="#">23</a>	
117.		E- 2Z- 6Z- all-E-	382 <sup>c</sup> 380 <sup>c</sup> 375 <sup>c</sup> 382 <sup>a</sup>				518 517 485 518		524 524 524 524	+   +	395   392	+++   +++		stable $\tau_{1/2\text{destr}}$ several hours  stable		In 50 mM sodium phosphate buffer pH 7.2. 24 h $\tau_{1/2\text{rec}}$ 2 min high yield. $\tau_{1/2\text{Mdecay}}$ 11ms	<a href="#">Biochem 1986, 25(8), 2022-2027</a> <a href="#">13</a>	
118.		all-E- all-E- 13Z-	398 $\epsilon$ 45000 392 <sup>a</sup> 396 <sup>a</sup>	376	458	430-460	555  ~520 broad sh.			+  - -		-  -		3810  unstable, stepwise destruction		str. 353P  H <sup>+</sup> -pump in egg lecithin vesicles. The same Lys residue bound in ABR. $\tau_{\text{rec}}$ 2 h	<a href="#">29</a> <a href="#">Biophys. J., 1977, 19, 191-198</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	384 <sup>c</sup>					500, 540sh	500, 540	+	400	++			unstable 5 mM in dark	unstable		30 mM sodium phosphate buffer, pH 7.0. Two distinct ABR appear to be formed which can interconvert with each other upon illumination or change of pH of the medium. Long irradiation with strong light destroys of ABR. Reversible L-D conversion 540-->500 nm or at raised pH →500 nm.	<a href="#">Photochem Photobiol</a> 1986 43(3) 297-303 
119.		all-E-					NO											str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">Biochem Soc. Trans.</a> 1976. 4(4), 556-559. 
		all-E-	400					460sh 523	460sh 527									str 353P	
120.		all-E-					NO											str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">Biochem Soc. Trans.</a> 1976. 4(4), 556-559. 
<b>F. Alteration or locking of the bond configuration. Non-isomerizable analogs</b>																			
121.		all-E-	384	360	448		570		570	+	410	+++	50/50 90/10	4800 4800				Hepes buffer, pH 6.5 $\tau_{\text{rec}}$ 30 min. ABR cycle compared to BRh. Short-lived "K", long-lived "M". No observed light-dark adaptation. H <sup>+</sup> -pump in in vesicles.	<a href="#">Retinal Proteins</a> 1987. 205-216  <a href="#">JACS</a> 1986 108(15) 4614-4618
																		Leu93X mutants.	

### Properties of artificial bacteriorhodopsin analogs

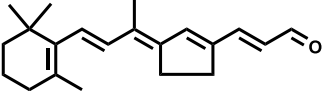
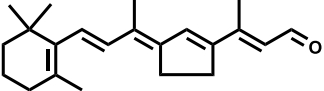
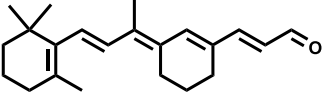
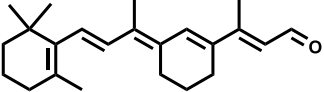
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh cm <sup>-1</sup>	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					567			+	+	100/0					Leu93 $\tau_{\text{Mdecay}}$ 1.1ms $\tau_{\text{Odecay}}$ 5ms Leu93→Ala $\tau_{\text{Mdecay}}$ 0.9ms $\tau_{\text{Odecay}}$ 3.4 ms. Leu93→Thr $\tau_{\text{Mdecay}}$ 90ms Leu93→Val + $\tau_{\text{Mdecay}}$ 2.2ms $\tau_{\text{Odecay}}$ 6.2 ms in 10mM sodium phosphate buffer at pH 7.0 22°C. Laser-induced transient spectra. Leu93→Ala dramatic acceleration 550-fold in the decay of the "O". Leu93→Thr 150-fold increase lifetime of "O". Leu93 →Val mutant has little effect on the lifetime of the "O".	<a href="#">PNAS</a> <a href="#">1997</a> <a href="#">94(10)</a> <a href="#">5028-</a> <a href="#">5033</a>	
						538			+	+	100/0								
						540			+	+	100/0								
						564			+	+	100/0								
																		<a href="#">J. Phys. Chem.</a> <a href="#">1995,</a> <a href="#">(19),</a> <a href="#">7801-</a> <a href="#">7805.</a>	
																		<a href="#">JPhysChem A</a> <a href="#">2002</a> <a href="#">106(14)</a> <a href="#">3325-</a> <a href="#">3336</a>	
																		Picosecond transient absorption (PTA) data show that the initial 200-ps interval of the ABR photocycle contains two intermediates: "J6.9" formed with <3-ps	

### Properties of artificial bacteriorhodopsin analogs

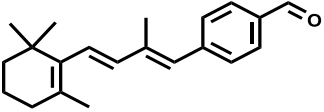
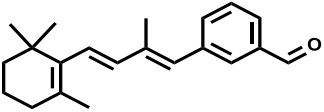
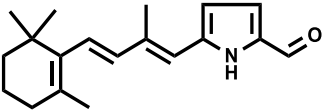
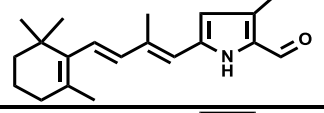
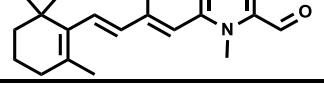
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	<p>time constant and decaying to "K6.9" with a 5-ps time constant ("K6.9" has a &gt;5-ns lifetime). Data show that no C13=C14 isomerization is needed to form "K6.9", even though ABR exhibits biochemical activity and the structure of ABR permits C13=C14 isomerization, it is evident that the biochemical mechanism in ABR, unlike native BRh, proceeds with a "K-intermediate" that can undergo C13=C14 isomerization, but does not. It is possible, of course, that C=C isomerization (either at the C13=C14 bond or at another C=C bond occurs later in the ABR photocycle,</p> <p>New model of the primary events of the BRh photocycle. Picosecond intermediates appearing in the respective photo-reactions ABR are measured by coherent anti-Stokes Raman spectroscopy (CARS).</p>	<a href="#">Chem Physics 2005, 313(1-3), 51-62.</a>



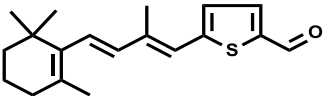
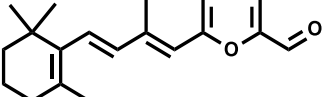
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					490 $\epsilon$ 31000					NO	100/0				str. R <sub>1</sub> M <sub>1</sub> . ABR does not isomerize. $\lambda_{\max}$ flu 605 nm. $\Phi$ $1.2 \cdot 10^{-3}$ . "K" is not formed and no rotation in the region of C-12-C-14 of ABR.	<a href="#">BBA</a> , <a href="#">1984</a> , <a href="#">767(3)</a> , <a href="#">635-639</a>	
125.		all-E-	411 <sup>a</sup>		475 <sup>a</sup>		608					0		4610		stable	str. R1S9 $\tau_{\text{rec}}$ 14 days No L-D-adaptation.	<a href="#">Recl.</a> , <a href="#">1994</a> , <a href="#">113(1)</a> , <a href="#">45-52</a>	
		all-E-	410	472	460	443	608							5290			str. 353P	<a href="#">Kirillova</a> <a href="#">Yu.G.</a> , <a href="#">Ph.D.</a> , <a href="#">thesis</a> , <a href="#">1994</a>	
126.		all-E-	411 <sup>a</sup>		480 <sup>a</sup>		624 $\epsilon$ 63000					45		4810		stable	str. R1S9 $\tau_{\text{rec}}$ 30 min	<a href="#">Recl.</a> , <a href="#">1994</a> , <a href="#">113(1)</a> , <a href="#">45-52</a>	
		all-E-	410	385	485	487	624	608	624	+	+	+		4590 4170 4590			str. 353P	<a href="#">Kirillova</a> <a href="#">Yu.G.</a> , <a href="#">Ph.D.</a> , <a href="#">thesis</a> , <a href="#">1994</a>	
127.		all-E-	395 <sup>a</sup>		466 <sup>a</sup>		NO										str. R1S9	<a href="#">Recl.</a> , <a href="#">1994</a> , <a href="#">113(1)</a> , <a href="#">45-52</a>	
		all-E-	393	371	460	420	NO			NO							str. 353P	<a href="#">Kirillova</a> <a href="#">Yu.G.</a> , <a href="#">Ph.D.</a> , <a href="#">thesis</a> , <a href="#">1994</a>	
128.		all-E-	395 <sup>a</sup>		466 <sup>a</sup>		NO										str. R1S9	<a href="#">Recl.</a> , <a href="#">1994</a> , <a href="#">113(1)</a> , <a href="#">45-52</a>	
		all-E-	393	355	485	428	NO			NO							str. 353P	<a href="#">Kirillova</a> <a href="#">Yu.G.</a>	

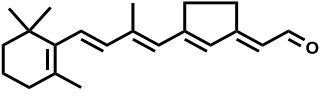
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )							Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M	NH <sub>2</sub> OH				all-E-RET	CD	others		
							(P)	DA	LA										
																			<a href="#">Ph.D. thesis, 1994</a>
129.		E-  E- 9Z-	336  337 332	324	390	325, 425  428 NO	NO  NO NO			NO								str. R1, 50mM MES, pH 6.5. 24 h. NC easy destroyed by Ag <sup>+</sup> / Triton X-100. C18-keton easy replaced NC  str. R1S9	<a href="#">Bioorgan. Khim. (Rus), 1984, 10(2), 256-259.</a> <a href="#">Bioorgan. Khim. (Rus), 1987, 13(8), 1116-1124</a>  <a href="#">Recl. 1984, 103(4), 105-109</a>
130.		E-	265, 295			343, 360	NO			NO								str. R1, 50mM MES, pH 6.5. 24h. NC easy destroyed by Ag <sup>+</sup> / Triton X-100. C18-keton easy replaced NC	<a href="#">Bioorgan. Khim. (Rus), 1987, 13(8), 1116-1124</a>
131.		E-	356			407, 427	NO			NO								str. R1S9	<a href="#">Recl. 1984, 103(4), 105-109</a>
132.		E-	362			400, 423	NO			NO								str. R1S9	<a href="#">Recl. 1984, 103(4), 105-109</a>
133.		E-	351			399, 424	NO			NO								str. R1S9	<a href="#">Recl. 1984, 103(4), 105-109</a>

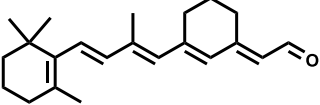
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
134.		E-	377			430	NO									str. R1S9	<a href="#">Recl. 1984</a> , <a href="#">103(4)</a> , <a href="#">105-109</a>	
135.		all-E-	233, 355 <sup>c</sup>			435	565				11		5290			str. R1S9	<a href="#">Recl. 1983</a> , <a href="#">102(1)</a> , <a href="#">42-46</a>	
		9Z-	242, 290, 355 <sup>c</sup>			NO												<a href="#">Recl. 1983</a> , <a href="#">102(1)</a> , <a href="#">46-51</a>
		all-E-	375 <sup>a</sup>	367 <sup>a</sup>	436 <sup>a</sup>		565			NO				5240		20mM HEPES, pH 7.0.	<a href="#">Retinal Proteins 1987</a> , <a href="#">205-216</a>	
		all-E-			436		568							5300		pKa (SBH <sup>+</sup> ) 6.0, pKa (ABR SB) 8.2. Titrations of ABR data	<a href="#">Biochem 1995</a> , <a href="#">34(37)</a> , <a href="#">12059-12065</a>	
		all-E-													pKa (ABR SB) 8.2. Titrations of ABR data	<a href="#">Biochem 1995</a> , <a href="#">34(37)</a> , <a href="#">12066-12074</a>		
													$\tau_{1/2\text{destr}}$ 330 s in the dark $\tau_{1/2\text{destr}}$ 778 s under light		Light-Induced NH <sub>2</sub> OH reactions occur with SB C13= C14 locked ABR	<a href="#">Biophys J 1998</a> , <a href="#">75(1)</a> , <a href="#">413-417</a>		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	step-scan FT-IR data <a href="#">LaserChem 1999 19(1-4) 169-172</a>  str. WT Electric-Field Effects in ABR films <a href="#">Photochem Photobiol 1999 70(1) 103-110</a>  Atomic force sensing (AFS) for dynamically probe ABR protein conformational changes with microsecond time resolution <a href="#">PNAS 1997. 94(15): 7937-7941</a>  Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. <a href="#">JBiolChem 2000 275(28) 21010-21016</a>	
136.		all-E- 13Z-	384	366	438	440 525	525 525		NO	NO	0/100 0/100	3780			Hepes buffer, pH 6.5. NC 440nm $\tau_{\text{rec}}$ 20 min ABR $\tau_{\text{rec}}$ 48 h in dark. 13Z form ABR 525 in $\tau_{\text{rec}}$ 20 min. ABR525 photocycle lacks the "M", long-lived red-shifted species, "L <sub>610</sub> " as in BRh13-cis. In NC 440 nm no photocycling was observed.	<a href="#">Retinal Proteins 1987. 205-216</a>  <a href="#">JACS 1986 108(15) 4614-4618</a>  <a href="#">7</a>		

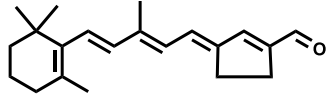
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-			438		524 560 560					3780				in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys J</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259-</a> <a href="#">1265</a>	
		all-E-				522										pKa (SBH <sup>+</sup> ) = 7.3, pKa (ABR SB) = 12.0. Titrations of ABR data	<a href="#">Biochem</a> <a href="#">1995</a> <a href="#">34(37)</a> <a href="#">12059-</a> <a href="#">12065</a>	
137.		all-E-	378	358	436		556		556	+	410	+++	50/50 90/10	5000 5000			Hepes buffer, pH 6.5 $\tau_{\text{rec}}$ 30 min. ABR cycle compared to BRh. Short-lived "K", long-lived "M". No observed light-dark adaptation. H <sup>+</sup> -pump in in vesicles.	<a href="#">Retinal Proteins</a> <a href="#">1987</a> <a href="#">205-216</a>  <a href="#">JACS</a> <a href="#">1986</a> <a href="#">108(15)</a> <a href="#">4614-</a> <a href="#">4618</a>  <a href="#">7</a>  <a href="#">Biophys J</a> <a href="#">1993</a> <a href="#">65(2)</a> <a href="#">964-972</a>
																573-nm excitation of ABR. ABR laser-induced transient picosecond absorption and picosecond time-resolved fluorescence spectra. Differences including slower formation rates for "J" <sub>610 nm</sub> and "K1" <sub>590nm</sub> as well as the presence of a second "K2" <sub>650 nm</sub> . Restricted motion in the C11=C12-C13 region of retinal found in ABR does not greatly change the overall photoreaction		

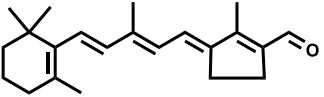
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					556		+ $\tau$		100/0					mechanism, but does alter the rates at which processes occur. Resonance Raman spectrum.		
							530		+		100/0					Leu93X mutants. Leu93 $\tau_{\text{Mdecay}}$ 0.6ms	<a href="#">PNAS 1997</a>	
							532		+		100/0					$\tau_{\text{Odecay}}$ 4 ms	<a href="#">94(10)</a>	
							552		+		100/0					Leu93 $\rightarrow$ Ala $\tau_{\text{Mdecay}}$ 0.7ms $\tau_{\text{Odecay}}$ 15ms	<a href="#">5028-</a>	
																Leu93 $\rightarrow$ Thr $\tau_{\text{Mdecay}}$ 60ms	<a href="#">5033</a>	
		all-E-					556									Leu93 $\rightarrow$ Val $\tau_{\text{Mdecay}}$ 1.0ms $\tau_{\text{Odecay}}$ 5.3ms. In 10 mM sodium phosphate buffer at pH 7.0 22°C. Laser-induced transient spectra. Leu93 $\rightarrow$ Val, Leu93 $\rightarrow$ Ala mutants, ABR accelerates decay of the "O" by 2-fold and 120-fold, respectively.		
		all-E-					556									str. S9. In water without buffer pH 6.5. Resonance Raman spectrum	<a href="#">JPhysChem 1993</a>	
		all-E-			436		556						5000			pKa (SBH <sup>+</sup> ) = 7.2, pKa (ABR SB) = 12.1. Titrations of ABR data	<a href="#">Biochem 1995</a>	
																New model of the primary events of the BRh photocycle. Picosecond intermediates	<a href="#">Chem Physics 2005</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					556									appearing in the respective photo-reactions ABR are measured by coherent anti-Stokes Raman spectroscopy (CARS).	3), 51-62.	
		all-E-														PR/CARS and PTR/CARS data measured from the sample ABR. The significantly slower rate ( $\tau$ 12-16 ps) for the "J" to "K" transformation in ABR relative to that in BRh-570 (3.5 ps) directly reflects the time required for trans to cis isomerization of the C13=C14 bond. The decreased isomerization rate in ABR arises from the proximity of the ring to the C13=C14 bond, which increases inertia near the C13=C14 bond and introduces new steric interactions between the ring and amino acid residues. As a consequence, the rate at which torsional motion is converted into isomerization of the C13=C14 bond slows.	JPhysChem A 2003 107(49) 10787-10797	
138.		all-E-	381 <sup>a</sup>		464 <sup>a</sup>		NO									str. R1S9	Recl. 1994, 113(1), 45-52.	
		all-E-	391	363	440	430	562		NO		NO		4930			str. 353P		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a>	
139.		all-E-				420sh 443, 470sh	576	576			NO	4140		displaced		$\tau_{\text{rec}}$ 15 days, 10mM HEPES, pH 7.0.	<a href="#">JACS 1983 105(15) 5162-5164</a> <a href="#">19</a>		
		all-E-					576											<a href="#">Biochem 1990 29(25) 5948-5953</a>	
		all-E-				439	555	555	555	NO	NO		light-induced reaction $\tau_{1/2\text{destr}}$ 65 min; in the dark $\tau_{1/2\text{destr}}$ 81 min			$\tau_{\text{rec}}$ 12 days. BO expressed in E. coli (eBO). Reaction with NH <sub>2</sub> OH in the dark and in the light were similar.	<a href="#">J.Biol. Chem., 1992, 267(10): 6757-6762</a>		
													$\tau_{1/2\text{destr}}$ 846 s in the dark			C13=C14 locked ABR tested an early photophysical events with subpicosecond time resolution. ABR cycle lack the characteristics of native bRh cycle, "I" ABR exhibit long lived decays of 18 ps, regenerating their original ground state.	<a href="#">Biochem M 2001 66(11) 1210-1219</a>		
																Light-Induced NH <sub>2</sub> OH reactions occur with SB C13= C14 locked ABR	<a href="#">Biophys J 1998 75(1) 413-417</a>		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-				464	574					4250	$\tau_{1/2\text{destr}}$ 375 s under light			<p>pKa (SBH<sup>+</sup>) 7.3, pKa (ABR SB) 11.5. Titrations of ABR data</p> <p>step-scan FT-IR data</p> <p>Primary Light-Induced Events in ABR  <math>h\nu \leq 30 \text{ fs}</math>  <math>\text{ABR} \rightarrow \text{H}^+(\text{FC}) \rightarrow</math>  <math>\rightarrow [\text{T}'_{460} \leftrightarrow \text{T}'_{660}] \rightarrow</math>  <math>\rightarrow \text{ABR}</math></p>	<p><a href="#">Biochem 1995, 34(37), 12059-12065</a></p> <p><a href="#">LaserChem 1999, 19(1-4), 169-172</a></p> <p><a href="#">JACS, 1996, 118(50), 12828-12829</a></p>		
		all-E-					578									<p>str. JW5. In aqueous solutions containing 100 mM NaCl. ABR T<sub>5,12</sub> transient species <math>\tau_{\text{decay}}</math> 18 ps. Laser-induced optoacoustic spectroscopy (LIOAS) was employed to inspect the ns-ms time region. Photothermal beam deflection data with the ABR suspensions. ABR no optical transients have been observed at times longer than several picoseconds.</p>	<p><a href="#">Photochem. Photo. biol. 2000, 72(5), 590-597</a></p>		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					576			NO	NO			slight sensitivity to in the dark		<p>str. S9. Potassium phosphate buffer pH 7.0. Femtosecond pump-probe spectroscopy ABR.</p> <p>In egg phosphatidylcholine vesicles. Flash photolysis at room and liquid nitrogen temperatures and Fourier-transform infrared difference spectroscopy data.</p> <p>Atomic force sensing (AFS) for dynamically probe ABR protein conformational changes with microsecond time resolution</p> <p>Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH<sub>2</sub>OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data.</p> <p>Primary dynamics of ABR in fs range.</p>	<p><a href="#">Chem. Phys. Letters 2003, 381(5-6), 549-555</a></p> <p><a href="#">Biophys. J. 1985, 47(4), 509-512</a></p> <p><a href="#">PNAS 1997, 94(15), 7937-7941</a></p> <p><a href="#">JBiolChem 2000, 275(28), 21010-21016</a></p> <p><a href="#">Chem. Phys. Lett. 1999, 314 429-434</a></p>		

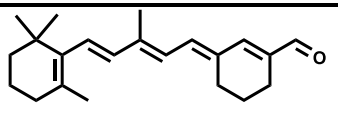
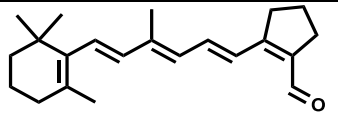
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	<p>Photoreduction process by NaBH<sub>4</sub> probing the photoreactivity of the SB of C13=C14 locked ABR</p> <p>Vibrational Spectrum of a ABR Picosecond Intermediate T5.12 (660 nm, &lt;3 ps formation and decay in 17ps) is measured by picosecond time-resolved coherent anti-Stokes Raman spectroscopy (PTR/CARS).</p> <p>New model of the primary events of the BRh photocycle. Picosecond intermediates appearing in the respective photo-reactions ABR are measured by coherent anti-Stokes Raman spectroscopy (CARS).</p> <p>Comparisons between the PTR/CARS spectra of "J-625" and "T5.12", in ABR with blocking C13=C14 isomerization, support the conclusion that the "J-625" structure reflects the reaction coordinates in the BRh photocycle that precede C13=C14 isomerization. Since these PTR/CARS</p>	<p><a href="#">Photochem Photobiol</a> <b>2002</b> <i>75</i>(6) 668-674</p> <p><a href="#">JACS</a> <b>2000</b> <i>122</i>(1) 96-106</p> <p><a href="#">Chem Physics</a> <b>2005</b>, <i>313</i>(1-3), 51-62.</p> <p><a href="#">JPhysChem A</a> <b>2000</b> <i>104</i>(18) 4130-4139</p>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-														<p>data show "J-625" to have an all-<i>trans</i> retinal, C13=C14 isomerization cannot be the primary reaction coordinate described in numerous models for the BRh photocycle.</p> <p>100 mM NaCl, 50 mM phosphate buffer, pH 7.0. <math>\tau_{\text{rec}}</math> 15 days. Femtosecond time-resolved mid IR and UV-vis spectroscopy. Excited state of ABR <math>\tau_{\text{decay}}</math> 18 ps.</p> <p>The fluorescence spectrum of ABR closely resembles that of BRh-570 although the relative fluorescence yield is higher (10-fold). Kinetic fits show that the red-absorbing intermediate "T5.12", appears within &lt;3 ps and decays with a time constant of <math>17 \pm 1</math> ps to form only ABR RR spectra of ABR.</p> <p>In ABR analogous dramatic changes associated with "I5.12" are arrested beyond the first 100 fs, reverting uniformly to the initial ground state with exponential</p>	<p><a href="#">J.Phys. Chem. B 2009, 113(22), 7851-7860</a></p> <p><a href="#">PNAS 1995, 92(6), 2101-2105</a></p> <p><a href="#">JPhysChemB 1999, 103(24), 5122-5130</a></p>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					578									time constants of 19 ps respectively. Evolution of "J625" BRh, are not, as previously thought, reliable measures of all-trans → 13-cis isomerization dynamics.		
		all-E-				460	+									Reaction Path Analysis of the Photoisomerization SB in ABR	<a href="#">JACS 2002, 124(15):4124-4134</a>	
		all-E-														PR/CARS and PTR/CARS data measured from the sample ABR	<a href="#">JPhysChem A 2003, 107(49):10787-10797</a>	
																$\tau_{\text{rec}}$ 4-5 days, spectrally and temporally resolved fluorescence properties of locked ABR	<a href="#">Biopolymers 2002, 67:306-309</a>	
140.		all-E-	374 <sup>a</sup>		460 <sup>a</sup>		NO			NO						str. R1S9	<a href="#">Recl. 1994, 113(1):45-52</a>	
		all-E-	384	362	440	393	NO			NO						str. 353P 5mM MES, 1mM EDTA pH 6.0.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a>	
141.		13Z-	376	360	442	420	548			NO			4380		stable in dark	str. 353P, 5mM MES, 1mM EDTA pH 6.0. $\tau_{\text{rec}}$ 72 h, reversible hydrolysis under light action. pKa (SB) 6.56.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-	366°		440	370sh 395sh 422, 440sh	547			NO		4480			330-/ 370+ / 510+ / 580-	10mM HEPES, pH 7.0. $\tau_{\text{rec}}$ 150 min Hydrolysis under light action.	<a href="#">Bioorgan. Khim. (Rus), 1993, 19(8), 825-835</a> <a href="#">JACS 1983, 105(15), 5162-5164</a> <a href="#">14</a>	
		13Z-					547 600									<a href="#">Biochem 1990, 29(25), 5948-5953</a> C13=C14 locked ABR tested an early photophysical events with subpicosecond time resolution. "I" ABR exhibit long lived decays 11 ps, regenerating their original ground state.	<a href="#">Biochem M 2001, 66(11), 1210-1219</a>	
		13Z-											$\tau_{1/2\text{destr}}$ 6300 s in the dark $\tau_{1/2\text{destr}}$ 100 s under light		Light-Induced NH <sub>2</sub> OH reactions occur with SB C13=C14 locked ABR	<a href="#">Biophys J 1998, 75(1), 413-417</a>	<a href="#">PNAS 1997, 94(15), 7937-7941</a> Atomic force sensing (AFS) for dynamically probe ABR protein conformational changes with microsecond time resolution	

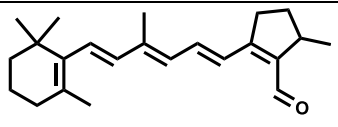
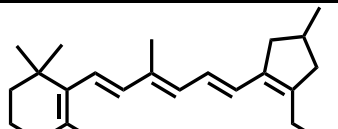
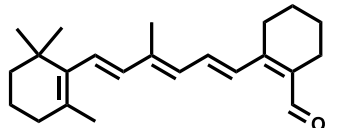
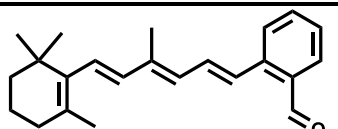
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-					550									<p>Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH<sub>2</sub>OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data.</p> <p>ABR was prepared from BRh, D85N, Y185F, and A103C mutants pH 7, 25°C <math>\tau_{\text{rec}}</math> 16 h. Light-induced protonated Schiff base hydrolysis reaction was studied. Two intermediates are formed during the hydrolysis reaction, H450 (<math>\lambda_{\max}</math> 450 nm) and H430 (<math>\lambda_{\max}</math> 430 nm). Upon blue light irradiation after the hydrolysis reaction, these intermediates rebind to the AM to reform ABR. Irradiation of the H450 intermediate forms the original pigment ABR, whereas irradiation of H430 at neutral pH results in a red shifted species (P580), which thermally decays back to ABR. ESR measurements.</p> <p>step-scan FT-IR data</p>	<p><a href="#">JBiolChem 2000 275(28):21010-21016</a></p> <p><a href="#">BiophysJ 2002 82(5):2617-2626</a></p> <p><a href="#">LaserCh</a></p>	

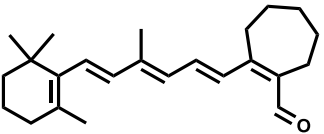
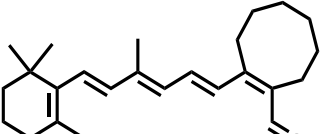
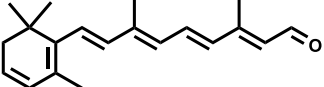
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		<a href="#">em 1999; 19(1-4); 169-172</a> <a href="#">Photochem Photobiol 2002; 75(6); 668-674</a> <a href="#">Chem. Phys. Letters 2003; 381(5-6); 549-555</a> <a href="#">JACS 2002; 124(15); 4124-4134</a> <a href="#">JPhysChemB 1999; 103(24); 5122-5130</a>
																	<p>Photoreduction process by NaBH<sub>4</sub> probing the photoreactivity of the SB of C13=C14 locked ABR</p> <p>str. S9. Potassium phosphate buffer pH 7.0. Femtosecond pump-probe spectroscopy ABR.</p> <p>Reaction Path Analysis of the Photoisomerization SB in ABR</p> <p>In ABR analogous dramatic changes associated with "15.13" are arrested beyond the first 100 fs, reverting uniformly to the initial ground state with exponential time constants of 11 ps respectively. Evolution of "J625" BRh, are not, as previously thought, reliable measures of all-trans → 13-cis isomerization dynamics.</p>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
142.		13Z-	370	365	445	420	548			NO		NO		4220				str. 353P, 5mM MES, 1mM EDTA pH 6.0. $\tau_{rec}$ 14 days	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a> <a href="#">Biolog. membranes (Rus), 1993, 10(4), 447-448</a>
143.		13Z-	370	365	445	415	NO			NO				-				str. 353P, 5mM MES, 1mM EDTA pH 6.0. pKa (SB) 6.52.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a> <a href="#">Biolog. membranes (Rus), 1993, 10(4), 447-448</a>
144.		13Z-	370	356	439	415	NO			NO				-				str. 353P, 5mM MES, 1mM EDTA pH 6.0.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a> <a href="#">Bioorgan. Khim. (Rus), 1993, 19(8), 825-835</a>
145.		13Z-	327, 369	338	420	343	NO			NO								str. R1, 50mM MES, pH 6.5. 24 h NC easy destroyed by Ag <sup>+</sup> / Triton X-100. C18-keton easy replaced NC	<a href="#">Bioorgan. Khim. (Rus), 1987, 13(8), 1116-1124</a>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				CD	others			
							(P)	DA	LA									
146.		13Z-	364	352	435	NO	NO										str. 353P, 5mM MES, 1mM EDTA pH 6.0.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a>
147.		13Z-	358	348	431	NO	NO										str. 353P, 5mM MES, 1mM EDTA pH 6.0.	<a href="#">Kirillova Yu.G. Ph.D. thesis, 1994</a>
<b>G. Alteration of the trimethylcyclohexenic ring. Ring modification</b>																		
148.		all-E-	396		471								4560				in water.	<a href="#">Biophys. J. 1986, 49(2), 479-483</a>
		all-E-						585	593	+		71		4140 4370			str. S9	<a href="#">Biochem Biophys. Res. Com. 1977, 78(2), 669-675</a>
		all-E-						590	602			+++		stable in the dark			str. R1	<a href="#">Biophys. J. 1977, 19, 191-198</a>
		all-E-						+				+++					str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">Biochem Soc. Trans. 1976, 4(4), 556-559</a>
		all-E-							593 $\epsilon$ 47500	603 $\epsilon$ 52200 606 77K			434 -60°C			DA-543+ /625- LA-555+ /577+	in water 2h or in 75% glycerol for low – temperature experiments. Spectrum of ABR is unchanged when pH 3.5 to 10.	<a href="#">Biochem. 1978, 17(10), 1915-1922</a>

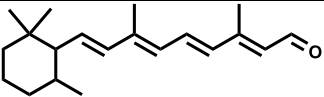
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-						603	+	434 77K	+++	95/5			/636-	str. R1. ABR tested by low temperature spectrophotometry at 77K. In 10mM phosphate buffer (pH 6.5). Glycerol was added to the sample to give a final concentration of 75%. Upon cooling from 272K (0°C) to 77K, the absorption maximum of ABR moved from 603 to 624 nm.	<a href="#">Photochem Photobiol.</a> <a href="#">1981.</a> <a href="#">33(4).</a> <a href="#">547-557</a>	
		all-E-	400		470		593	603			70			4690		str. 353-P, pH 6.0, 20-23°C. Cycle and ATP synthesis by ABR cells similar to BRh.	<a href="#">Archiv. Biochem Biophys.</a> <a href="#">1989.</a> <a href="#">270(1).</a> <a href="#">184 -197</a>	
		all-E-					593	603	+	+						Kinetics of the photo-induced processes in ABR	<a href="#">J. Photochem. Photobiol. B: Biology</a> <a href="#">2001.</a> <a href="#">62(3).</a> <a href="#">128-132</a>	
		all-E-	401 387°	381	463		592	603 $\epsilon$	430	+	+++			4710 5010		str. 353-P, pH 6.0, 20-23°C	<a href="#">29</a>	

### Properties of artificial bacteriorhodopsin analogs

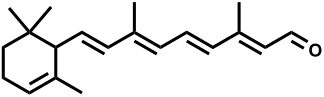
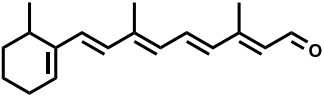
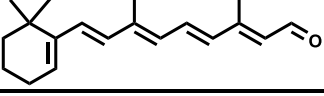
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					594									542+	in 20 mM sodium phosphate buffer, pH 7.0. CD spectra.	<a href="#">Chirality 2006, 18(2), 72-83</a>
		all-E-					592 589 580 593	603 596 582 600									str. 353-P, ET1001, D96N, 100 mM NaCl, 5 mM MES, pH 6.0, 20-23°C, $\tau_{\text{rec}}$ 1h. str. 353-P str. ET1001 str. D96N str. JW5 ABR cycle similar to BRh (M, O). "M" time constants ABR ( $\tau_{\text{Mdec}}$ ) coincide with BRh data.	<a href="#">Biolog. membranes (Rus), 2009, 26(3), 40-46</a> <a href="#">Rus. J. Bioorg. Chem., 2002, 28(6), 487-493</a> <a href="#">Mironov a E.V. Ph.D. thesis, 2002</a>
		all-E-				603			425				5010				In 100 mM NaCl, 5 mM MES, 3 mM potassium citrate, pH 6.0.	<a href="#">Sensors and Actuators B: 1997, 39(1-3), 218-221</a> <a href="#">Mol. Cryst. Liq. Cryst. 2000, 345, 317-322</a>
																	str. S9 Model of the color sensitive artificial	<a href="#">BioSystems 2000, 54(3)</a>

### Properties of artificial bacteriorhodopsin analogs

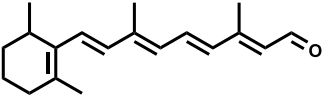
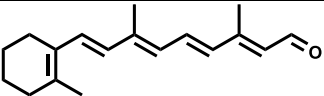
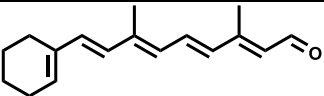
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
																retina with wild type 3,4-didehydro and 4-oxo-ABR	131-140		
																WT BRh 3,4-didehydro-ABR and 4-oxo-ABR, were studied as potential materials for optoelectronic and molecular electronic applications. Thick-film elements based on the three types of BRh and PVA were prepared to determine the photoelectric properties of the materials for the development of a color-sensitive optoelectronic sensor.	Optical Mater 2004, 27(1), 57-62		
149.		all-E-			431		466	466	464			65/35 31/69	1750 1650				pH 7.0, 50 mM Hepes	Photochem Photobiol 1991, 54(6), 969-976	
		all-E-5,6-trans	370		430				478					2340				Biophys J 1986, 49(2), 479-483	
		all-E-5,6-cis	369		432				467					1740					
		all-E-	368 <sup>a</sup>			395		475 $\epsilon$ 53600	475	+	370	+++	60/40		destroyed after 1h in the dark	$\tau_{1/2repl}$ 10h		in distilled water at 25°C pH 6.8. $\tau_{rec}$ 30 min, L→D-adaptation faster, than in BRh. At 77 K "K" formed then →"M" $\tau_{1/2Mdec}$ ABR 2min.	Biochem 1981, 20(2), 428-435
		all-E-	370		425			476						2500					



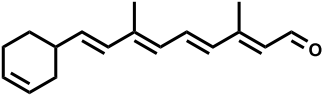
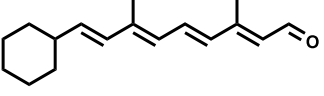
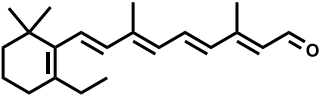
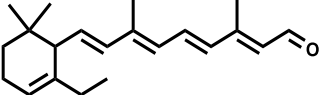
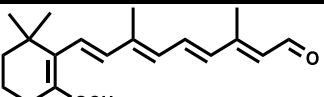
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		in 20 mM sodium phosphate buffer, pH 7.0. CD spectra.	<a href="#">Chirality</a> 2006 18(2) 72-83
150.		all-E-  13Z-	370 <sup>b</sup> $\epsilon$ 48800			492 $\epsilon$ 68000		484	+		+	85/15 60/40		unstable $\tau_{1/2\text{destr}}$ 40 min, 20°C				str. AO151, cells suspensions or BO at pH 5.5-7.5. $\tau_{\text{rec}}$ 150 min. Transient changes in flash photolysis ABR two species were found. One 520 nm $\tau_{\text{form}}$ 100ms, $\tau_{1/2\text{decay}}$ 400 ms and 370 nm $\tau_{\text{form}}$ 10ms. Neither of these species were comparable to the BRh cycle.	<a href="#">FEBS Lett.</a> 1980 117(1) 363-367.
		all-E-			430	476	476	472	+			70/30 45/55	2250 2050					pH 7.0, 50 mM Hepes	<a href="#">PhotochemPhotobiol</a> 1991 54(6) 969-976
		all-E-				495												str. ET1001. In 4 M NaCl, 25 mM Tris-HCl buffer, pH 7.2 $\tau_{1/2\text{rec}}$ 5 min	<a href="#">PhotochemPhotobiol</a> 1994 60(4) 388-393
		all-E-	368		431			484					2540					In water.	<a href="#">BiophysJ</a> 1986 49(2) 479-483
151.		all-E-	392		465		537	549			40		3100 3300		stable			str. R1S9	<a href="#">Recl.</a> 1987 106(4) 112-119
152.		all-E-	388		453	420/ 460	540	548			70	50/50 100/0	3600 3800		stable			str. R1S9 $\tau_{\text{rec}}$ in 3 faster than BRh. in H <sub>2</sub> O	<a href="#">Recl.</a> 1987 106(4) 112-119

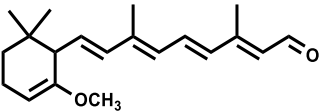
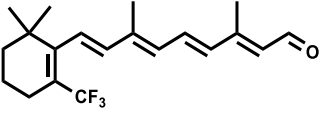
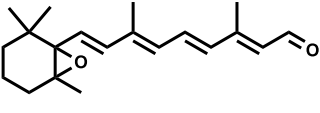
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-	388 <sup>a</sup>			420/460	550	546	551	410	+++ 114	62/38 92/8		$\tau_{1/2\text{destr}}$ 40 min, 20°C in the dark.		str. R <sub>1</sub> M <sub>1</sub> , in 70 mM potassium phosphate, pH 6.5. $\tau_{\text{rec}}$ 20 min. ABR cycle compared to BRh. "M" $\tau_{\text{form}}$ 1.5 ms, "O" 640 nm $\tau_{\text{form}}$ 9 ms. str. W296.	<a href="#">Biochem 1983 22(11) 2637-2644</a>	
		13Z-	381 <sup>a</sup>			420/460	533											
		all-E-	388 <sup>a</sup>			420/460	548	540	548	70		50/50 100/0		stable		str. R1S9, $\tau_{\text{rec}}$ 15 min	<a href="#">FEBSL 1983 154(1) 180-184</a>	
		13Z-	381 <sup>a</sup>			420/460	535	540	548			50/50 100/0						
		11Z-9Z-	384 <sup>a</sup> 380 <sup>a</sup>			425 NO	NO NO											
153.		all-E-	396		470		558		566		99		3350 3600		stable	str. R1S9	<a href="#">Recl. 1987 106(4) 112-119</a>	
154.		all-E-	401		474		553		564		96		3000 3400		stable	str. R1S9	<a href="#">Recl. 1987 106(4) 112-119</a>	
		all-E-					552 592 560									in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys. J. 1989 56(6) 1259-1265</a>	
155.		all-E-	387		458		539		544		57		3300 3500		stable	str. R1S9 $\tau_{\text{rec}}$ in 1.5 faster than BRh. in H <sub>2</sub> O.	<a href="#">Recl. 1987 106(4) 112-119</a>	
		all-E-		368	457		535		545	410			3190 3200			pH 6.5 Hepes buffer.	<a href="#">Retinal Proteins 1987 205-216</a>	

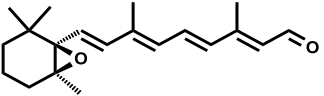
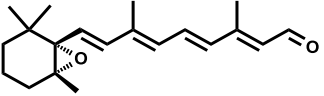
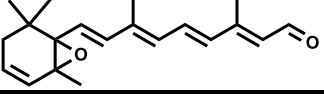
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-			457		535		545	+	410			3190 3200				pH 7.0, HEPES buffer. ABR cycle compared to BRh. Short-lived "K", long-lived "M".	<a href="#">FEBS Lett. 1984. 166(2): 245-247</a>
156.		all-E-					495	495		+	+	+				stable		str. ET1001 ABR cycle compared to BRh. str. JW 2N white membrane cells for H <sup>+</sup> -pump.	<a href="#">Photochem Photobiol 1991 54(6): 873-879</a>
157.		all-E-					485											str. ET1001. In 4 M NaCl, 25 mM Tris-HCl buffer, pH 7.2, $\tau_{1/2\text{rec}}$ 2 min.	<a href="#">Photochem Photobiol 1994 60(4): 388-393</a>
158.		all-E-  13Z-	378 <sup>b</sup>			420	504 In H <sub>2</sub> O $\epsilon$ 50000 545 in 4M NaCl					++						str. JW 5 white membrane cells, $\tau_{\text{rec}}$ 4 min	<a href="#">Angew Chem IE 1987 26(6): 580-583</a>
159.		all-E-					450											str. ET1001. In 4 M NaCl, 25 mM Tris-HCl buffer, pH 7.2, $\tau_{1/2\text{rec}}$ 15 min	<a href="#">Photochem Photobiol 1994 60(4): 388-393</a>
160.		all-E- $\beta$ -isomer	385				570					20 ( $\alpha+\beta$ )						str. JW 5 white membrane cells	<a href="#">Angew Chem IE 1987 26(6): 580-583</a>

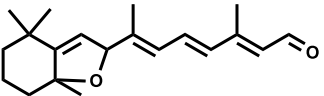
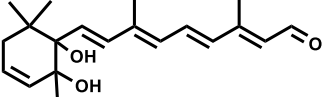
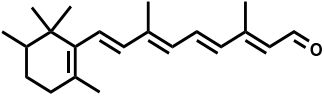
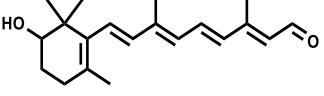
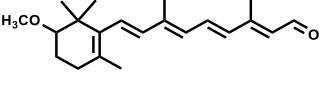
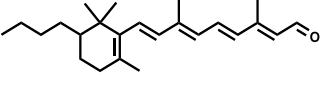
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
161.		all-E- $\alpha$ -isomer					460				20 ( $\alpha+\beta$ )						str. JW 5 white membrane cells	<a href="#">Angew Chem IE</a> 1987, 26(6), 580-583
162.		all-E-		350	418		465				0		2400					<a href="#">Photochem. Photo. biol.</a> 1993, 58(5), 701-705
		all-E-	360	350	418		465	465	465	NO	0	70/30 30/70	2400 2400					<a href="#">JACS</a> 1986, 108(19), 6077-6078 <a href="#">Tetrahedron L.</a> 1989, 26(50), 6209-6212
163.		all-E-rac	362		420		452		+		2.5-16		1690 1690		stable	415- /500-	str. 353-P, pH 6.0, 20-23°C, $\tau_{\text{rec}}$ 30 min ABR cycle kinetics drastically slowed $\phi_{\text{rel}}$ 0.14±0.06.	<a href="#">Archiv. Biochem. Biophys.</a> 1989, 270(1), 184-197 <a href="#">Biolog. membranes (Rus.)</a> 1984, 1(11), 1125-1142 <a href="#">Rus. J. Bioorg. Chem.</a> 2002, 28(6), 487-493
		13Z-rac							452									
		all-E-(5S,6R)	249, 365 <sup>a</sup>		421 <sup>e</sup>		485 $\epsilon$				7	95/5 50/50	3100 2830		stable $\tau_{1/2}$ repl	245+ /355-	str. R <sub>1</sub> CD-ABR-460(+), 520 (-)	<a href="#">Biochim. Biophys.</a>

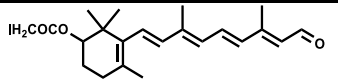
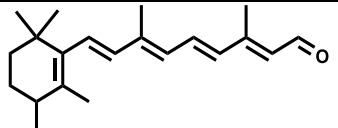
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-	$\epsilon$ 45300 253, 358 <sup>a</sup>				41000							8000 min	CHO	$\tau_{1/2\text{rec}}$ 400s, 10°C X-rays diffraction data	<a href="#">Acta. 1987. 891(2).</a> <a href="#">177-193</a>	
		all-E- (5R,6S)	249, 365 <sup>a</sup> $\epsilon$ 45300		421 <sup>e</sup>		445 $\epsilon$ 40000		445		+	96/4 48/52	1300	stable $\tau_{1/2 \text{ repl}}$ 260 min	245- /355 + CHO	CD-ABR-435(+), 490 (-) sh $\tau_{1/2\text{rec}}$ 48s, 10°C X-rays diffraction data		
		13Z-	253, 358 <sup>a</sup>												250- /350 + CHO			
		all-E-rac					+									str. R <sub>1</sub> M <sub>1</sub> cells suspensions with 1 mM nicotine	<a href="#">Biochem Soc. Trans. 1976. 4(4). 556-559.</a>	
		all-E-rac					452			375			1680			In 100 mM NaCl, 5 mM MES, 3 mM potassium citrate pH 6.0.	<a href="#">Sensors and Actuators B: 1997. 39(1-3). 218-221.</a> <a href="#">Mol. Cryst. Liq. Cryst. 2000. 345. 317-322</a>	
164.		all-E-	363		422		460						1960				<a href="#">23</a>	

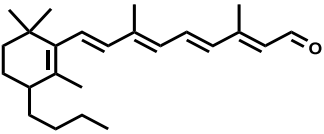
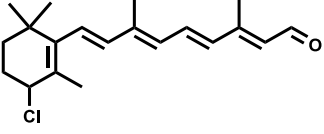
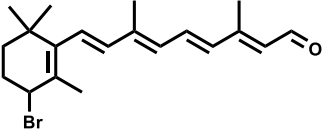
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1}cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
165.		all-E-	331		380		412		412				2040			430+ /370-		<a href="#">29</a>
166.		all-E-	365				465											<a href="#">29</a>
167.		all-E-					557 558 556										In water. pH 7.0 pH 2.5 pH 0.5  Molecular Dynamics Study ABR  Molecular Dynamics Study ABR	<a href="#">BiophysJ</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259</a> <a href="#">1265</a>  <a href="#">Biochem</a> <a href="#">1994</a> <a href="#">33(12)</a> <a href="#">3668</a> <a href="#">3678</a>  <a href="#">BiophysJ</a> <a href="#">1995</a> <a href="#">68(4)</a> <a href="#">1270</a> <a href="#">1282</a>
168.		all-E-	380 <sup>a</sup>				520										Protein- $\beta$ -Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes.	<a href="#">JPhysChem B</a> <a href="#">2003</a> <a href="#">107(25)</a> <a href="#">6221</a> <a href="#">6225</a>
169.		all-E-	380 <sup>a</sup>				470										Protein- $\beta$ -Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes.	<a href="#">JPhysChem B</a> <a href="#">2003</a> <a href="#">107(25)</a> <a href="#">6221</a> <a href="#">6225</a>
170.		all-E-	380 <sup>a</sup>				460										Protein- $\beta$ -Ionone Ring Interactions. Second harmonic generation (SHG) to probe the	<a href="#">JPhysChem B</a> <a href="#">2003</a> <a href="#">107(25)</a>

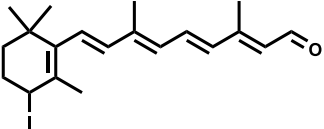

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	light-induced dipolar changes.	<a href="#">6221-6225</a>
171.		all-E-	222, 240, 362 <sup>a</sup>				510		510									<a href="#">J. Sci. Ind Res. 1982. 41(11). 665-673</a>
172.		all-E-			438		470	470	470	+		62/38 62/38	1550 1550				50 mM Hepes, pH 7.0	<a href="#">Photochem Photobiol 1991 54(6): 969-976</a>
		all-E-					462 494 505			+							in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys J 1989 56(6): 1259-1265</a>
		all-E-		360	440		465/ 550sh			+	390			1220 4500			Hepes buffer pH 7.0. ABR consists from 2 species with independent cycles.	<a href="#">Retinal Proteins 1987. 205-216</a>
																		<a href="#">JACS 1984 106(8): 2435-2437</a>
																		<a href="#">Biochem 1994 33(12): 3668-3678</a>
																		<a href="#">Biophys J 1995 68(4): 1270-1282</a>

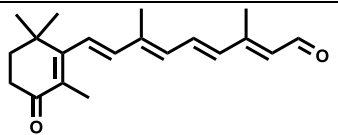
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			+				M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
173.		all-E-					465		465	+	390						Hepes buffer pH 7.0. ABR consists from 2 species with independent cycles.	<a href="#">JACS 1984, 106(8), 2435-2437</a>	
		all-E-		360	440		465/550sh			+			1220 4550					<a href="#">Retinal Proteins 1987, 205-216</a>	
		all-E-					469 503 510										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">BiophysJ 1989, 56(6), 1259-1265</a>	
174.		all-E-	348°					462		NO							30 mM sodium phosphate buffer, pH 7.2 unstable. On standing for several hours, or on exposure to light, the ABR absorption maximum shifts to 530 nm	<a href="#">Photochem. Photo. Biol. 1986, 43(3), 297-303</a>	
175.		all-E-	352°					460		NO							30 mM sodium phosphate buffer, pH 7.2 unstable. On standing for several hours, or on exposure to light, the ABR absorption maximum shifts to 530 nm	<a href="#">Photochem. Photo. Biol. 1986, 43(3), 297-303</a>	
		all-E- 11,12- <sup>3</sup> H						470 464 470 NO									str. IV-8, in 50 mM sodium phosphate buffer, pH 7.4. WT Met118Cys Thr121Cys Ser141Cys	<a href="#">Biochem 1994, 33(38), 11624-11630</a>	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	<p>Incorporation of tritiated chromophore into the Met118Cys mutant ABR. Modified by N-ethylmaleimide BO formed a pigment with 4-bromoretinal but no cross-linking was observed, providing evidence that the cross-linking of the chromophore is to the Cys118 (ABR470nm)</p> <p>MD analysis suggests the following ranking of binding site mutants in order of reactivity: R118C&gt; S118C&gt;&gt; S121C&gt; R141C&gt;&gt; S141C&gt;&gt;&gt; R121C, R138C, S138C. Chiral center of 4-bromo-Ret produces variable impact on potential crosslinking. Chirality appears to have limited effect for the M118C mutants but shows more dramatic impact for the T121C and S141C mutants.</p>	<a href="#">Biochem MolBiol</a> <a href="#">nter</a> <a href="#">1999</a> <a href="#">47(5)</a> <a href="#">773-780</a>
176.		all-E-	340°				455		NO							<p>30 mM sodium phosphate buffer, pH 7.2 unstable. On standing for several hours, or on exposure to light, the ABR absorption maximum shifts to 530 nm</p>	<a href="#">Photochem. Photo. Biol.</a> <a href="#">1986</a> <a href="#">43(3)</a> <a href="#">297-303</a> 	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.		
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others			
							(P)	DA	LA											
177.		all-E-	294, 380 $\epsilon$ 43700		445		506		506		+			2710 2710			390+ /462 + /540-	str. R1 in water $\tau_{\text{rec}}$ 24 h	<a href="#">Bioorgan Khim (Rus), 1979, 5(7), 1053-1058</a>	
		13Z-	294, 373 $\epsilon$ 35300				506		506		+						470+ /535-			
		all-E-	380 $\epsilon$ 43700				506				+								str. R1, in 50 mM phosphate buffer at pH 7.0	<a href="#">Bioorgan Khim (Rus), 1981, 7(11), 1731-1733</a>
		all-E-	378 <sup>a</sup>	369 <sup>a</sup>	425 <sup>a</sup>		524		506		502	+	410- 412	+	4400 3770 3610	stable till 1h in 20 mM	stable		in distilled water, pH 7.0. $\tau_{\text{rec}1/2} \sim 5$ min "M"-intermediate decay kinetics and proton uptake are much slower than in BRh.	<a href="#">Photochem. Photo biol. 1991, 54(6), 977-983.</a> <a href="#">Biochem 1991, 30(11), 2976-2988</a>
		all-E-					520												str. R1M1 cells grows in presence of 4-oxo-Ret when synthesis of natural Ret blocked.	<a href="#">FEBSL 1976, 71(2), 333-336.</a>
		all-E-			425		527			511		+			4550 3960				str. 353-P, pH 6.0.	<a href="#">Biokhim (Rus), 1989, 54(1), 136-138</a>
		13Z-					504				507	+								
		all-E-	380	369	425		506						25-70		3770				str. 353-P, pH 6.0, 20-23°C. $\phi_{\text{rel}}$ 0.7±0.1.	<a href="#">Archiv. Biochem</a>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-  13Z-					527  504			410							4-oxoRet formed with BO ABR. ABR cycle with drastically slowed intermediates and high value of $\phi_{\text{rel}}$ . all-E-4-oxo-ABR cycle has full period in a several min. "M" formation rate close to BRh, but its decay is in biphasic mode. One component compared to control BR and tails contain slowed components. It was compared the kinetics of spectral transformations of individual forms of E- and Z-4-oxo-ABR and it was found that the E-cycle contains no long-wavelength intermediates, and all signals recorded in this region on uncontrolled samples are a summary of "K"like long-lived intermediates of the Z-isomer cycle.	<a href="#">Biophys.</a> <a href="#">1989.</a> <a href="#">270(1).</a> <a href="#">184-197</a> <a href="#">Biolog.</a> <a href="#">membra</a> <a href="#">nes</a> <a href="#">(Rus).</a> <a href="#">1984.</a> <a href="#">1(11).</a> <a href="#">1125-</a> <a href="#">1142.</a> <a href="#">Vestnik</a> <a href="#">St-</a> <a href="#">Peterbur</a> <a href="#">g</a> <a href="#">Univer.</a> <a href="#">Ser 3</a> <a href="#">2012.</a> <a href="#">(4).</a> <a href="#">82-</a> <a href="#">92</a> <a href="#">Biochem</a> <a href="#">(M)</a> <a href="#">2012.</a> <a href="#">77(9).</a> <a href="#">1008-</a> <a href="#">1010</a>

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					526 527	527 526 527 490	511 508 503 483								str. 353-P, ET1001, D96N, 100 mM NaCl, 5 mM MES, pH 6.0, 20-23°C, $\tau_{\text{rec}}$ 1h. str. 353-P str. ET1001 str. D96N in str. JW5 cells. Both for ET1001 and for D96N strains the "M"-relaxation of the 4-oxo-ABR was distinctly biphasic, with the slow phase comprising about 10–15% of the signal amplitude. For ABR the efficiency of the "M"-intermediate formation did not exhibit any reliable dependence on the point mutation. It was shown an additional deceleration of "M"-relaxation of the 4-oxo-ABR in D96N str.	<a href="#">Biolog. membranes (Rus.) 2009, 26(3), 40-46</a> <a href="#">Rus. J. Bioorg. Chem., 2002, 28(6), 487-493</a> <a href="#">Mironov a E.V. Ph.D. thesis, 2002</a>
		all-E-				506			+	410					In 100 mM NaCl, 5 mM MES, 3 mM potassium citrate, pH 6 and in PVA dry films.	<a href="#">Sensors and Actuators B: 1997, 39(1-3), 218-221</a> <a href="#">Mol. Cryst. Liq. Cryst. 2000, 345, 317-322</a>		
															The effect of pH and	<a href="#">Biophys</a>		

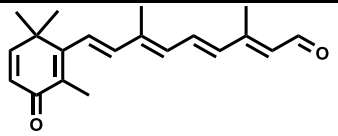
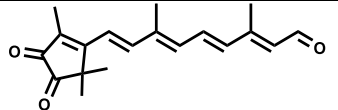
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	<p>sodium azide on the photochemical cycle of 4-oxo-ABR has been investigated</p> <p>The effect of applied constant electric field was investigated (<math>10^7</math> V/m) on spectral properties of 4-oxo-ABR embedded in the gelatin-based matrix.</p> <p>ABR cycle was investigated in water suspension by pulse and low-temperature absorption spectroscopy. The scheme of ABR photochemical reactions was proposed.</p> <p>Incorporation of the 4-oxo-Ret into D85N AM was unexpectedly slow: more than 10 days were required, and the yield was &lt; 10%. It was demonstrated that electric field-induced SB deprotonation take place. SB pK = 6.15.</p> <p>Spectral and kinetic transformation studies of gelatin films based on 4-oxo WT ABR and D96N mutant ABR were carried out using absorbance spectroscopy. It was studied the influence</p>	<p>(Rus), 1992, 37, 79-84</p> <p>Biophys (Rus), 1992, 37, 86-90</p> <p>Biologic heskie Membrany 1991, 8(5), 460-467</p> <p>Thin Solid Films, 1997, 302(1-2), 231-234</p> <p>Thin Solid Films, 1997, 293(1-2), 281-284</p>

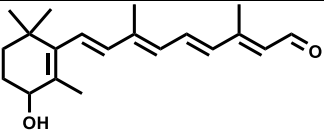
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																<p>of chemical additives and sodium azide on "M"-decay kinetics.</p> <p>str. 353P, R1M1 or ET-1000 Photochromic and electrochromic spectral properties of 4-oxo-ABR embedded in a polymer matrix were studied.</p> <p>str. R1M1 or ET-1000 Photochemical reactions in a 4-oxo-ABR were studied by using low-temperature and pulsed laser absorption spectroscopy.</p> <p>WT BR, 3,4-didehydro-ABR and 4-oxo-ABR, were studied as potential materials for optoelectronic and molecular electronic applications. Thick-film elements based on the three types of BRh and PVA were prepared to determine the photoelectric properties of the materials for the development of a color-sensitive optoelectronic sensor</p> <p>WT PM. theoretical model for the nonlinear transmittance</p>	<p><a href="#">BioSystems 1995 35(1) 129-132</a></p> <p><a href="#">BioSystems 1995 35(1) 133-136</a></p> <p><a href="#">Optical Mater 2004 27(1) 57-62</a></p> <p><a href="#">Optical Mater 1999 12(4)</a></p>	

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No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	properties of 4-oxo-ABR.  str. S9 Model of the color sensitive artificial retina with WT 3,4-didehydro and 4-oxo-ABR  compared the proton uptake and release of WT and two mutant BRh D96N, D85N in ABR films or L-B layers on ATO	473-480 <a href="#">ProcSPI E 1998</a> 3347, 58-60  <a href="#">BioSystems 2000</a> , 54(3) 131-140  <a href="#">BioelectrochemBioenergetics 1997</a> 44(1)-37-43
178.		all-E-	380 <sup>a</sup>	370 <sup>a</sup>	426 <sup>a</sup>		522	508	500	+	400	+		4400 3700 3470	stable till 1h in 20 mM	stable	in distilled water pH 7.0. $\tau_{1/2\text{rec}} \sim 5$ min "M"-intermediate decay kinetics and proton uptake are much slower than in BRh.	<a href="#">Photochem. Photobiol.</a> 1991, 54(6), 977-983.  <a href="#">Biochem</a> 1991 30(11), 2976-2988
179.		all-E-	435 <sup>a</sup> $\epsilon$ 45000	442 <sup>a</sup>	455 <sup>a</sup>		515	500	500	+	360-370			2600 1980 1980	stable till 1h in 20 mM		in distilled water pH 7.0. $\tau_{\text{rec}} \sim \text{BRh}$ $\tau_{1/2\text{Mdec}} \gg 200\text{ms}$	<a href="#">Photochem. Photobiol.</a> 1991.

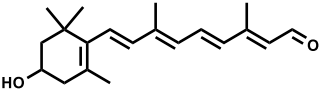
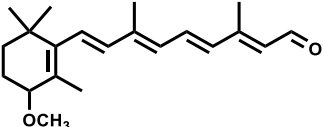
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																	cross-links with Arg residues doesn't formed.	<a href="#">54(6)</a> , <a href="#">977-983</a> , <a href="#">Biochem 1991</a> , <a href="#">30(11)</a> , <a href="#">2976-2988</a>	
180.		all-E-	254, 375 $\epsilon$ 40100		440		535		543	+			4040 4310			360+ /420- /520 +/ 577-	str. R1 in water $\tau_{rec}$ 24 h	<a href="#">Bioorgan Khim 1979</a> , <a href="#">5(7)</a> , <a href="#">1053-1058</a>	
		13Z-	254, 375 $\epsilon$ 30800		440		530		543				4040 4310			380+ /503 +/ 577-			
		all-E-			437		525	525	527	+		85/15 65/35	3800 3900				50 mM Hepes, pH 7.0	<a href="#">Photochem Photobiol 1991</a> , <a href="#">54(6)</a> , <a href="#">969-976</a>	
		all-E-					535		540								in 50 mM sodium acetate buffer pH 5.5.	<a href="#">Photochem Photobiol 1981</a> , <a href="#">33(4)</a> , <a href="#">489-494</a>	
		all-E-	370°				530		540	+	400	+++					30 mM sodium phosphate buffer, pH 7.2	<a href="#">Photochem Photobiol 1986</a> , <a href="#">43(3)</a> , <a href="#">297-303</a>	
		all-E-					540										in 67 mM phosphate buffer at pH 7.0	<a href="#">Photochem Photobiol 1981</a> , <a href="#">33(4)</a> , <a href="#">483-488</a>	

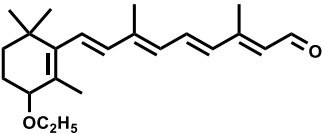
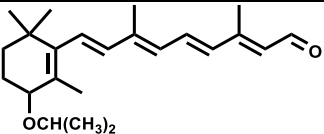
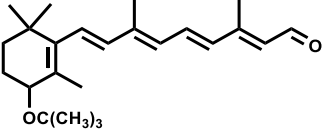
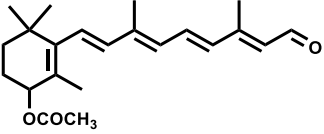
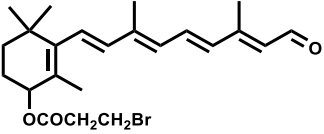
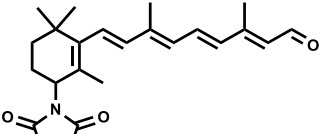
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No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-		360	440		550			+			4550				Hepes buffer pH 7.0.	<a href="#">Retinal Proteins</a> 1987, 205-216	
		all-E-					530			+	390						Hepes buffer pH 7.0	<a href="#">JACS</a> 1984, 106(8), 2435-2437	
		all-E-	375 $\epsilon$ 40100				538			+							str. R1, in 50 mM phosphate buffer at pH 7.0	<a href="#">Bioorgan. Khim. (Rus.)</a> 1981, 7(11), 1731-1733	
		all-E-	375		440		538			+	400	+++		4140			str. 353-P, pH 6.0, 20-23°C. Cycle ABR ("M" "O") similar to BRh, but time constants altered. Rate of "M"-intermediate decay is higher than the relaxation rate to ABR. $\phi_{\text{rel}} 0.7 \pm 0.1$ .	<a href="#">Archiv. Biochem. Biophys.</a> 1989, 270(1), 184-197	
		all-E-	375		440		538			+	400	+++		4140			str. 353-P, pH 6.0, 20-23°C. Cycle ABR ("M" "O") similar to BRh, but time constants altered. Rate of "M"-intermediate decay is higher than the relaxation rate to ABR. $\phi_{\text{rel}} 0.7 \pm 0.1$ .	<a href="#">Biolog. membranes (Rus.)</a> 1984, 1(11), 1125-1142	
		all-E-					538			+	400						In 100 mM NaCl, 5 mM MES, 3 mM potassium citrate pH 6.0.	<a href="#">Sensors and Actuators B:</a>	

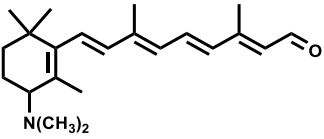

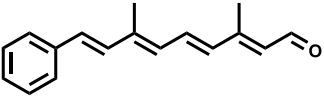

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		1997, 39(1-3), 218-221	
181.		all-E-					556 610 552										in water. pH 7.0 pH 2.5 pH 0.5	Biophys.J 1989 56(6) 1259-1265	
182.		all-E- 4- [O <sup>13</sup> CH <sub>3</sub> ]	370 $\epsilon$ 42000			+	470									450+	str. R1, in 50 mM phosphate buffer at pH 7.0	Biorgan.Khim (Rus), 1981, 7(11), 1731-1733	
		all-E-	370		440		475		+		+		1680				str. 353-P, pH 6.0, 20-23°C, ABR consists from at least 2 species with independent cycles. No long-wave intermediates were detected in 4-methoxy-ABR. $\phi_{\text{rel}}$ 0.15±0.04.	Biolog.membranes (Rus), 1984, 1(11), 1125-1142	
		all-E-	370		440		475		+		+		1680				str. 353-P, pH 6.0, 20-23°C, ABR consists from at least 2 species with independent cycles. No long-wave intermediates were detected in 4-methoxy-ABR. $\phi_{\text{rel}}$ 0.15±0.04.	Archiv.Biochem.Biophys. 1989, 270(1), 184-197	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
183.		all-E-	375 $\epsilon$ 43000			+	500									460+	str. R1, in 50 mM phosphate buffer at pH 7.0	<a href="#">Bioorgan (Rus), 1981, 7(11), 1731-1733</a>
184.		all-E-	375 $\epsilon$ 40000			+	500-530									460+	str. R1, in 50 mM phosphate buffer at pH 7.0	<a href="#">Bioorgan (Rus), 1981, 7(11), 1731-1733</a>
185.		all-E-	375 $\epsilon$ 40500			+	500-530									460+	str. R1, in 50 mM phosphate buffer at pH 7.0	<a href="#">Bioorgan (Rus), 1981, 7(11), 1731-1733</a>
186.		all-E-	375 $\epsilon$ 41000			+	470									470+	str. R1, in 50 mM phosphate buffer at pH 7.0. slowly hydrolysed in 4-hydroxy-ABR	<a href="#">Bioorgan (Rus), 1981, 7(11), 1731-1733</a>
187.		all-E-	375 $\epsilon$ 40500			+	455										str. R1, in 50 mM phosphate buffer at pH 7.0. easily hydrolysed in 4-hydroxy-ABR	<a href="#">Bioorgan (Rus), 1981, 7(11), 1731-1733</a>
188.		all-E-	376	355	436		457		460				1050 1200				str R1S9, pH 7.0 $\tau_{\text{rec}}$ 4 h	<a href="#">29</a>

### Properties of artificial bacteriorhodopsin analogs

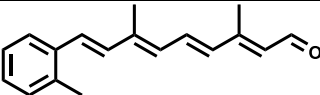
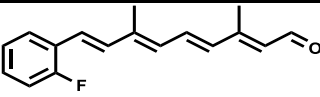
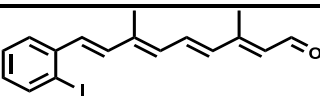
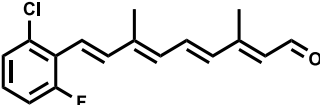
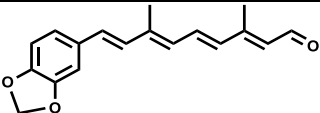
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			+				M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
189.		all-E-					455			455	+	390					Hepes buffer pH 7.0.	<a href="#">JACS</a> <a href="#">1984</a> <a href="#">106(8)</a> <a href="#">2435-</a> <a href="#">2437</a>	
		all-E-		360	440		455						750				Hepes buffer pH 7.0	<a href="#">Retinal</a> <a href="#">Proteins</a> <a href="#">1987</a> <a href="#">205-216</a>  <a href="#">Biochem</a> <a href="#">1994</a> <a href="#">33(12)</a> <a href="#">3668-</a> <a href="#">3678</a>  <a href="#">Biophys J</a> <a href="#">1995</a> <a href="#">68(4)</a> <a href="#">1270-</a> <a href="#">1282</a>	
<b>H. Alteration of the trimethylcyclohexenic ring. Replacement ring to aromatic or heterocyclic fragments</b>																			
190.		all-E-	391 $\epsilon$ 56700	371	452		508		504	+	+	+	2440 2260				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10-12 h	<a href="#">Bioorgan</a> <a href="#">Khim.</a> <a href="#">1987</a> <a href="#">13(2)</a> <a href="#">238-251</a> 	
		13Z-	385 $\epsilon$ 55400	368	448		499		501	+	+		2280 2360						<a href="#">Photoche</a> <a href="#">mPhotobiol</a> <a href="#">1981</a> <a href="#">33(4)</a> <a href="#">483-488</a>
		all-E-			455			480					1150				str. R1, pH 7.0 in water		
		all-E-	388 <sup>a</sup>	357, 372, 387	453	+		480		487	+			1240 1540			485+ 555-	str. R1, in 10mM HEPES buffer, pH 7.0	<a href="#">Photoche</a> <a href="#">m.Photo</a> <a href="#">biol.</a> <a href="#">1984</a> <a href="#">39(5)</a> <a href="#">661-665</a>



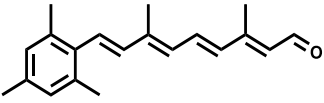
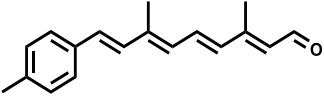
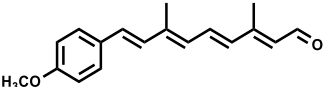
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-					499		504	+	+	20-50					str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C. $\phi_{rel} > 0.5$ . all-E-ABR cycle has "M" and compared with BRh cycle. In 13Z-ABR cycle "M" absent and have at least 2 long-waved intermediates. L-D-adaptation drastically retarded.	<a href="#">Biokhimiia (Rus.), 1987, 52(9), 1559-1569.</a> <a href="#">Biokhimiia (Rus.), 1993, 58(6), 819-826</a> <a href="#">Colloque INSERM 1992, 221, 167-170</a>
		all-E-					512 509 508	508	508	+	+						str. 353-P, ET1001, D96N, 100 mM NaCl, 5 mM MES, pH 6.0, 20-23°C, $\tau_{rec}$ 1h. str. 353-P str. ET1001 str. D96N ABR cycle similar to BRh (M, O). Strong retardation of "M" time decay ABR ( $\tau_{Mdec}$ ) it was shown for str. ET1001 BRh and mutant D96N.	<a href="#">Biolog. membranes (Rus.), 2009, 26(3), 40-46</a>
		all-E-					500										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>
		all-E-					480 / 520										in 20 mM phosphate buffer (pH 7, 298 K) in the dark	<a href="#">Biochemistry, 2003, V. 42 №38.</a>

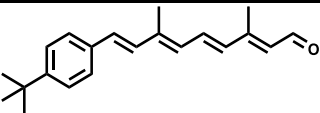
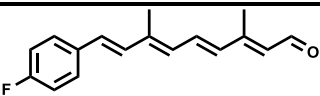
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
191.		all-E- 13Z-	387 <sup>a</sup> 381 <sup>a</sup>		453		540 dif +				5/95	3560				str. R1M1 in 5 mM phosphate buffer, apomembrane suspensions in 50% glycerol pH 6.6, 20°C	<a href="#">P. 11281-11288.</a> <a href="#">Biochem 1984, 23(11), 2507-2513</a>		
192.		13Z- all-E-	383 380				504 492 $\epsilon$ 43000 506 $\epsilon$ 54000					2960				str. R <sub>1</sub> M <sub>1</sub> 100 mM sodium acetate buffer pH 5.0, $\tau_{\text{rec}} \sim \text{h}$ . X-ray photoelectron spectroscopy	<a href="#">JPhysSocJapan, 1982, 51(8), 2383-2384</a> <a href="#">JPhysSocJapan, 1984, 53(4), 1557-1564</a>		
193.		all-E-	218, 273, 355, 372, 390 <sup>a</sup>				466									str. R <sub>1</sub> M <sub>1</sub> pH 7.0, 25°C 10 mM HEPES buffer X-ray photoelectron spectroscopy	<a href="#">J. Sci. Ind Res. 1982, 41(11), 665-673</a>		
194.		all-E- 13Z-	378 <sup>a</sup> 371 <sup>a</sup>		434	430/ 460	470, 510 520 Dif 490				5/95	890 3020 3810				str. R1M1 in 5 mM phosphate buffer, apomembrane suspensions in 50% glycerol pH 6.6, 20°C	<a href="#">Biochem 1984, 23(11), 2507-2513</a>		
195.		all-E- 13Z-					+ +									str. R1M1 in 5 mM phosphate buffer, apomembrane suspensions in 50% glycerol pH 6.6, 20°C	<a href="#">Biochem 1984, 23(11), 2507-2513</a>		

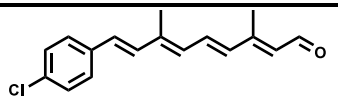
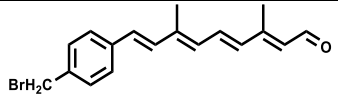
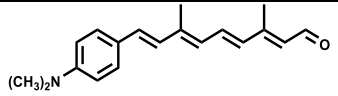
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
196.		all-E-	380 $\epsilon$ 50800	359	439		474		485	+	+		1680 2160				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C	<a href="#">Bioorgan. Khim. 1987, 13(2), 238-251</a>	
		13Z-	375 $\epsilon$ 49700	352	436		490		485				2530 2320						
		all-E-	384 <sup>a</sup> $\epsilon$ 46500				460 $\epsilon$ 39000	460		+	375 -60°C	+						str. R1, in 40 mM phosphate buffer pH 7.0	<a href="#">PhotochemPhotobiol 1985, 41(3), 303-307</a>
		13Z-	380 <sup>a</sup>																
		all-E-	380 <sup>a</sup>		442		460 500sh 535 dif		485				96/4 15/85	890 2010 3930				str. R1M1 in 5 mM phosphate buffer, apomembrane suspensions in 50% glycerol pH 6.6, 20°C. $\tau_{\text{rec}}$ 3 h	<a href="#">Biochem 1984, 23(11), 2507-2513</a>
197.		all-E-	395 $\epsilon$ 48100	373	463		493		503	+	+		1320 1720				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10-12 h	<a href="#">Bioorgan. Khim. 1987, 13(2), 238-251</a>	
		13Z-	389 $\epsilon$ 45200	369	456		505		498				2130 1850						
		all-E-			458		497	497	498			66/34 30/70	1700 1750				pH 7.0, 50 mM Hepes	<a href="#">PhotochemPhotobiol 1991, 54(6), 969-976</a>	
		all-E-					524										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
198.		all-E-	404 $\epsilon$ 49600		471		530		521	+		+	2360 2040				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10-12 h	<a href="#">Bioorgan. Khim. 1987,</a>	

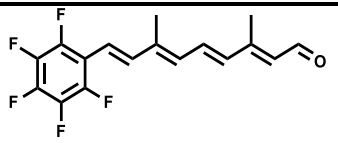
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1}cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		13Z-	400 $\epsilon$ 49800	379	474		512		520				1570 1870					<a href="#">13(2)</a> , <a href="#">238-251</a> <a href="#">27</a>
199.		all-E-	397,5 $\epsilon$ 49700	376	462		491		494				1280 1400				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{rec}$ 12 h	<a href="#">Bioorgan Khim.</a> <a href="#">1987</a> , <a href="#">13(2)</a> , <a href="#">238-251</a> <a href="#">27</a>
		13Z-	390 $\epsilon$ 51600	372	460		493		495				1460 1540					<a href="#">13(2)</a> , <a href="#">238-251</a> <a href="#">27</a>
200.		all-E-	387,5 $\epsilon$ 47700	369	452		524		510	+	+		3040 2520				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{rec}$ 10-12 h	<a href="#">Bioorgan Khim.</a> <a href="#">1987</a> , <a href="#">13(2)</a> , <a href="#">238-251</a> <a href="#">27</a>
		13Z-	383 $\epsilon$ 43200	366	443		503		508	+			2690 2880				str. 353P, in 50mM MES, 5mM EDTA, pH 6.0, 20°C. all-E-ABR cycle has "M" and compared with BRh cycle. In 13Z-ABR cycle "M" absent and have at least 2 long-waved intermediates. L-D-adaptation drastically retarded.	<a href="#">Biokhimiia (Rus.)</a> <a href="#">1987</a> , <a href="#">52(9)</a> , <a href="#">1559-1569</a> , <a href="#">Biokhimiia (Rus.)</a> <a href="#">1993</a> , <a href="#">58(6)</a> , <a href="#">819-826</a> <a href="#">Colloque INSERM 1992</a> , <a href="#">221. 167-170</a>
		all-E-					514			+	395						100 mM NaCl, 5 mM MES, 3 mM potassium citrate, pH 6.0	<a href="#">Sensors and Actuators B: 1997</a> , <a href="#">39(1-3)</a> , <a href="#">218-221</a> <a href="#">Mol. Cryst. Liq. Cryst.</a>

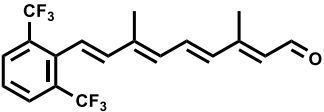
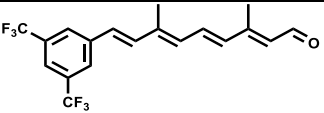
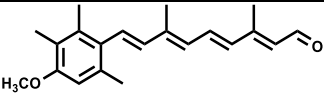
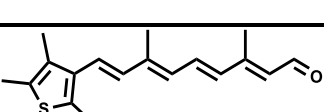
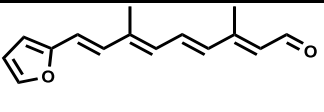
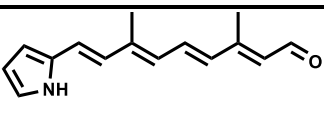
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		2000, 345, 317-322 Rus. J. Bioorgan. Chem., 2022, V. 48 No6, P. 694 - 706
201.		all-E-  13Z-	389 $\epsilon$ 46500  385 $\epsilon$ 42100	375  369	450  439		518  503		506  506	+  		+  		2920 2460  2900 3020				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10-12 h Bioorgan. Khim. 1987, 13(2), 238-251 27
202.		all-E-	385 <sup>a</sup>		448 <sup>a</sup>				480  484	+  		410		1490 1660				100 mM Hepes buffer pH 7.0. $\tau_{1/2K_{\text{dec}}}$ 35 $\mu\text{s}$ Photochem. Photobiol. 1983, 38(2), 197-203
203.		all-E-  all-E-  all-E-  all-E-	438 <sup>a</sup>  442  442	400 <sup>a</sup>	533 <sup>a</sup>  550  550		570  570 611 618			+  				1220  -510 -170  -510 -170				20mM HEPES pH 7.0. ABR cycle similar to BRh "K" and "M", "L" not observed.  pH 7.0 in water  in water. pH 7.0 pH 2.5 pH 0.5  in distilled water or 67 mM phosphate buffer, Biochem. 1985, 24(5), 1260 - 1265 Photochem. Photobiol. 1981, 33(4), 483-488 Biophys. J. 1989, 56(6), 1259-1265 JACS, 1980.

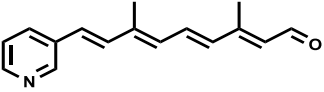
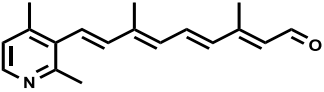
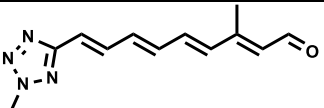
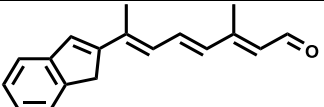
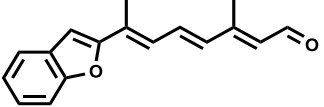
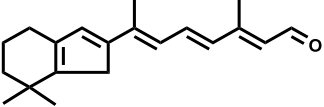
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																	<p>pH 7.0, <math>\tau_{\text{rec}}</math> ABR535 nm 20 h</p> <p>Atomic force sensing (AFS) for dynamically probe ABR protein conformational changes with microsecond time resolution. ABR reduced by NABH<sub>4</sub></p> <p>Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH<sub>2</sub>OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH<sub>4</sub></p> <p>Protein-<i>b</i>-Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes.</p>	<p><a href="#">102(27)</a>, <a href="#">7947-7949</a></p> <p><a href="#">PNAS</a> <a href="#">1997</a>, <a href="#">94(15)</a>, <a href="#">7937-7941</a></p> <p><a href="#">JBiolChem</a> <a href="#">2000</a>, <a href="#">275(28)</a>, <a href="#">21010-21016</a></p> <p><a href="#">JPhysChem B</a> <a href="#">2003</a>, <a href="#">107(25)</a>, <a href="#">6221-6225</a></p>	
204.		<p>all-E-</p> <p>13Z-</p> <p>all-E-</p> <p>13Z-</p>	<p>367</p> <p>364</p> <p>364</p> <p>424</p> <p>364</p> <p>364</p> <p>424</p>	<p>493, 460sh</p> <p>475</p> <p>496</p> <p>473</p>	<p>474</p> <p>478</p> <p>474</p> <p>478</p>	<p>+</p> <p>+</p> <p>+</p>				<p>1420</p> <p>2660</p>			<p>str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, <math>\tau_{\text{rec}}</math> 10-12 h</p> <p>str. 353P, in 50mM MES, 5mM EDTA, pH 6.0, 25°C. <math>\tau_{\text{Mdec}} &gt; 1</math> min L-D-adaptation drastically retarded.</p>	<p><a href="#">29</a></p>					

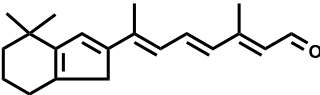
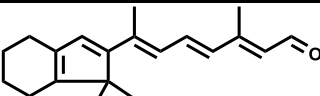
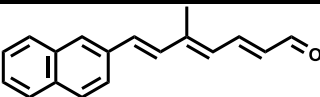
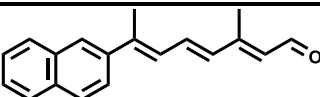
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
205.		all-E-			410 <sup>a</sup>		442					1700	replaced in 12-24 h	unstable		str. M1 <sup>19</sup> F-NMR $\delta$ -56.9 ppm In 5% DDM / D <sub>2</sub> O	<a href="#">J.Phys. Chem. 1996, 100(21), 9172 - 9174</a>		
206.		all-E-			429 <sup>a</sup>		452					1200	replaced in 12-24 h	unstable		str. M1 <sup>19</sup> F-NMR $\delta$ -66.2 ppm In 5% DDM / D <sub>2</sub> O	<a href="#">J.Phys. Chem. 1996, 100(21), 9172 - 9174</a>		
207.		all-E-					480		+		15					str. S9 in distilled water	<a href="#">Biochem Biophys. Res. Com. 1977, 78(2), 669-675</a>		
208.		all-E-					510		+		31					str. S9 in distilled water	<a href="#">Biochem Biophys. Res. Com. 1977, 78(2), 669-675</a>		
209.		all-E-					+									pH 7.0	<a href="#">Photochem. Biol. 1984, 39(5), 661-665</a>  <a href="#">Heterocycles, 1986, V. 24 No1, 0268</a>		
210.		all-E-			530 <sup>l</sup>		537 550		+	+						pH 7.0  605 nm (pH 1.5)	<a href="#">Photochem. Biol. 1984, 39(5), 661-665</a>		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		Heterocycles, 1986, V. 24 No1, 0268	
211.		all-E-	380	350, 367, 375	419			485	473				3250 2720				str. R1, in 10mM HEPES buffer, pH 7.0	Photochem. Photo. Biol., 1984, 39(5), 661-665	
212.		all-E-	368	351	410			476	465				3380 2880				str. R1, in 10mM HEPES buffer, pH 7.0	Photochem. Photo. Biol., 1984, 39(5), 661-665	
213.		all-E-	356	333, 349, 367	398			445	457				2650 3240				str. R1, in 10mM HEPES buffer, pH 7.0	Photochem. Photo. Biol., 1984, 39(5), 661-665	
214.		all-E-	403 <sup>a</sup>	380	470			535	535				2950 2950			507+ /575-	str. R1, in 10mM HEPES buffer, pH 7.0	Photochem. Photo. Biol., 1984, 39(5), 661-665	
215.		all-E-		376	454		510						2300					Photochem. Photo. Biol., 1993, 58(5), 701-705.	
216.		all-E-	425		503		574						2500				in 10 mM HEPES buffer. $\tau_{\text{rec}}$ 30 min	Photochem. Photo. Biol., 1992,	

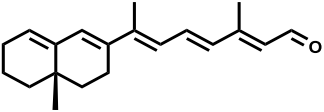
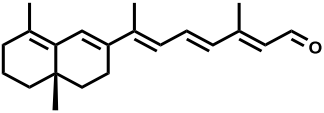
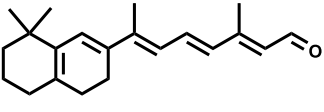
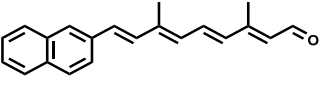
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
217.		all-E-	425		502		594/ 505				173		3100				in 10 mM HEPES buffer. $\tau_{\text{rec}}$ 30 min. Two bands or two species of ABR formed in depend of Ret/BO ratio.	<a href="#">56(6), 921-927.</a> <a href="#">Photochem. Photo. Biol. 1992, 56(6), 921-927.</a>	
218.		all-E-	425		504		584				63		2700				in 10 mM HEPES buffer. $\tau_{\text{rec}}$ 2 h	<a href="#">Photochem. Photo. Biol. 1992, 56(6), 921-927.</a>	
219.		all-E-  2Z-	362°					482	485	+	370	+		stable during 4h	replaced in several hours		30 mM sodium phosphate buffer, pH 7.2.	<a href="#">Photochem. Photo. Biol. 1986, 43(3), 297-303.</a>	
220.		all-E-  all-E-  all-E-		353	425		504						3700				in 200 mM potassium phosphate buffer, pH 5.0, in the presence of NaCl. $\tau_{\text{rec}}$ ABR rate was about 3 times faster than BRh.	<a href="#">Photochem. Photo. Biol. 1993, 58(5), 701-705.</a>	
			368 <sup>a</sup> $\epsilon$ 47000		425 <sup>a</sup>		504 $\epsilon$ 43000						3700		relatively stable				<a href="#">JChem Soc Chem Commun 1982 (1) 44-46</a>
			370 <sup>a</sup>			400	442	442	480	+	390 -65°C	++	88\12 37\63	$\tau_{1/2\text{dest}}$ 40 min	replaced	440+	str. R1M1, in 10 mM sodium phosphate buffer (pH 6.8) or 10 mM HEPES buffer (pH 6.8) ratio RCHO:BO from 1 / 12 – 1 / 1	<a href="#">Biochem 1984, 34(5), 838-843</a> <a href="#">Biochem 1988, 27(7),</a>	

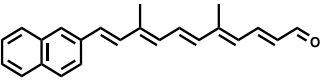
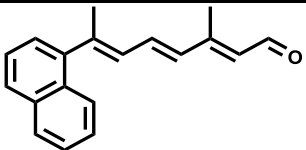
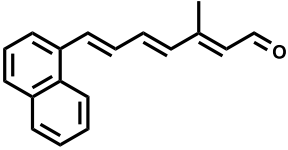
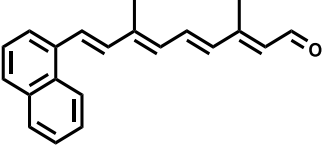
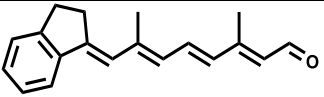
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.		
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others			
							(P)	DA	LA											
								503	503	503	+	390 -65°C	++	87\13 83\17		$\tau_{1/2\text{dest}}$ 200 min	replaced	460+ 530-	ratio RCHO:BO < 1 / 10 ABR442 converted in ABR503 during several days.	<a href="#">2416-2419</a>
221.		all-E-	395 381°	369	467		552	546	552 $\epsilon$ 54000	+		51		3300 3100 3300		Not displaced in 24h		str. R1S9, 4°C. $\tau_{\text{rec}}$ 15 min - ABR rather than BRh rate. ABR does show light-dark adaptation. Full analysis of the <sup>1</sup> H-NMR spectrum.	<a href="#">Recl. 1993, 112(4), 237-246</a> <a href="#">Recl. 1994, 113(2), 99 - 108</a>	
222.		all-E-	416 402°	391	490			582 / 504		+		20		3230 570	destroyed	Not displaced in 24h		str. R1S9, 4°C. $\tau_{\text{rec}}$ ABR rather than BRh rate. ABR582 band converted in ABR504 in 2 h.	<a href="#">Recl. 1993, 112(4), 237-246</a>	
223.		all-E-	372 358°	355	428			501	501 $\epsilon$ 47000	+		23		3410 3410		Not displaced in 24h		str. R1S9, 4°C. $\tau_{\text{rec}}$ 30 min. L-D adaptation absent.	<a href="#">Recl. 1993, 112(4), 237-246</a>	
224.		all-E-	410 <sup>a</sup>		480 <sup>a</sup>			513	518	+	405			1390 1580				100 mM Hepes buffer pH 7.0. $\tau_{1/2K\text{dec}}$ 100 $\mu\text{s}$	<a href="#">PhotochemPhotobiol 1983, 38(2), 197-203</a>	
225.		all-E- rac	397 <sup>a</sup> $\epsilon$ 47000 395	373	467	438	552 $\epsilon$ 57000	547	552			52		3300 3130 3300				str. R1S9, 4°C. $\tau_{\text{rec}}$ 20 min - ABR rather than BRh rate. 1R ABR formed 2.1 times more rapidly than 1S ABR rate.	<a href="#">Recl. 1992, 111(1), 29 - 40.</a>	
		all-E- (1R)				441	552 $\epsilon$ 56000	547	552			48		3300 3130 3300				str. R1S9, 4°C. $\tau_{\text{rec}}$ 10 min. CD(1R-CHO) 273(+)/383(+)		

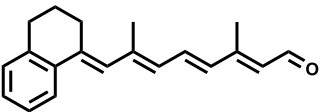
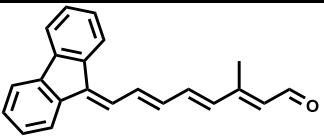
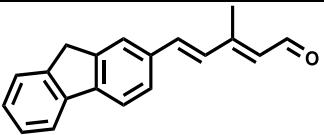
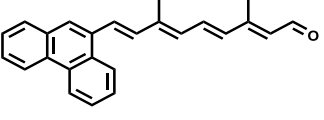
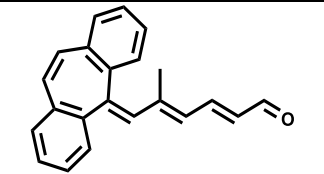
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E- (1S)				436	552 $\epsilon$ 62000	547	552			44	3300 3130 3300				str. R1S9, 4°C. $\tau_{\text{rec}}$ 21 min. CD(1R-CHO) 273(-)/383(-) full analysis of the <sup>1</sup> H-NMR spectrum	<a href="#">Recl. 1994</a> , <a href="#">113(2)</a> , <a href="#">99 - 108</a>	
226.		all-E-	400		465	430-460	564			+		90	3780				$\tau_{\text{rec}}$ 68 min, 2°C. ABR does show light-dark adaptation.	<a href="#">JACS 1986</a> , <a href="#">108(20)</a> , <a href="#">6410 - 6411</a>	
		all-E-	400	376	465	435	564	570 $\epsilon$ 60000		+		90	3780 3950					<a href="#">Recl. 1989</a> , <a href="#">108(3)</a> , <a href="#">83 - 92</a>	
227.		all-E-	415		485		509, 596			+		20	970 3840				$\tau_{\text{rec}}$ 16 h, L-D adaptation absent	<a href="#">JACS 1986</a> , <a href="#">108(20)</a> , <a href="#">6410 - 6411</a>	
		all-E-	415	388	485	435	509, 596						970 3840					<a href="#">Recl. 1989</a> , <a href="#">108(3)</a> , <a href="#">83 - 92</a>	
228.		all-E-	395	267, 381	277, 321, 463		493		501	+			1320 1640				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10-12 h	<a href="#">29</a>	
		2Z-	390				498		495										<a href="#">29</a>
		all-E-	395°					492	497	+	395	++		reasonably stable	reasonably stable		30 mmol sodium phosphate buffer, pH 7.2.	<a href="#">Photochem. Photo. biol. 1986</a> , <a href="#">43(3)</a> , <a href="#">297 -303</a>	
		6Z-					460	492	497				6Z-60/40 all-E	in dark decomposed within 30 min	in dark decomposed within 30 min		Slow ABR cycle in 5 times than BRh cycle.	<a href="#">18</a>	
		2Z-					+						no 6Z-						

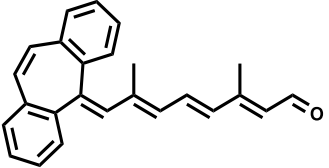
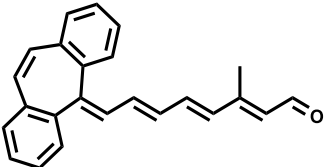
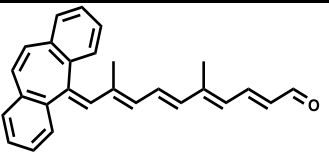
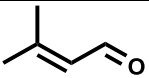

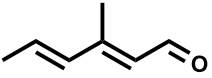

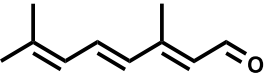
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
229.		all-E-	405°					460-480	460-480	+	405	+			unstable decomposed within 1h	unstable decomposed within 1h		30 mM sodium phosphate buffer, pH 7.2.	<a href="#">Photochem. Photo. Biol.</a> 1986, 43(3), 297-303 <a href="#">18</a>
230.		all-E-		333	390		NO												<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705
231.		all-E-		369	425		472						2300						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705
232.		all-E-	398	382	460			490					1330					str. S 9	<a href="#">Tetrahedron Lett.</a> 1999, 40(13), 2645-2648
		all-E-																electronic and structural properties of retinal analog were studied using semiempirical, ab initio Hartree-Fock, and DFT methods	<a href="#">J. Chem. Phys.</a> , 2006, V. 125, 144901
233.		all-E-		382	472		540						2700						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705

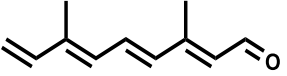
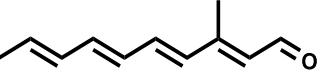
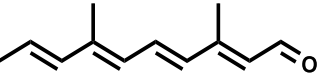
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
234.		all-E-		374	456		502					2000						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705	
235.		all-E-		411	470		472					0						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705	
236.		all-E-	365	353	420		432									str. S 9 low yield	<a href="#">Tetrahedron Lett.</a> 1999, 40(13), 2645-2648		
237.		all-E-	399	385	461		499					1650				str. S 9	<a href="#">Tetrahedron Lett.</a> 1999, 40(13), 2645-2648  <a href="#">J. Chem. Phys.</a> , 2006, V. 125, 144901  electronic and structural properties of retinal analog were studied using semiempirical, ab initio Hartree-Fock, and DFT methods		
238.		all-E-		342	407		NO											<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705	


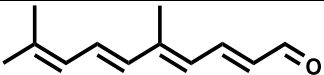
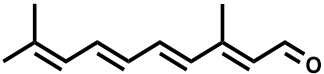
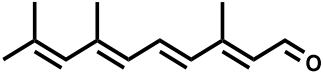
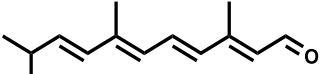

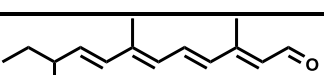

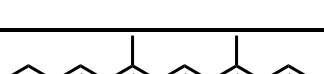

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
239.		all-E-		371	450		482					1500						<a href="#">Photochem. Photo. Biol. 1993, 58(5), 701-705</a>	
240.		all-E-		370	446		480					1600						<a href="#">Photochem. Photo. Biol. 1993, 58(5), 701-705</a>	
241.		all-E-		392	477		NO											<a href="#">Photochem. Photo. Biol. 1993, 58(5), 701-705</a>	
<b>I. Alteration of the trimethylcyclohexenic ring. Acyclic analogs</b>																			
242.		E-	277 <sup>c</sup>				NO										In 50 mM sodium phosphate buffer pH 7.2. 24 h	<a href="#">Biochem. 1986, 25(8), 2022-2027.</a> 	
			257 <sup>a</sup>				NO												
243.		all-E-	268 <sup>c</sup>				NO										In 50 mM sodium phosphate buffer pH 7.2. 24 h	<a href="#">Biochem. 1986, 25(8), 2022-2027.</a> 	
244.		all-E-			382		446				40/60 69/31	3750 3750					pH 7.0, 50 mM Hepes	<a href="#">Photochem. Photo. Biol. 1991, 54(6), 969-976</a>	
		all-E-	335		385		430										displaced after 24 h	str. R1S9 <a href="#">Eur. J. Biochem.</a>	

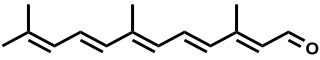
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				CD	others			
							(P)	DA	LA									
		all-E- 2Z-	312° 310°				$\epsilon$ 6000  422 420		425 425	NO	NO NO			moderately stable destroyed after 1 h, in the dark	displaced after 1 h	ABR formation rates of the in H <sub>2</sub> O compared to BRh. Irreversible decomposition on 50% after 10 min illumination.  In 50 mM sodium phosphate buffer pH 7.2. 24 h. no flash-induced absorption changes. $\tau_{1/2\text{rec}}$ 20 min	<a href="#">1984</a> <a href="#">140(1)</a> <a href="#">173-176</a>  <a href="#">Biochem</a> <a href="#">1986</a> <a href="#">25(8)</a> <a href="#">2022</a> <a href="#">2027</a>	
245.		all-E-	351		405		452 $\epsilon$ 12000		452		NO		2600 2600		displaced after 24 h	str. R1S9 ABR formation rates of the in H <sub>2</sub> O compared to BRh. Irreversible decomposition on 50% after 10 min illumination	<a href="#">EurJBiochem</a> <a href="#">1984</a> <a href="#">140(1)</a> <a href="#">173-176</a>	
246.		all-E-					460	460	500			75/25 60/40				pH 7.0, 50 mM Hepes The formation stable long-lived ABR 500 nm under illumination. $k_{\text{decay}}$ 44.9 x 10 <sup>-4</sup> s <sup>-1</sup> at 303 K.	<a href="#">PhotochemPhotobiol</a> <a href="#">1991</a> <a href="#">54(6)</a> <a href="#">969-976</a>	
247.		all-E-  all-E-  all-E-	  364  347°		418  422		470  472 $\epsilon$ 11000  462	470  470	470  472  466		NO		72/28 80/20  2600 2600	2650 2650		reasonably stable displaced after	pH 7.0, 50 mM Hepes  str. R1S9 ABR formation rates of the in H <sub>2</sub> O compared to BRh. Irreversible decomposition on 30% after 10 min illumination	<a href="#">PhotochemPhotobiol</a> <a href="#">1991</a> <a href="#">54(6)</a> <a href="#">969-976</a>  <a href="#">EurJBiochem</a> <a href="#">1984</a> <a href="#">140(1)</a> <a href="#">173-176</a>  <a href="#">Biochem</a> <a href="#">1986</a>

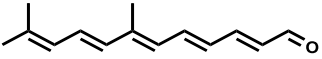
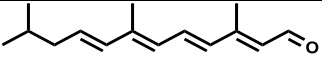
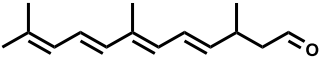
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		2Z-	346 <sup>c</sup>				460		466					destroyed after 1.5 h, in the dark	1.5 h		In 50 mM sodium phosphate buffer pH 7.2. $\tau_{1/2\text{rec}}$ 10 min	<a href="#">25(8)</a> , <a href="#">2022</a> , <a href="#">2027</a> 	
248.		all-E- 2Z- 4Z-	370 <sup>f</sup> 370 <sup>f</sup> 370 <sup>f</sup>				NO NO NO											<a href="#">PhotochemPhotobiol</a> 1985, <a href="#">41(2)</a> , <a href="#">171-174</a>	
249.		all-E-				460		500			46/54 52/48						pH 7.0, 50 mM Hepes The formation stable long-lived ABR 500 nm under illumination. $k_{\text{decay}}$ $15.9 \times 10^{-4} \text{ s}^{-1}$ at 303 K.	<a href="#">PhotochemPhotobiol</a> 1991, <a href="#">54(6)</a> , <a href="#">969-976</a>	
250.		all-E-			401		490		490		37/63 63/37	4550 4550					pH 7.0, 50 mM Hepes	<a href="#">PhotochemPhotobiol</a> 1991, <a href="#">54(6)</a> , <a href="#">969-976</a>	
251.		all-E- 2Z-	364 <sup>a</sup> 358 <sup>a</sup>				487 $\epsilon$ 28000 477		487 477	+ 365	++			stable destroyed after 5h, in the dark	displaced after 24 h		$\tau_{1/2\text{rec}}$ 285-305 s Raman spectra data	<a href="#">JACS</a> 1984, <a href="#">106(26)</a> , <a href="#">8325-8327</a> 	
252.		all-E- 2Z-	364 <sup>a</sup> 361 <sup>a</sup>				487 $\epsilon$ 28000 477		487 477	+ 363	++			stable destroyed after 5h, in the dark	displaced after 72 h		$\tau_{1/2\text{rec}}$ 160-180 s Raman spectra data	<a href="#">JACS</a> 1984, <a href="#">106(26)</a> , <a href="#">8325-8327</a> 	
253.		all-E- 2Z-	373 <sup>a</sup> 368 <sup>a</sup>				487 $\epsilon$ 28000 476		487 476	+ 372	++			stable destroyed after 5h, in the dark	displaced after 72 h		$\tau_{1/2\text{rec}}$ 160-180 s Raman spectra data	<a href="#">JACS</a> 1984, <a href="#">106(26)</a> , <a href="#">8325-8327</a> 	

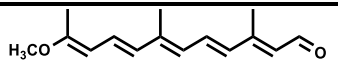
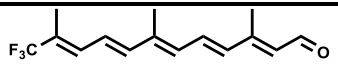
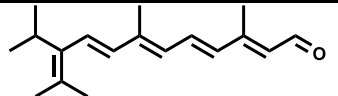
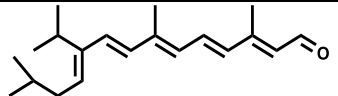
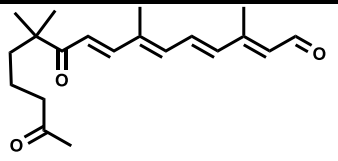
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup> pKa	NC	Pigments			+				M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
254.		all-E-	400	373	468 pKa 7.4		527 pKa 12.1			+			2400						<a href="#">17</a>
		all-E-	393		465	420/ 460	538	528 $\epsilon$ 34000	538	+		30	2600 2900	stable		str. R1S9 $\tau_{rec}$ 16 min. ABR formation rates of the in H <sub>2</sub> O compared to BRh.	<a href="#">EurJBioc</a> <a href="#">hem</a> <a href="#">1984</a> <a href="#">140(1)</a> <a href="#">173-176</a>		
		all-E-	400 <sup>a</sup>				513	519				++						<a href="#">18</a>	
		all-E-	400 <sup>f</sup> $\epsilon$ 52400				524		528					stable destroyed after 3h, in the dark	displaced after 4.5h	$\tau_{1/2rec}$ 156 s	<a href="#">Photoche</a> <a href="#">mPhotob</a> <a href="#">iol 1985</a> <a href="#">41(2)</a> <a href="#">171-174</a>		
		2Z-	400 <sup>f</sup> $\epsilon$ 41600				522		528					stable destroyed after 3h, in the dark	displaced after 4.5h	$\tau_{1/2rec}$ 168 s			
		6Z-	400 <sup>f</sup> $\epsilon$ 40700				487		528					unstable destroyed after 35 min, in the dark	displaced after 30 min	$\tau_{1/2rec}$ 750 s			
		all-E-			468			530		532			59/41 25/75	2500 2550			pH 7.0, 50 mM Hepes	<a href="#">Photoche</a> <a href="#">mPhotob</a> <a href="#">iol 1991</a> <a href="#">54(6)</a> <a href="#">969-976</a>	
		all-E-					527 558 533										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">BiophysJ</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259-</a> <a href="#">1265</a>	
		all-E-	400	373	468		527				+			2400					

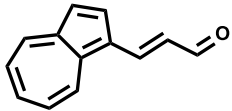
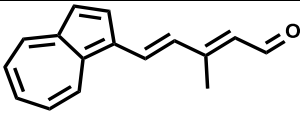
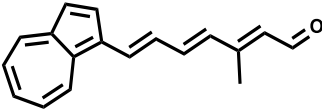
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-					532									10 mM Hepes buffer, pH 6.5 at 25°C for 1 hr. pKa (SBH <sup>+</sup> ) = 7.4, pKa (SB ABR) = 12.1	PNAS 1986, 83(10), 3262-3266.	
		all-E-					535									Molecular Dynamics Study ABR	Biochem 1994, 33(12), 3668-3678.	
		all-E-	380 <sup>a</sup>				530									Molecular Dynamics Study ABR	BiophysJ 1995, 68(4), 1270-1282.	
																Protein-b-Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes.	JPhysChem B 2003, 107(25), 6221-6225.	
255.		all-E- all-E-	373 390 <sup>a</sup>	468		527		520 522			+		2400				15 15	
256.		all-E-	364	423		483		$\epsilon$ 29000 483		390	very low		2900 2900			str. R1S9 slow decomposition under irradiation	EurJBiochem 1984, 140(1), 173-176.	
257.		all-E-	307 <sup>a</sup> 2 sh			321							1420			in 20 mM Tris/HCl and 4 M NaCl at pH 7.0. $\tau_{\text{rec}}$ 40 min Mutagenesis studies and two photon spectroscopy studies argue against a discrete charge in the binding site but not	JBiolChem. 1995, 270(50), 29668-29670.	

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	against the local electrostatic fields, which would fulfill the conditions of the original point charge model. 11-fold inhibition of the native retinal incorporation in ABR.	
258.		all-E-					572 615 590										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys J</a> 1989 56(6) 1259-1265
259.		all-E-	377	363	428 pK <sub>a</sub> 7.1		480 pK <sub>a</sub> 11.9			+			2500					<a href="#">Retinal Proteins</a> 1987 205-216
		all-E-	377	423	468		480			+			2500				10 mM Hepes buffer, pH 6.5 at 25°C for 1 h. pK <sub>a</sub> (SBH <sup>+</sup> ) = 7.1, pK <sub>a</sub> (SB ABR) = 11.9	<a href="#">PNAS</a> 1986, 83(10), 3262-3266.
260.		all-E-					565										str. ET1001. In 4 M NaCl, 25 mM Tris-HCl buffer, pH 7.2, $\tau_{1/2\text{rec}} < 1$ min	<a href="#">Photochem Photobiol</a> 1994 60(4) 388-393
261.		all-E-																<a href="#">Bioorgan Chem</a> 1989 17(2) 217-223
		13Z-																
		5Z-																
		5Z,13Z-																
262.		all-E-	269 364 $\epsilon$ 49900	270 364 381	399 409		450  450 440 445sh			NO					displaced in 2 h	100mM NaCl, 5 mM MES, pH 6.0, $\tau_{\text{rec}}$ 10 min.  ET1001 D96N JW5,	<a href="#">Rus. J. Bioorg Chem.</a> 2002.	

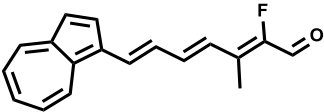
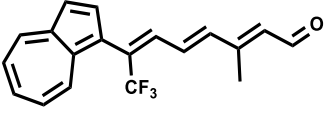
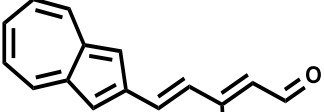
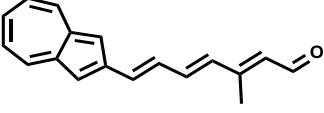
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	No photo-responses on light flash, no cyclic photoreactions ABR.	28(6), 487-493 Mironov a E. V., Ph.D. thesis, 2002
<b>J. Miscellaneous modifications</b>																		
263.		E-		418	494												Experimental and calculated data of UV-Vis spectra	Organic Lett. 2000, 2(3), 269-271
264.		all-E-	435 <sup>a</sup>		575		620						3300	$\tau_{1/2\text{dest}}$ 40 min			$\tau_{1/2\text{rec}}$ 17h	JPhotochemPhotobiol C: 2003, 4(3), 179-194
		all-E-					621						3300			$\tau_{1/2\text{rec}}$ 17h	Tetrahedron Lett. 1998, 39(1/2), 5-8	
		all-E-		414	515												Experimental and calculated data of UV-Vis spectra	Organic Lett. 2000, 2(3), 269-271
		all-E-	435 <sup>a</sup>		575		620							3300	$\tau_{1/2\text{dest}}$ 40 min		$\tau_{1/2\text{rec}}$ 17h	PhotochemPhotobiol 2001, 74(6), 837-845
265.		all-E-		430	541		644						3000					PhotochemPhotobiol. 1993.

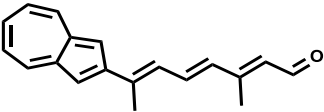
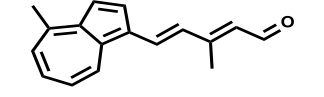
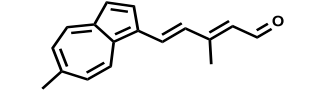
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	446 <sup>c</sup>	430 <sup>a</sup>	541 <sup>a</sup>		644					2960						<a href="#">58(5), 701-705.</a>	
		13Z-	444 <sup>c</sup>	426 <sup>a</sup>	542 <sup>a</sup>		631					2600						<a href="#">JACS 1990, 112(20), 7398-7399</a>	
		all-E-	446 <sup>a</sup>	430	542 <sup>a</sup>		644					2960						<a href="#">Photochem. Photo. Biol. 1991, 54(4), 625-631</a>	
		all-E-	455 <sup>a</sup>		542		645					3000	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 4h		<a href="#">JPhotochemPhoto Biol C: 2003, 4(3), 179-194</a>	
		all-E-		430	541		644											<a href="#">J.Phys.Chem. A 1998, 102(28), 5481-5483.</a>	
		all-E-	455 <sup>a</sup>		542		645					3000	$\tau_{1/2\text{dest}}$ 1 min					<a href="#">Organic Lett. 2000, 2(3), 269-271</a>	
																		<a href="#">PhotochemPhoto Biol 2001, 74(6), 837-845</a>	

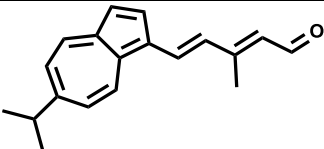
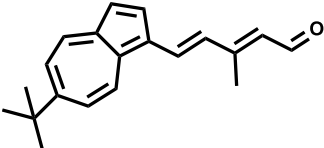
**Properties of artificial bacteriorhodopsin analogs**

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
266.		all-E-		436	572		730					3800						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	
		all-E-	463 <sup>a</sup>		572 <sup>a</sup>		694 / 748					2400 / 4100				$\tau_{1/2\text{rec}}$ 40 min		<a href="#">JPhotochemPhoto Biol C</a> 2003, 4(3), 179-194.	
		all-E-	463 <sup>a</sup>		572		694 / 748					2400 / 4100				$\tau_{1/2\text{rec}}$ 40 min		<a href="#">PhotochemPhotobiol</a> 2001, 74(6), 837-845.	
267.		all-E-		401	489		520					1200						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	
		all-E-	416 <sup>c</sup>	401 <sup>a</sup>	489 <sup>a</sup>		520					1220						<a href="#">JACS</a> 1990, 112(20), 7398-7399.	
268.		all-E-		401	443												Experimental and calculated data of UV-Vis spectra	<a href="#">Organic Lett.</a> 2000, 2(3), 269-271.	
269.		all-E-		425	405		475					1200						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	

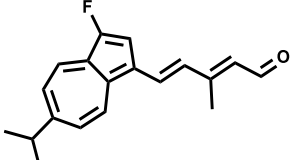
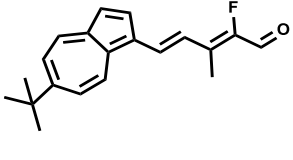
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					475					1170						<a href="#">JACS 1990, 112(20), 7398-7399</a>	
270.		all-E-			450												Experimental and calculated data of UV-Vis spectra	<a href="#">Organic Lett. 2000, 2(3), 269-271</a>	
271.		all-E-	438 <sup>a</sup>		522 <sup>a</sup>		618/620					3000 3100	$\tau_{1/2\text{dest}}$ 4 min			$\tau_{1/2\text{rec}}$ 20h	<a href="#">JPhotochemPhotobiol C: 2003, 4(3), 179-194</a>		
		all-E-					618					3000			$\tau_{1/2\text{rec}}$ 20h	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			
		all-E-	438 <sup>a</sup>		522		620					3000	$\tau_{1/2\text{dest}}$ 4 min		$\tau_{1/2\text{rec}}$ 20h	<a href="#">PhotochemPhotobiol 2001, 74(6), 837-845</a>			
272.		all-E-	440 <sup>a</sup>		540 <sup>a</sup>		629/674					2600 3700	$\tau_{1/2\text{dest}}$ 100 min			$\tau_{1/2\text{rec}}$ 50min	<a href="#">JPhotochemPhotobiol C: 2003, 4(3), 179-194</a>		
		all-E-					674					3700			$\tau_{1/2\text{rec}}$ 53min	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			

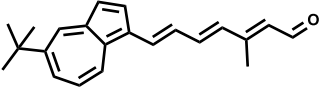
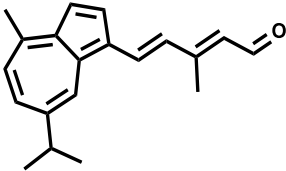
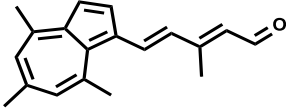
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	440 <sup>a</sup>		540		629/ 674					2600 3700	$\tau_{1/2\text{dest}}$ 100 min			$\tau_{1/2\text{rec}}$ 50min	<a href="#">Photochem Photobiol 2001 74(6) 837-845</a>		
273.		all-E-	438 <sup>a</sup>		535 <sup>a</sup>		630/ 674					2800 3900	$\tau_{1/2\text{dest}}$ 9 h			$\tau_{1/2\text{rec}}$ 50min	<a href="#">JPhotochem Photobiol C: 2003 4(3) 179-194</a>		
		all-E-					674					3860			$\tau_{1/2\text{rec}}$ 50min	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			
		all-E-	438 <sup>a</sup>		535		630/ 674					2800 3900	$\tau_{1/2\text{dest}}$ 9 h			$\tau_{1/2\text{rec}}$ 50min	<a href="#">Photochem Photobiol 2001 74(6) 837-845</a>		
274.		all-E-	436 <sup>a</sup>		532 <sup>a</sup>		628/ 673					2900 3900	$\tau_{1/2\text{dest}}$ 10 h			$\tau_{1/2\text{rec}}$ 53min	<a href="#">JPhotochem Photobiol C: 2003 4(3) 179-194</a>		
		all-E-					673					3900			$\tau_{1/2\text{rec}}$ 53min	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			
		all-E-					675								In water. $\tau_{\text{rec}}$ 2 h. Transient absorption studies of the ABR shown that no transient absorption	<a href="#">J.Phys.Chem. A 1998 102(28), 5481-5483.</a>			

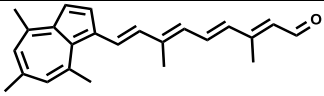
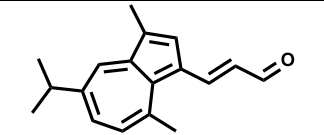
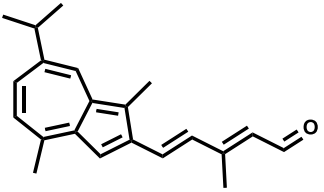
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	436 <sup>a</sup>		532		628/ 673					2900 3900	$\tau_{1/2\text{dest}}$ 10 h			changes were detected. $\tau_{1/2\text{rec}}$ 53min	<a href="#">Photochem Photobiol 2001 74(6) 837-845</a>		
275.		all-E-	443 <sup>a</sup>		526 <sup>a</sup>		630 / 672					3200 4130	$\tau_{1/2\text{dest}}$ 3 h			$\tau_{1/2\text{rec}}$ 48min	<a href="#">J Photochem Photobiol C: 2003 4(3) 179-194</a>		
		all-E-					672					4130			$\tau_{1/2\text{rec}}$ 48min	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			
		all-E-	443 <sup>a</sup>		526		630 / 672					3200 4130	$\tau_{1/2\text{dest}}$ 3 h			$\tau_{1/2\text{rec}}$ 48min	<a href="#">Photochem Photobiol 2001 74(6) 837-845</a>		
276.		all-E-	450 <sup>a</sup>		558 <sup>a</sup>		632/ 686					3000 3340	$\tau_{1/2\text{dest}}$ 12 min			$\tau_{1/2\text{rec}}$ 47min	<a href="#">J Photochem Photobiol C: 2003 4(3) 179-194</a>		
		all-E-					686					3340			$\tau_{1/2\text{rec}}$ 47min	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>			
		all-E-	450 <sup>a</sup>		558		632/ 686					3000 3340	$\tau_{1/2\text{dest}}$ 12 min			$\tau_{1/2\text{rec}}$ 47min	<a href="#">Photochem Photobiol 2001 74(6) 837-845</a>		

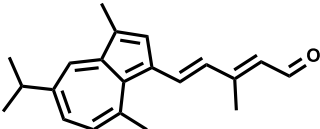
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
277.		all-E-	653 <sup>a</sup>		562 <sup>a</sup>		664					2700				$\tau_{1/2\text{rec}}$ 72h	<a href="#">JPhotochemPhoto Biol C: 2003 4(3) 179-194</a>	
		all-E-	453 <sup>a</sup>		562		664					2700				$\tau_{1/2\text{rec}}$ 72h	<a href="#">PhotochemPhoto Biol 2001 74(6) 837-845</a>	
278.		all-E-	450 <sup>a</sup>		538 <sup>a</sup>		595					1800	$\tau_{1/2\text{dest}}$ 6 min			$\tau_{1/2\text{rec}}$ 36h	<a href="#">JPhotochemPhoto Biol C: 2003 4(3) 179-194</a>	
		all-E-					596					1800				$\tau_{1/2\text{rec}}$ 36h	<a href="#">Tetrahedron Lett. 1998, 39(1/2), 5-8</a>	
		all-E-	450 <sup>a</sup>		538		595					1800	$\tau_{1/2\text{dest}}$ 6 min			$\tau_{1/2\text{rec}}$ 36h	<a href="#">PhotochemPhoto Biol 2001 74(6) 837-845</a>	
279.		all-E-	444 <sup>a</sup>		533 <sup>a</sup>		629					2900				$\tau_{1/2\text{rec}}$ 96h	<a href="#">JPhotochemPhoto Biol C: 2003 4(3) 179-194</a>	
		all-E-					608					2300				$\tau_{1/2\text{rec}}$ 4 days	<a href="#">Tetrahedron Lett. 1998,</a>	

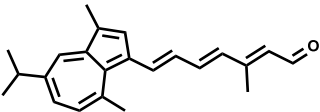
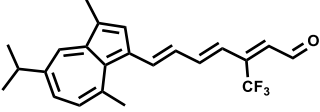
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-	444 <sup>a</sup>		533		629					2300				$\tau_{1/2\text{rec}}$ 4 days	<a href="#">39(1/2), 5-8</a> <a href="#">PhotochemPhotobiol 2001 74(6) 837-845</a>	
280.		all-E-	246 290 355 467	245 285 355 445	241 302 328 579		308 605					740  660				$\tau_{\text{rec}}$ 70h	<a href="#">39</a>	
281.		E-  E-  E-	436 <sup>a</sup>	418	494		519		NO			980				$\tau_{\text{rec}}$ 15days  The pigment was found to be stable at pH 7; however, no steady-state absorption changes were detected.  WT BO. 10°C. $\tau_{\text{rec}}$ 20 days, pH 9.5. "M" like 400 nm forms???? Sample possible contaminated by BRh due to REToxime hydrolysis.	<a href="#">PhotochemPhotobiol 1991 54(4) 625-631</a> <a href="#">J.Phys.Chem. A 1998 102(28) 5481-5483</a> <a href="#">PhotochemPhotobiol 1996 64(5) 867-869</a>	
282.		all-E-  all-E-		401	443		475					1500  3100				$\tau_{1/2\text{rec}}$ 36h	<a href="#">PhotochemPhotobiol 1993 58(5) 701-705</a> <a href="#">JPhotochemPhotobiol C:</a>	

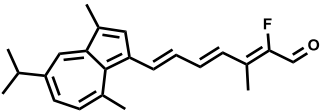
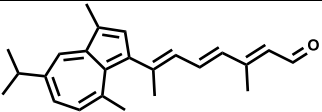
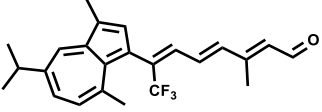
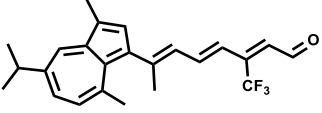
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )							Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments				M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA										
		all-E-	403 <sup>a</sup>		443		514						3100				$\tau_{1/2\text{rec}}$ 36h	2003 4(3) 179-194 PhotochemPhotobiol 2001 74(6) 837-845	
283.		all-E-		439	560		644						2330				$\tau_{\text{rec}}$ 23days	PhotochemPhotobiol 1993 58(5) 701-705	
		mixture 69%-E- 31%-Z-	465 <sup>a</sup>	439 <sup>a</sup>	560 <sup>a</sup>		644						2330				$\tau_{1/2\text{rec}}$ 13 days	PhotochemPhotobiol 1991 54(4) 625-631	
		all-E-	465 <sup>a</sup>		560 <sup>a</sup>		642						2300	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 13 days	JPhotochemPhotobiol C: 2003 4(3) 179-194	
		all-E-					644						2300				$\tau_{1/2\text{rec}}$ 13 days	Tetrahedron Lett. 1998 39(1/2) 5-8	
		all-E-	465 <sup>a</sup>		560		640						2300	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 13 days	PhotochemPhotobiol 2001 74(6) 837-845	

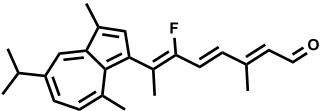
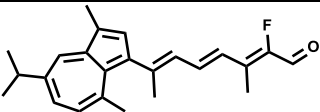
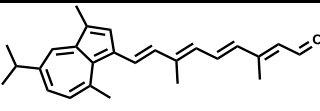
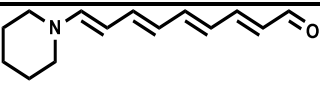

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
284.		all-E-	484 <sup>a</sup>	450	590		694, 750sh					2540				$\tau_{\text{rec}}$ 20days	<a href="#">Photochem. Biol. 1991, 54(4), 625-631</a>	
		all-E-	473 <sup>c</sup>	450	590		694					2540					<a href="#">JACS 1990, 112(20), 7398-7399</a>	
		all-E-	482 <sup>a</sup>		590 <sup>a</sup>		660/ 764					1700 3800	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 20min	<a href="#">JPhotochemPhoto Biol C: 2003, 4(3), 179-194</a>	
		all-E-	482		590		660/ 764					1700 3800	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 20min	<a href="#">PhotochemPhotobiol 2001, 74(6), 837-845</a>	
285.		13Z-	506 <sup>c</sup>	388 <sup>a</sup>	545 <sup>a</sup>		830					6300					<a href="#">JACS 1990, 112(20), 7398-7399</a>	
		13Z-	506 <sup>a</sup>		556		640/ 830					2400 6000	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 10min	<a href="#">JPhotochemPhoto Biol C: 2003, 4(3), 179-194</a>	
			506 <sup>a</sup>		506		640/ 830					2400 6000	$\tau_{1/2\text{dest}}$ 1 min			$\tau_{1/2\text{rec}}$ 10min	<a href="#">PhotochemPhotobiol 2001, 74(6), 837-845</a>	

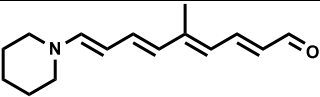
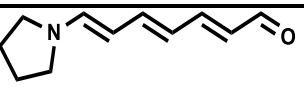
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
286.		all-E- 13Z-  all-E-  all-E-	490 <sup>c</sup> 465 <sup>c</sup>  493 <sup>a</sup>  493 <sup>a</sup>	460 <sup>a</sup> 450 <sup>a</sup>    640 <sup>a</sup>	640 <sup>a</sup> 638 <sup>a</sup>  640 <sup>a</sup>  640	~605     684/ 799	795 795  684/ 799					3050 3100  1000 3100  1000 3100	   $\tau_{1/2\text{dest}}$ 1 min  $\tau_{1/2\text{dest}}$ 1 min		$\tau_{\text{rec}} \sim 18\text{h}$   $\tau_{1/2\text{rec}}$ 16 min  $\tau_{1/2\text{rec}}$ 16 min	<a href="#">JACS 1990, 112(20), 7398-7399</a>  <a href="#">JPhotochemPhoto Biol C: 2003, 4(3), 179-194</a>  <a href="#">PhotochemPhotobiol 2001, 74(6), 837-845</a>			
287.		all-E-		450	590		694					2500					<a href="#">PhotochemPhotobiol 1993, 58(5), 701-705</a>		
288.		all-E-  all-E- 13Z-		421	532		601					2200  2160 2830					<a href="#">PhotochemPhotobiol 1993, 58(5), 701-705</a>  <a href="#">JACS 1990, 112(20), 7398-7399</a>		
289.		all-E-		450	556		830					5900					<a href="#">PhotochemPhotobiol 1993, 58(5), 701-705</a>		

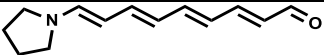
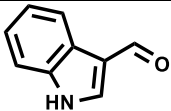
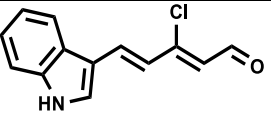
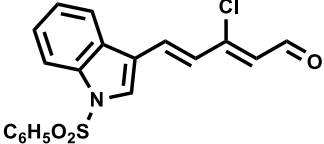
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
290.		all-E-		455	590		753					3700						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	
291.		all-E-		460	640		795					3100						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	
292.		all-E-		465	614		750					3000						<a href="#">Photochem. Photo. Biol.</a> 1993, 58(5), 701-705.	
		all-E-	496 <sup>a</sup>	465	614		750					2950				$\tau_{\text{rec}}$ 23 days		<a href="#">Photochem. Photo. Biol.</a> 1991, 54(4), 625-631	
		all-E-	477 <sup>a</sup>		614 <sup>a</sup>		624/ 774					260 3000				$\tau_{\text{rec}}$ 10 min		<a href="#">JPhotochemPhoto Biol. C</a> : 2003, 4(3), 179-194	
293.		all-E	477 $\epsilon$ 61000		606			662			NO	1400	decomposed in 5 h	stable	640+ /680-	str. R1. In 10 mM HEPES pH 7.0, 20°C ABR formed were stable in the dark, only ca. 20% reduction in the 662-nm maxima being observed at 6 days at 22 °C. Light >530 nm		<a href="#">JACS</a> 1983, 105(3), 646-648 	

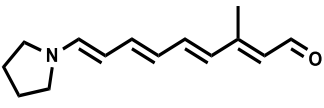
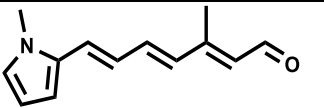
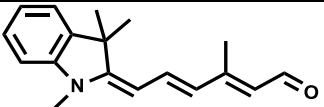
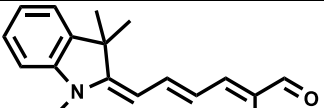
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E				646										irradiation 80% bleached in 4 h at 20°C.  Spin-labeled Pigments (ABR mutants A103C, M163C, or E74C). Reduction reaction with NH <sub>2</sub> OH is light-catalyzed in the A103C-labeled pigment, but not in E74C or M163C. ESR data. ABR reduced by NABH <sub>4</sub>  640+ /680- in 20 mM sodium phosphate buffer, pH 7.0. CD spectra.	<a href="#">JBiolChem 2000 275(28):21010-21016</a>  <a href="#">Chirality 2006 18(2):72-83</a>	
294.		all-E	475 $\epsilon$ 74000		623		662 $\epsilon$ 13000			NO		950	decomposed in 2 h, 20°C	stable	635+ /670-	str. R1 In 10 mM HEPES pH 7.0, 20°C $\tau_{1/2\text{rec}} \sim 40\text{min}$ ABR formed were stable in the dark, only ca. 20% reduction in the 662-nm maxima being observed at 6 days at 22°C. Light >530 nm irradiation 90% bleached in 40 min at 20°C.	<a href="#">JACS 1983 105(3):646-648</a>  <a href="#">14</a>  <a href="#">14</a>	
295.		all-E-  all-E-			480	530										pH 6.5, 20 mM HEPES buffer, 25°C $\tau_{\text{rec}} \sim 48\text{h}$  in water, pH 7.0	<a href="#">Angew Chem IE 1986 98(3):284-286</a>  <a href="#">BiophysJ 1989</a>	

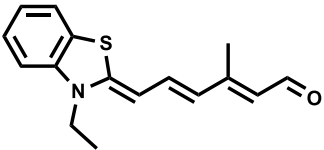
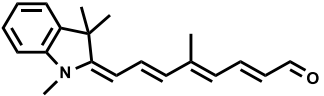
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
								529 529									pH 2.5 pH 0.5  Pulsed photolysis ABR red-shifted intermediate "I".	<a href="#">56(6)</a> <a href="#">1259</a> <a href="#">1265</a>  <a href="#">JACS</a> <a href="#">1989</a> <a href="#">111(9)</a> <a href="#">3203</a> <a href="#">3211</a>
296.		all-E-					640										pH 6.5, 20 mM HEPES buffer. 25°C $\tau_{\text{rec}} \sim 1\text{h}$	<a href="#">Angew. Chem IE</a> <a href="#">1986</a> <a href="#">98(3)</a> <a href="#">284-286</a>
		all-E-					640 640 640										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys J</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259</a> <a href="#">1265</a>
297.			296	292	330		NO											<a href="#">Lettersin OrgChem 2007</a> <a href="#">4(4)</a> <a href="#">300-305</a>
298.		all-E-	406 <sup>a</sup>		502		522						760					<a href="#">PhotochemPhotobiol 2007</a> <a href="#">83(1)</a> <a href="#">50-62</a> <a href="#">Lettersin OrgChem 2007</a> <a href="#">4(4)</a> <a href="#">300-305</a>
299.		all-E-	358	344	422		NO											<a href="#">Lettersin OrgChem 2007</a> <a href="#">4(4)</a> <a href="#">300-305</a>

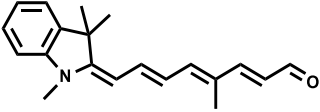
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
300.		all-E-					665 662 661										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys. J.</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259</a> <a href="#">1265</a>
301.		all-E-	420 <sup>a</sup>	391 <sup>a</sup>	504 <sup>a</sup>		NO										BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5	<a href="#">Photochem. Photobiol. Sci.</a> <a href="#">2024, V. 23, P. 31-53</a>
302.		all-E-	463 <sup>a</sup>	420 <sup>a</sup>	578 <sup>a</sup>		610		610	NO			908 908				BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR did not show any absorption changes after white light illumination for 10 min.	<a href="#">Angew. Chem. IE 1997.</a> <a href="#">36(15)</a> <a href="#">1630-1633</a>  <a href="#">Photochem. Photobiol. Sci.</a> <a href="#">2024, V. 23, P. 31-53</a>
303.		all-E-	456 <sup>a</sup>	422 <sup>a</sup>	567 <sup>a</sup>		NO										BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5.	<a href="#">Angew. Chem. IE 1997.</a> <a href="#">36(15)</a> <a href="#">1630-1633</a>  <a href="#">Photochem. Photobiol. Sci.</a> <a href="#">2024, V. 23, P. 31-53</a>

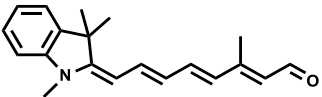
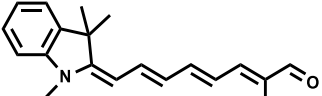
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
304.		all-E-	511		701		736					680					<a href="#">VII Internat Conference on Retinal Proteins, 1996, 66.</a>		
305.		all-E-	491 <sup>a</sup>	453 <sup>a</sup>	665 <sup>a</sup>		711					973				<p>ABR shown photochemical properties remarkably different from that of BRh. No changes in the parent state absorption could be detected time range of about 100 ns to 10 ms. Formation of the blue-shifted species ABR 648 nm under illumination 10 min, but is followed by an even slower process after several days in the dark the initial ABR at 698 nm is partially restored.</p> <p>BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and white light illumination (10 min) caused an only small reduction of the absorption band (around 2%) that is followed by a very slow thermally driven process of further intensity reduction of the absorption band concomitant with the</p>	<a href="#">Angew. Chem. IE 1997, 36(15), 1630 - 1633</a>  <a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31 - 53</a>		

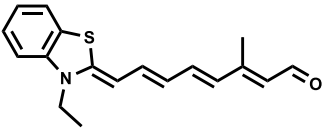
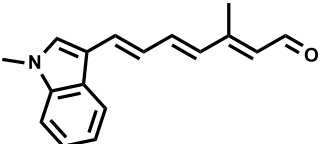
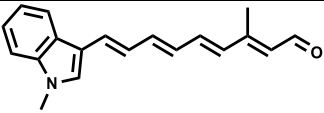
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	growth of a hypsochromically shifted new absorption band intermediate, $\lambda_{\max}$ 654 nm).	
306.		all-E-	490 <sup>a</sup>	452 <sup>a</sup>	657 <sup>a</sup>		698					894					<p>ABR shown photochemical properties remarkably different from that of BRh. No changes in the parent state absorption could be detected time range of about 100 ns to 10 ms.</p> <p>BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and white light illumination (10 min) caused an only small reduction of the absorption band (around 2%) that is followed by a very slow thermally driven process of further intensity reduction of the absorption band concomitant with the growth of a hypsochromically shifted new absorption band intermediate, <math>\lambda_{\max}</math>: 654 nm). ABR exhibit <math>\Phi</math>s up to several orders of magnitude greater than bRh.</p>	<p><a href="#">Angew. Chem.</a> <b>1997</b>, <i>36</i>(15), 1630 - 1633</p> <p><a href="#">Photochem. Photobiol. Sci.</a>, <b>2024</b>, <i>V. 23</i>, P. 31 - 53</p>

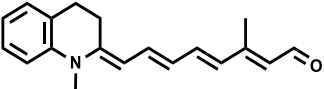
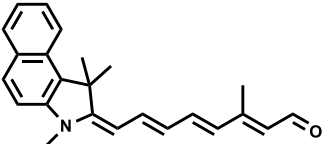
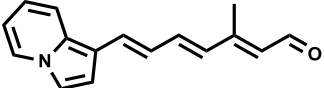
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
307.		all-E-	487 <sup>a</sup>	448 <sup>a</sup>	666 <sup>a</sup>		755					1770		stable	740+ /770-	$\tau_{\text{rec}} \sim 12\text{h}$ ABR shown photochemical properties remarkably different from that of BRh. No changes in the parent state absorption could be detected time range of about 100 ns to 10 ms.  BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and did not show any absorption changes after white light illumination for 10 min.	<a href="#">Angew. Chem. IE 1997, 36(15), 1630 - 1633</a>  <a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31 - 53</a>	
308.		all-E-	482 <sup>a</sup>	465 <sup>a</sup>	657 <sup>a</sup>		700					935			680+ /730-	ABR shown photochemical properties remarkably different from that of BRh. No changes in the parent state absorption could be detected time range of about 100 ns to 10 ms  BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and did not show any absorption changes after white light illumination for 10 min.	<a href="#">Angew. Chem. IE 1997, 36(15), 1630 - 1633</a>  <a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31 - 53</a>	

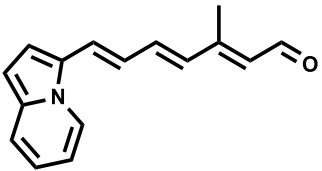
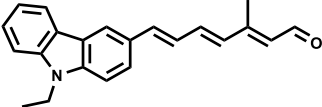
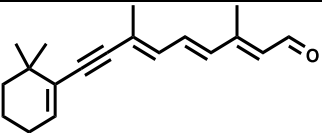
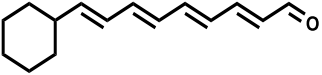
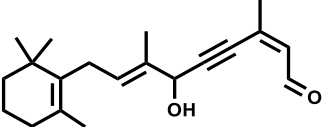
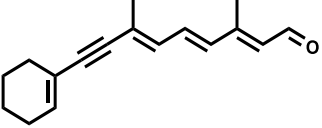
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
309.		all-E-	511 <sup>a</sup>	465 <sup>a</sup>	701 <sup>a</sup>		736					678				BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and showed an entirely unknown photochemical reactivity. When ABR undergoes white light illumination, it shown a reduction in absorption band intensity on 40%. ABR the covalent bond to the protein is disrupted upon illumination.	<a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31-53</a>		
310.		all-E-	420 $\epsilon$ 17270	390	510			558/ 582				1690 2430	decomposed in 2 days, 20°C	stable several days		str. S9 in 50 mM phosphate buffer, pH 6.5. $\tau_{1/2\text{rec}}$ 22.3 min. At acidic pH values, ABR shows a main band at 616 nm, with a minor species absorbing around 592 nm	<a href="#">ChemBioChem, 2005, 6(11), 2078-2087</a>		
		all-E-	421 <sup>a</sup>	390 <sup>a</sup>	515 <sup>a</sup>		NO									BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5.	<a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31-53</a>		
311.		all-E-	441 <sup>a</sup>	411 <sup>a</sup>	533 <sup>a</sup>		NO									BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5.	<a href="#">VII Internat. Conference on Retinal Proteins, 1996, 66</a>		

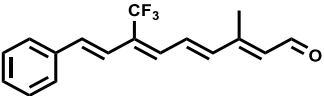
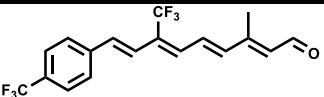
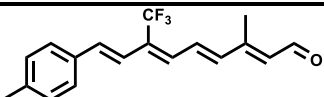
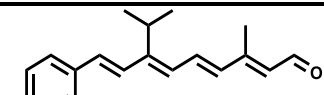
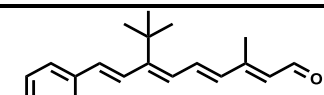
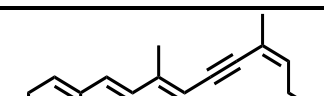
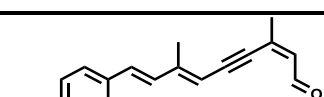
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		<a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31-53</a>
312.		all-E-	540 <sup>a</sup>	479 <sup>a</sup>	730 <sup>a</sup>		766					644					BO was prepared from the retinal-deficient <i>H. salinarum</i> strain JW5. ABR has strongly red-shifted absorption and showed an entirely unknown photochemical reactivity. ABR the covalent bond to the protein is disrupted upon illumination. When ABR undergoes white light illumination, it shown a reduction in absorption band intensity on 20%.	<a href="#">VII Internat. Conference on Retinal Proteins, 1996, 66</a>  <a href="#">Photochem. Photobiol. Sci., 2024, V. 23, P. 31-53</a>
313.		all-E-	502 <sup>a</sup>				NO										Computation of Vertical Excitation Energies of Retinal Analogs	<a href="#">J. Comput. Chem., 2006, 27(1), 116-123</a>
314.		all-E-	460 $\epsilon$ 5330	428	574			545/ 693				-930 2990	decomposed in 1 h, 20°C	stable 48 h		str. S9 in 50 mM phosphate buffer, pH 6.5. $\tau_{1/2rec}$ 61.2min	<a href="#">ChemBioChem, 2005, 6(11), 2078-2087</a>	

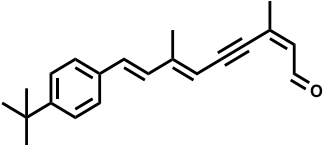
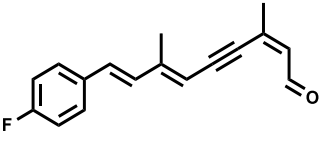
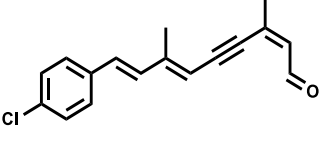
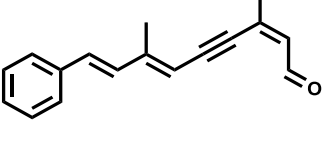
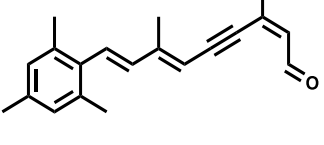
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
315.		all-E-	472 $\epsilon$ 8160	424	610			552/ 571/ 725					-1720 -1120 2600	decomposed in 1 h, 20°C	stable 48 h		str. S9 in 50 mM phosphate buffer, pH 6.5. $\tau_{1/2\text{rec}}$ 32.6 min	<a href="#">ChemBioChem</a> 2005, 6(11):2078-2087	
316.		all-E-	406 <sup>a</sup>					NO									Computation of Vertical Excitation Energies of Retinal Analogs	<a href="#">J.Comput.Chem.</a> 2006, 27(1):116-123	
317.		all-E- 13Z-					518 500		+	390	24	70-90%-E					H <sup>+</sup> -pump in JW5 cells $\tau_{\text{rec}}$ 15min "O" - 590 nm $\tau_{\text{Odec}}$ 200ms $\tau_{1/2\text{Mdec}}$ 6ms	<a href="#">JACS</a> 1984, 106(19):5654-5659	
318.		all-E-	340 <sup>a</sup>			370	460	460	450	+	350	++		1h,dark	replaced		in distilled water at 25°C pH 6.8. $\tau_{\text{rec}}$ 3 h, Light-induced absorption changes relatively small, although they are consistent with a BRh cycle. There is no apparent L→D-adaption. "M" produces an absorption near 350 nm that reverts in the dark to the ABR.	<a href="#">Biochem</a> 1981, 20(2):428-435	
319.		13Z-				+	NO										str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C	<a href="#">2</a>	
320.		all-E- 13Z-					504 486		+		7.5	70-90%-E					H <sup>+</sup> -pump in JW5 cells inactive in photophosphorylation	<a href="#">JACS</a> 1984, 106(19):5654-5659	

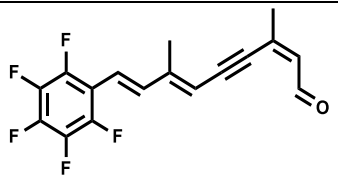
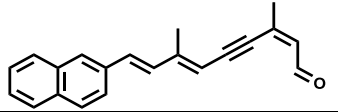
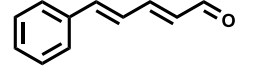
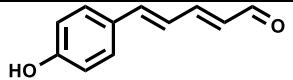
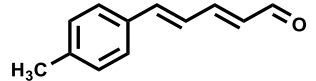
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
321.		all-E-					450										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
322.		all-E-					430										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
323.		all-E-					462										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
324.		all-E-					480										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
325.		all-E-					430										Second harmonic generation signal ABR	<a href="#">JACS 2002, 124(40), 11844-11845</a>	
326.		13Z-	368 $\epsilon$ 37700	358	432		485		450				2530 930				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 13 h	<a href="#">27</a> <a href="#">Bioorgan. Khim. 1987, 13(2), 238-251</a>	
327.		13Z-	379 $\epsilon$ 38300	366	444		493		462				2240 780				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 13 h	<a href="#">27</a> <a href="#">Bioorgan. Khim. 1987,</a>	

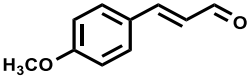
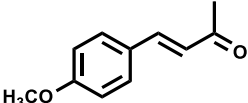
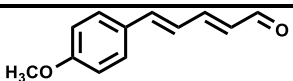
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		13(2), 238-251
328.		13Z-	368 $\epsilon$ 34800	357	431		473						2060 1270				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 13 h	27 Bioorgan. Khim. 1987. 13(2). 238-251
329.		13Z-	359 $\epsilon$ 25400	354	428		474		+				2270 1190				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 10 h light adaptation slowed $\geq$ 80 times	27 Bioorgan. Khim. 1987. 13(2). 238-251
330.		13Z-	358 $\epsilon$ 31700	353	426		475						2370 850				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 14 h	27 Bioorgan. Khim. 1987. 13(2). 238-251
331.		13Z-	357 $\epsilon$ 38000	352	423		471		+				2410 1320				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 14 h	27 Bioorgan. Khim. 1987. 13(2). 238-251
332.		13Z-	357 $\epsilon$ 28700	343	415		468						2730 1730				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 15 h	27 Bioorgan. Khim. 1987. 13(2). 238-251

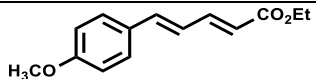
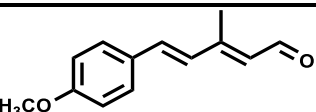
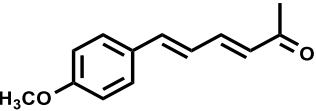
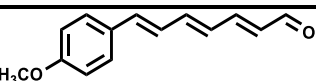
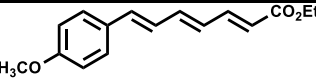
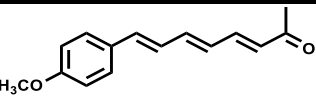
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
333.		13Z-	347	339	411		442		423				1710 690				str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 11 h	<a href="#">27</a> <a href="#">Bioorgan. Khim. 1987, 13(2), 238-251</a>
334.		13Z-	274, 368				481		475								str. 353P, in 50mM MES, 5mM EDTA, pH 6.5, 20°C, $\tau_{\text{rec}}$ 24h	<a href="#">28</a>
335.		all-E-	323 <sup>a</sup>		378 <sup>a,k</sup>		406						1820				strain JW5 in water Donor-acceptor substituted retinal analogs with substituents varying in donor and acceptor strength have reconstituted with BO. Quantum-chemical calculations chromophore-protein complexes were investigated.	<a href="#">J. Phys. Chem. A, 2010, 114(5), 2179-2188</a>
336.		all-E-	357 <sup>a</sup>		433 <sup>a,k</sup>		480						1930				strain JW5 in water Donor-acceptor substituted retinal analogs with substituents varying in donor and acceptor strength have reconstituted with BO. Quantum-chemical calculations chromophore-protein complexes were investigated.	<a href="#">J. Phys. Chem. A, 2010, 114(5), 2179-2188</a>
337.		all-E-	334 <sup>a</sup>		391 <sup>a,k</sup>		423						2260				strain JW5 in water Donor-acceptor substituted retinal analogs with substituents varying in donor and acceptor	<a href="#">J. Phys. Chem. A, 2010, 114(5), 2179-2188</a>

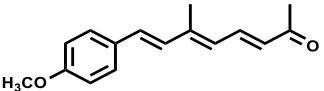
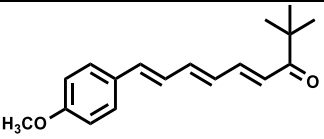
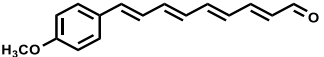
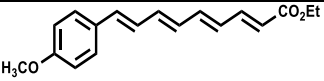
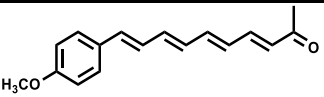
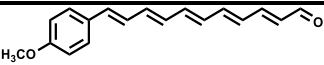
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																	strength have reconstituted with BO. Quantum-chemical calculations chromophore-protein complexes were investigated.		
338.		all-E-	319 <sup>a</sup> $\epsilon$ 30800  324 <sup>d</sup>			329  412				+		NO					340+ /429-	str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>
339.		all-E-	320 <sup>a</sup> $\epsilon$ 26300			325 $\epsilon$ 26000	NO											str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>
340.		all-E-	349 <sup>a</sup> $\epsilon$ 40400  356 <sup>d</sup>  351 <sup>a</sup>			364  453  459				+					2020		360+ /460-	str. R1 in 10mM MES, pH 6.0   strain JW5 in water Donor-acceptor substituted retinal analogs with substituents varying in donor and acceptor strength have reconstituted with BO. Quantum-chemical calculations chromophore-protein complexes were investigated.	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>  <a href="#">J. Phys. Chem. A, 2010, 114(5), 2179-2188</a>

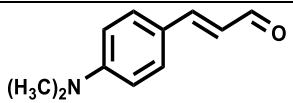
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
341.		all-E-	333 <sup>a</sup> $\epsilon$ 38300			342 $\epsilon$ 28700	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
342.		all-E-	355 <sup>a</sup> $\epsilon$ 34200 359 <sup>d</sup>			370 406 <sup>d</sup>	NO 460			+							str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
343.		all-E-	348 <sup>a</sup> $\epsilon$ 41700			360 $\epsilon$ 33500	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
344.		all-E-	377 <sup>a</sup> $\epsilon$ 49400 383 <sup>d</sup>			393 431 <sup>d</sup>	NO 489			+		NO		stable nearly several hours	stable nearly several hours	375+ /485-	str. R1 in 10mM MES, pH 6.0. L--D adaptation absent. ABR cycle with low efficiency.	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
345.		all-E-	382 <sup>a</sup> $\epsilon$ 55900			370 $\epsilon$ 34000	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
346.		all-E-	375 <sup>a</sup> $\epsilon$ 48300			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	

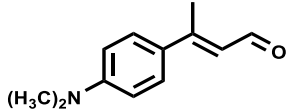
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1}cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
347.		all-E-	378 <sup>a</sup> $\epsilon$ 50400			398 $\epsilon$ 39300	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
348.		all-E-	378 <sup>a</sup> $\epsilon$ 50000			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
349.		all-E-	398 <sup>a</sup> $\epsilon$ 58700  408 <sup>d</sup>			380, 408, 434		531		+		+		stable nearly several hours	stable nearly several hours	510+	str. R1 in 10mM MES, pH 6.0 L--D adaptation absent. ABR cycle with low efficiency.	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
350.		all-E-	382 <sup>a</sup> $\epsilon$ 55900			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
351.		all-E-	397 <sup>a</sup> $\epsilon$ 47300			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	
352.		all-E-	417 <sup>a</sup> $\epsilon$ 68000  428 <sup>d</sup>			385, 414, 433		567				NO		stable nearly several hours	stable nearly several hours	555+	str. R1 in 10mM MES, pH 6.0. L--D adaptation absent. ABR cycle with low efficiency.	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>	

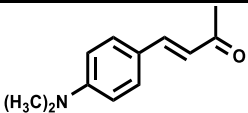
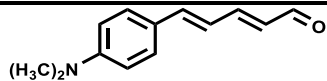
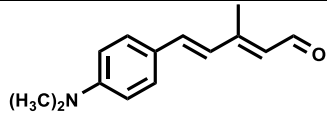
**Properties of artificial bacteriorhodopsin analogs**

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
353.		E-	389 <sup>a</sup> $\epsilon$ 37500			405	508			+		NO			stable nearly several hours	stable nearly several hours	395+ /524-	str. R1 in 10mM MES, pH 6.0. L--D adaptation absent. ABR cycle with low efficiency	<a href="#">Bioorgan. Khim. (Rus.) 1981, 7(8), 1169-1194</a>
		E-	390 <sup>d</sup>	364 <sup>d</sup>	464 <sup>d</sup>								2130						<a href="#">Retinal Proteins 1987, 205-216</a>
		E-	390 <sup>a</sup>	352	460		510			+			2130					20mM HEPES pH 7.0. ABR cycle has "K", but "O" and "L", "M" not observed.	<a href="#">Biochem 1985, 24(5), 1260-1265</a>
		E-					518 540 540											in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys. 1989, 56(6), 1259-1265</a>
		E-			460 <sup>a</sup> 460 <sup>a</sup> 460 <sup>a</sup>		508 492 494						2050 1400 1500					CB X=CHO NC X=NH <sup>+</sup> CH <sub>3</sub> NC X=NH <sup>+</sup> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub> The properties of noncovalently bound PSB pigments (NC) can be prepared in native BO that retains its Lys-216 residue in its binding site. Reconstitution was carried out at pH 7 using 5 mM phosphate buffer. Comparison of data of CB (polyenals) and NC (SB) pigments. pKa (PSB) 7.1 in	<a href="#">Biochem 2001, 40(44), 13310-13319</a>

**Properties of artificial bacteriorhodopsin analogs**

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																	ethanol/water, 1:1, solution containing 10 mM phosphate buffer. pKa (PSB) X=NH <sup>+</sup> CH <sub>3</sub> CB pigment 12 pKa (PSB) X=NH <sup>+</sup> CH <sub>3</sub> NC pigment 10.8		
354.		E-	390 <sup>a</sup>	347 <sup>a</sup>	464 <sup>a</sup>		518			NO			2250				20mM HEPES pH 7.0.	<a href="#">Biochem 1985, 24(5), 1260-1265</a>	
		E-			460 <sup>a</sup> 460 <sup>a</sup> 460 <sup>a</sup>		520 514 510						2500 2300 2130				CB X=CHO NC X=NH <sup>+</sup> CH <sub>3</sub> NC X=NH <sup>+</sup> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub> The properties of noncovalently bound PSB pigments (NC) can be prepared in native BO that retains its Lys-216 residue in its binding site. Reconstitution was carried out at pH 7 using 5 mM phosphate buffer. Comparison of data of CB (polyenals) and NC (SB) pigments. pKa (PSB) 6.6 in ethanol/water, 1:1, solution containing 10 mM phosphate buffer. pKa (PSB) X=NH <sup>+</sup> CH <sub>3</sub> CB pigment 11.5 pKa (PSB) X=NH <sup>+</sup> CH <sub>3</sub> NC pigment 10.6	<a href="#">Biochem 2001, 40(44), 13310-13319</a>	
		E-	380 <sup>a</sup>				520										Protein- $\beta$ -ionone Ring Interactions. Second harmonic generation (SHG) to probe the	<a href="#">JPhysChem B 2003, 107(25)</a>	

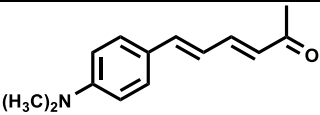
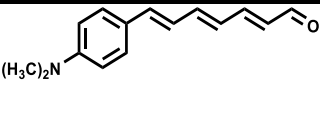
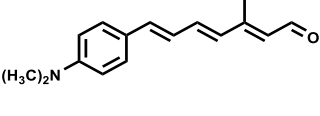
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	light-induced dipolar changes	<a href="#">6221-6225</a>
355.		E-	384 <sup>a</sup> $\epsilon$ 33800			390 $\epsilon$ 29500	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">Bioorgan. Khim. (Rus), 1981, 7(8), 1169-1194</a>
356.		all-E-	418 <sup>a</sup>	384 <sup>a</sup>	509 <sup>a</sup>		582			+			2470				20mM HEPES pH 7.0. ABR cycle" has 2 "L", blue-shifted	<a href="#">Biochem. 1985, 24(5), 1260-1265</a>
		all-E-					582 630 634										in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys. J. 1989, 56(6), 1259-1265</a>
		all-E-	416 <sup>a</sup>		533 <sup>a,k</sup>		580							1520			strain JW5 in water Donor-acceptor substituted retinal analogs with substituents varying in donor and acceptor strength have reconstituted with BO. Quantum-chemical calculations chromophore-protein complexes were investigated.	<a href="#">J. Phys. Chem. A, 2010, 114(5), 2179-2188</a>
357.		all-E-		384	511		576			+			2210					<a href="#">Retinal Proteins 1987, 205-216</a>

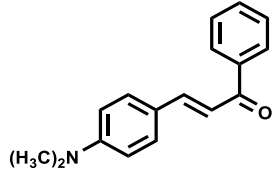
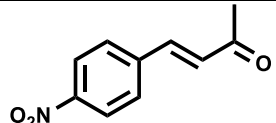
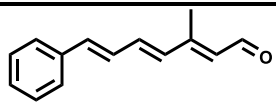
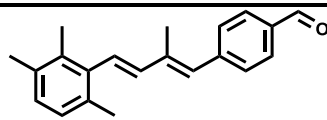
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			+				M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-	407 <sup>a</sup>	384 <sup>a</sup>	511 <sup>a</sup>		576					2210				20mM HEPES pH 7.0. ABR cycle "K", "O" and "L", but "M" not observed	<a href="#">Biochem 1985, 24(5), 1260-1265</a>		
		all-E-					576 620 631									in water. pH 7.0 pH 2.5 pH 0.5	<a href="#">Biophys J 1989, 56(6), 1259-1265</a>		
		all-E-			511		580					2300				pKa (SBH <sup>+</sup> ) = 7.0, pKa (ABR SB) = 12.0. Titrations of ABR data	<a href="#">Biochem 1995, 34(37), 12059-12065</a>		
		all-E-														pKa (ABR Asp85) = 5.2. Titrations of ABR data	<a href="#">Biochem 1995, 34(37), 12066-12074</a>		
		all-E-			510 <sup>a</sup> 510 <sup>a</sup> 510 <sup>a</sup>		578 618 600					2300 3430 2950				CB X=CHO NC X=NH <sup>+</sup> CH <sub>3</sub> NC X=NH <sup>+</sup> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub> The properties of noncovalently bound PSB pigments (NC) can be prepared in native BO that retains its Lys-216 residue in its binding site. Reconstitution was carried out at pH 7 using 5 mM phosphate buffer. Comparison of data of CB (polyenals) and NC (SB) pigments. pKa (PSB) 6.2 in ethanol/water, 1:1, solution containing 10 mM phosphate buffer.	<a href="#">Biochem 2001, 40(44), 13310-13319</a>		

### Properties of artificial bacteriorhodopsin analogs

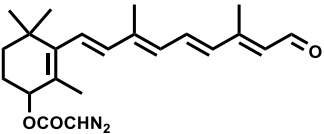
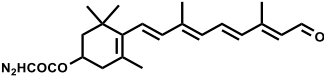
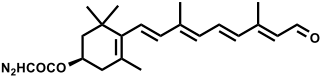
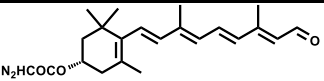
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
		all-E-	424 <sup>a</sup>				570									<p>pKa (PSB) X=NH<sup>+</sup>CH<sub>3</sub>                      CB pigment 12                      pKa (PSB) X=NH<sup>+</sup>CH<sub>3</sub>                      NC pigment 10.9</p> <p>Protein-<i>b</i>-Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes</p>	<a href="#">JPhysChem B 2003, 107(25): 6221-6225</a>	
358.		all-E-	408 <sup>a</sup> $\epsilon$ 35300			420 $\epsilon$ 30500	NO									str. R1 in 10mM MES, pH 6.0	<a href="#">BioorganKhim. (Rus), 1981, 7(8): 1169-1194</a>	
359.		all-E-  all-E-	435 <sup>a</sup>	396 <sup>a</sup>	525 <sup>a</sup>		615			+			2790			<p>20mM HEPES pH 7.0. ABR cycle similar to BRh "K"<sup>720</sup>, "O"<sup>520</sup> and "M" but "L" not observed.</p> <p>in water.                      pH 7.0                      pH 2.5                      pH 0.5</p>	<a href="#">Biochem 1985, 24(5): 1260-1265</a>  <a href="#">BiophysJ 1989, 56(6): 1259-1265</a>	
360.		all-E-  all-E-		398	524		590			+				2140			<p>20mM HEPES pH 7.0. ABR cycle similar to BRh "K", "O" and "M" but "L" not observed.</p> <p>in water.</p>	<a href="#">Retinal Proteins 1987, 205-216</a>  <span style="background-color: green; color: white; padding: 2px;">17</span>  <a href="#">Biochem 1985, 24(5): 1260-1265</a>

### Properties of artificial bacteriorhodopsin analogs

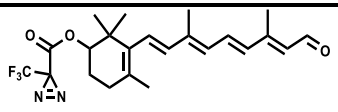
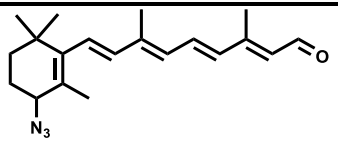
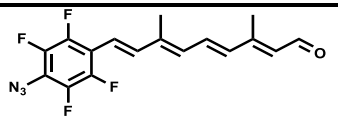
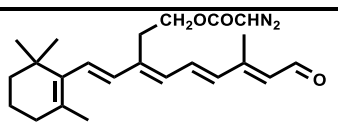
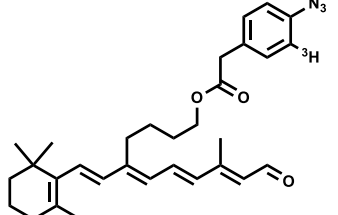
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
		all-E-					590 635 635										pH 7.0 pH 2.5 pH 0.5	<a href="#">BiophysJ</a> <a href="#">1989</a> <a href="#">56(6)</a> <a href="#">1259</a> <a href="#">1265</a>	
		all-E-	428 <sup>a</sup>				620										Protein-b-Ionone Ring Interactions. Second harmonic generation (SHG) to probe the light-induced dipolar changes	<a href="#">JPhysChem B</a> <a href="#">2003</a> <a href="#">107(25)</a> <a href="#">6221</a> <a href="#">6225</a>	
361.		all-E-	419 <sup>a</sup> $\epsilon$ 37400			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">BioorganKhim.</a> <a href="#">(Rus).</a> <a href="#">1981,</a> <a href="#">7(8).</a> <a href="#">1169</a> <a href="#">1194</a>	
362.		all-E-	305 <sup>a</sup> $\epsilon$ 24300			+	NO										str. R1 in 10mM MES, pH 6.0	<a href="#">BioorganKhim.</a> <a href="#">(Rus).</a> <a href="#">1981,</a> <a href="#">7(8).</a> <a href="#">1169</a> <a href="#">1194</a>	
363.		all-E-			406			438	438			74/26 74/26	1800 1800				pH 7.0, 50 mM Hepes	<a href="#">PhotochemPhotobiol</a> 1991 <a href="#">54(6)</a> <a href="#">969-976</a>	
364.		all-E-	326 $\epsilon$ 27500			+	NO										str. R1	<a href="#">BioorganKhim.</a> <a href="#">(Rus).</a> <a href="#">1984, v.</a> <a href="#">10, N 2,</a> <a href="#">256-259</a>	

K. Labelled BR derivatives (radioactive, photo-affinic, fluorophoric, heavy-atom, paramagnetic (SL), ionophoric and photochromic probes)

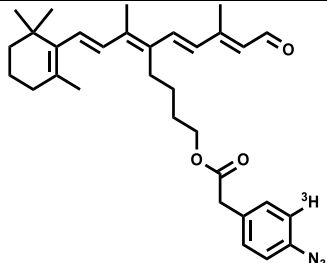
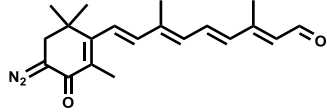
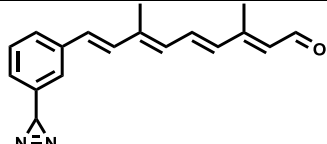
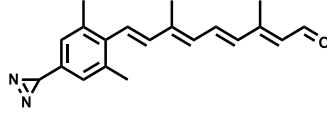
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
365.		all-E-					540										ABR in dark in 67 mM phosphate buffer at pH 7.0 immediately hydrolysed in 4-hydroxy-ABR	<a href="#">Photochem Photobiol 1981 33(4) 483-488</a>
366.		all-E-					525	525	+					unstable in dark			In water pH7.0, $\tau_{\text{rec}}$ 1.5 h. UV-induced cross-links. Reversible L-D adaptation	<a href="#">Photochem Photobiol 1981 33(4) 483-488</a>
		all-E-1-( <sup>14</sup> C)	245 $\epsilon$ 18000 360° $\epsilon$ 49000					440sh 525	532	+	50	75\25		unstable under irradiation similar to natural BR	stable	LA-505+ /590-	10 mM Hepes buffer, pH7.0. Reversible L-D adaptation. UV-induced cross-links 25%. ABR532 stable to irradiation with light >530 nm	<a href="#">JACS 1983 105(15) 5160-5162</a>
		13Z-					500											
367.		all-E-3S(3 $\beta$ )1-( <sup>14</sup> C)						525	538	+	402	100					in distilled H <sub>2</sub> O $\tau_{\text{rec}}$ 5 h "K" 610 nm. H <sup>+</sup> -transport in 4M NaCl, JW2N cells. UV irradiation at 254 nm generated highly reactive carbenes, which cross-linked the radiolabeled retinals to amino acid residues in the vicinity of the $\beta$ -ionone ring. UV-induced cross-links with Thr121/ Gly122.	<a href="#">Tetrahedron Lett. 1988 29(19) 2275-2278</a> <a href="#">Biochem 1990 29(20) 4898-4904</a>
368.		all-E-3R(3 $\alpha$ )-1-( <sup>14</sup> C)						535	545	+	410	100					in distilled H <sub>2</sub> O $\tau_{\text{rec}}$ 5 h "K" 590 nm. H <sup>+</sup> -transport in 4M NaCl, JW2N cells. UV irradiation at 254 nm generated highly reactive carbenes,	<a href="#">Tetrahedron Lett. 1988 29(19) 2275-2278</a>

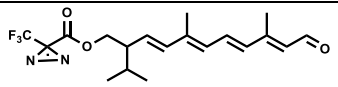
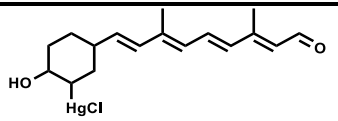
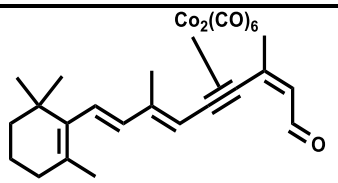
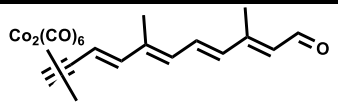
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																	which cross-linked the radiolabeled retinals to amino acid residues in the vicinity of the $\beta$ -ionone ring. UV-induced cross-links.	<a href="#">Biochem 1990 29(20): 4898 - 4904</a>
369.		all-E-					475											<a href="#">Tetrahedron 1984 40(3): 493-500</a>
370.		all-E-	272 $\epsilon$ 1300, 375 $\epsilon$ 39500			+	475										str. R1, pH7.0. Label stable to UV-induced cross-links formation.	<a href="#">Bioorgan Khim (Rus) 1981 7(11): 1731-1733</a>
371.		all-E-	390 <sup>a</sup>				517		507	+	410	40		slowly destroyed in 2h	slowly displaced		In distilled water. Slowed "M"-decay kinetics. Interaction of tritiated RetA as a potential photoactivatable cross-linking agent to BRh showed no labeling of the protein with a detection limit estimated at 5%.	<a href="#">Photochem. Photobiol. 1994 60(1): 64-68</a>
372.		all-E-					452					12					pH 7.0, 25°C in dark	<a href="#">JACS 1989 111(13): 4997-4998</a>
373.		all-E-					475					+++		1430			$\tau_{\text{rec}}$ 2 h, 35% yield. ABR labeling resulted in cross-linking to many amino acids.	<a href="#">Biophys Chem 1995 56(1-2): 13-22</a>  <a href="#">JACS 1994 116(15)</a>

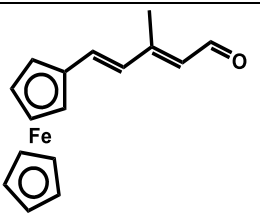
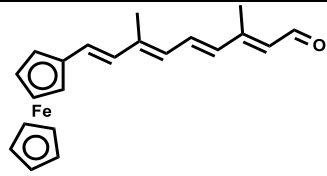
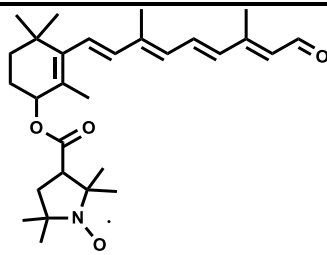
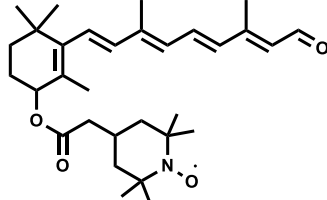
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
374.		all-E-					503				+++		2340			290-496 +	$\tau_{\text{rec}}$ 186 h, 50% yield. UV-induced cross-links 7% Asn176/Arg175	<a href="#">6823-6831</a> <a href="#">Biophys Chem</a> 1995, <a href="#">56(1-2)</a> , <a href="#">13-22</a> <a href="#">JACS</a> 1994, <a href="#">116(15)</a> , <a href="#">6823-6831</a>	
375.		all-E-  15- <sup>3</sup> H	385 $\epsilon$ 50500				497				20						UV-induced cross-links 15% Ala126/Leu127 and Trp137/138. 1 min irradiation at 475 nm led to reduction in ABR497 and rapid decrease in H-pump ability	<a href="#">JACS</a> , 1990, <a href="#">112(21)</a> , <a href="#">7779-7782</a>	
376.		all-E-  15- <sup>3</sup> H	390 <sup>a</sup> $\epsilon$ 45700				470 $\epsilon$ 35300										str. R1S9 pH 6.5, 22°C. $\tau_{\text{rec}}$ 6 h. UV-induced cross-links 30% Ser193/Glu194.	<a href="#">JBiolChem</a> , 1982, <a href="#">257(22)</a> , <a href="#">13616-13623</a>	
377.		all-E-  15- <sup>3</sup> H	364 <sup>c</sup> $\epsilon$ 64000				450										In 100mM HEPES buffer solution pH 7.2. UV-induced cross-links 30%	<a href="#">J. Label. Compounds Radiopharm.</a> , 1987, <a href="#">24(7)</a> , <a href="#">787-795</a> <a href="#">PhotochemPhotobiol</a> 1985, <a href="#">41(3)</a> , <a href="#">303-307</a>	

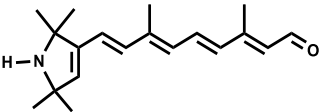
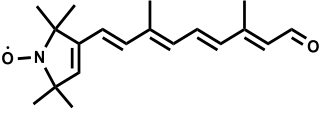
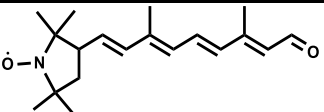
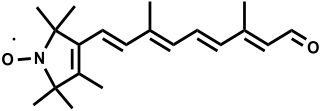
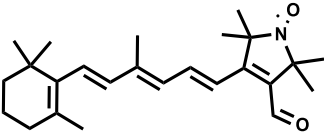
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
378.		all-E-					448	453	450	+	345/ 360				slowly replaced			<a href="#">Biophys. J. 1993. 64(2-P2). A211</a>
379.		all-E-					478	478			+	+			stable	str. ET1001, 25 mM phosphate buffer, pH 7.0. X-ray diffraction data. ABR cycle comparable to BRh, but rate constants are altered.	<a href="#">Photochem Photobiol 1991 54(6) 873-879</a> <a href="#">Biophys. J. 1989. 55(2). 255a.</a>	
380.		13Z-	320 $\epsilon$ 22300, 578sh $\epsilon$ 2800			NO	NO									str. 353P, R1 and ET1001 pH 6.0 No pigment formation during 2 days incubation	<a href="#">Shevyakov S.V. Ph.D. thesis. 2000</a> <a href="#">Biochem M 2001 66(11) 1323-1333</a>	
381.		all-E-	390 $\epsilon$ 44900				450 500sh									str. 353P, R1 and ET1001 pH 6.0 $\tau_{\text{rec}} \sim 2$ h Unstable and self destroyed in 2 days	<a href="#">Shevyakov S.V. Ph.D. thesis. 2000</a> <a href="#">Biochem M 2001 66(11) 1323-1333</a>	

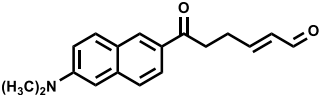
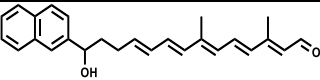
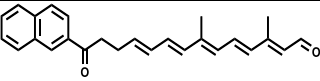
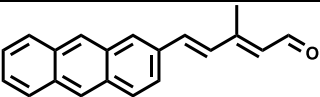
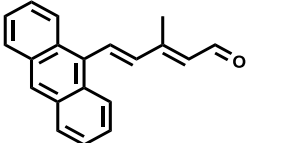
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1}cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
382.		all-E-	280 $\epsilon$ 8700 337 $\epsilon$ 26700 503 $\epsilon$ 3100	327 479sh	392 578		426 517					2040				str. 353P, R1 and ET1001 pH 6.0 $\tau_{rec}$ ~25 days	<a href="#">Shevyakov S.V. Ph.D. thesis, 2000</a> <a href="#">Biochem M 2001 66(11) 1323-1333</a>	
383.		all-E-	296 $\epsilon$ 12900 394 $\epsilon$ 38700 508 $\epsilon$ 6400	373 484sh	454 568sh		485 590sh  483 593sh			NO		1410  1320				str. 353P, R1 and ET1001 pH 6.0 $\tau_{rec}$ ~5 days Stable 2 months	<a href="#">Shevyakov S.V. Ph.D. thesis, 2000</a> <a href="#">Biochem M 2001 66(11) 1323-1333</a>	
384.		all-E-	380 <sup>a</sup>				480						0.1M, 4h complete hydroxylaminolysis of ABR480 without ABR480->ABR535	stable		in 50 mM sodium acetate buffer pH 5.5. Easy hydrolyzed in 4-hydroxy-ABR535 after 0.5 h. ESR spectrum	<a href="#">Photochem Photobiol 1981, 33(4), 489-494</a>	
385.		all-E-	250 $\epsilon$ 4100, 370 $\epsilon$ 41500			+	465									str. R1, in 50 mM phosphate buffer at pH 7.0, slowly hydrolyzed in 4-hydroxy-ABR. ESR spectrum	<a href="#">Bioorgan Khim (Rus), 1981, 7(11), 1731-1733</a>	

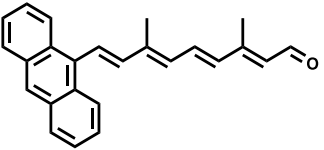
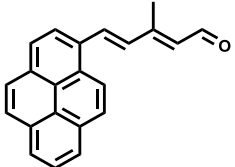
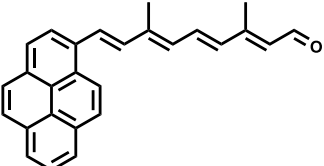
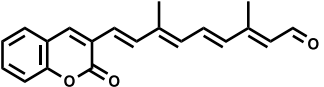
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
386.		all-E-	384 <sup>a</sup> 366 <sup>c</sup>	365				459 459			NO		1000		replaced in 48h		str. R1S9 in water. ABR not show light-dark adaptation. $\tau_{\text{rec}}$ ~several min	<a href="#">Recl. 1995, 114(9-10), 403-409</a>
387.		all-E-	374				454 459			NO	0			stable 60 min 0.1M	stable		ESR spectrum. ABR show light-dark adaptation.	<a href="#">JACS 1981, 103(24), 7364-7366.</a>
		13Z-	375				454 459											<a href="#">IS</a>
		all-E-	384 <sup>a</sup> 366 <sup>c</sup>	365			459	459 459			NO		1000		replaced in 48h		str. R1S9 in water. ABR not show light-dark adaptation. $\tau_{\text{rec}}$ ~several min. ESR spectrum.	<a href="#">Recl. 1995, 114(9-10), 403-409</a>
		all-E-					460										$\tau_{\text{rec}}$ ~several h. Binding of Mn <sup>2+</sup> to deionized wild-type and mutants E74C, A103C, and M163C	<a href="#">Biophys. J. 2001, 81(2), 1155-1162.</a>
388.		all-E-	360 <sup>a</sup>				440 450		+	365	++							<a href="#">IS</a>
389.		all-E-	270 $\epsilon$ 10800 377 <sup>a</sup> $\epsilon$ 33600														Synthetic route	<a href="#">Monatsh. Chem. 2014, 145, 651-656.</a>
390.		13Z-	258 $\epsilon$ 8300 384 <sup>a</sup> $\epsilon$ 21300														Synthetic route	<a href="#">Monatsh. Chem. 2014, 145, 651-656.</a>

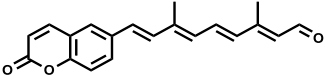
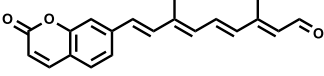
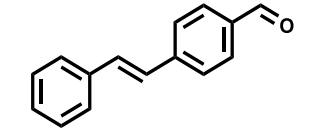
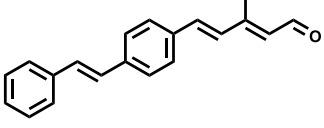
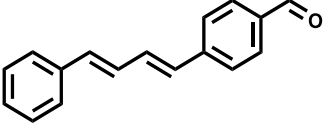
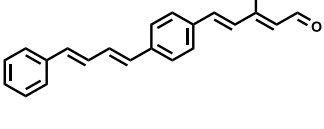
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
391.		E-	372 <sup>a</sup> 351 <sup>c</sup> 380 <sup>g</sup>			352											In 10 mM Hepes buffer pH 6.5. Emission spectra for: CHO: 401 <sup>c</sup> , 445 <sup>f</sup> , 510 <sup>a</sup> . NC: 440nm -> 425nm ABR: 532 nm	<a href="#">JACS</a> 1987, <a href="#">109(5)</a> , <a href="#">1594 - 1596</a> .
392.		all-E-	380-390 <sup>g</sup>		460 <sup>a</sup>		460	460	460					stable, replaced within ~12h		flash-photolysis ABR460~>"K"1.5μs->"L"500μs>"M"100ms->P460	<a href="#">Biochem</a> 1991, <a href="#">30(23)</a> , <a href="#">5400 - 5409</a>	
393.		all-E-	376 <sup>a</sup> 380-390 <sup>g</sup>		460 <sup>a</sup>		460	460	460					stable, replaced within ~12h			<a href="#">Biochem</a> 1991, <a href="#">30(23)</a> , <a href="#">5400 - 5409</a>	
394.		all-E-  13Z-	227, 249, 331, 368, 386  227, 251, 310, 329, 368, 386		345, 365, 440  345, 365, 440	NO  NO											<a href="#">29</a> <a href="#">JAppl Spectrosc</a> copy (Rus) 1990, <a href="#">52(1)</a> , <a href="#">24 - 30</a>	
395.		all-E-	253 $\epsilon$ 205300 387 $\epsilon$ 11250	254 386	254 456		552					3810	stable in 8 h	stable		in 10 mM Hepes buffer at 25°C. Steady state fluorescence measurements.	<a href="#">CanJ Chem</a> 1990, <a href="#">68(3)</a> , <a href="#">383-390</a>  <a href="#">JPhotochemPhoto Biol B</a> 1991, <a href="#">8(3)</a> , <a href="#">325-335</a>	

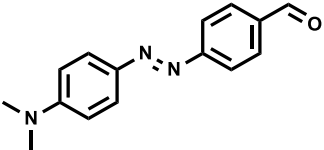
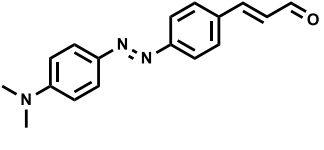
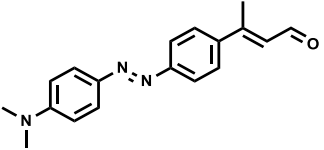
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			+				M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
396.		all-E-	261 $\epsilon$ 80600 410 $\epsilon$ 24800	395  260 393	429  261 418		545		550	+	400		4820 5130	stable in 24 h	stable		in 10 mM Hepes buffer at 25°C. Steady state fluorescence measurements.	<a href="#">CanJ Chem</a> 1990, 68(3), 383-390  <a href="#">JPhotochemPhoto Biol B</a> 1991, 8(3), 325-335	
397.		all-E-		384	466		498			+	400	++	1380	stable in 4 h	stable in 6 h		str. S9, in 50 mM phosphate buffer at pH 7.2. ABR do not show dark adaptation. ABR cycle "M".	<a href="#">Photochem. Photo Biol.</a> 1999, 70(6), 949-956	
398.		all-E-		422 422 422	500 500 500		514 512 516			+	430	++	550 470 620	stable in 4 h	stable in 6 h		WT E194Q E204Q str. S9, in 50 mM phosphate buffer at pH 7.2, E194Q and E204Q mutants ABR do not show dark adaptation. ABR cycle "M" "O". "M" decay in 10 times slower. "O" decay $\tau$ = 200 ms.	<a href="#">Photochem. Photo Biol.</a> 1999, 70(6), 949-956	
399.		all-E-  all-E-	407	394	460		475			+							str. 353P, str. ET1001, 5mM MES, pH 6.0  electronic and structural properties of retinal analog were studied using semiempirical, ab initio Hartree-Fock, and DFT methods	<a href="#">Tetrahedron</a> 1996, 52(28), 9581-9588  <a href="#">J. Chem. Phys.</a> 2006, V. 125, 144901	

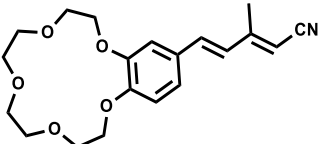
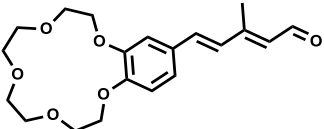
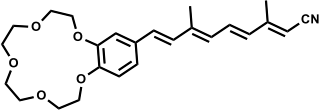
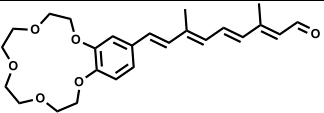
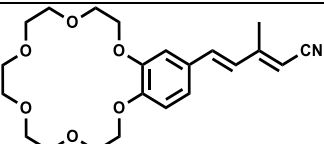
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
400.		all-E-  all-E-	391	388	464		478					630				str. S 9  electronic and structural properties of retinal analog were studied using semiempirical, ab initio Hartree-Fock, and DFT methods	<a href="#">Tetrahedron Lett. 1999, 40(13), 2645-2648</a>  <a href="#">J. Chem. Phys., 2006, V. 125, 144901</a>		
401.		all-E-	401 420sh	395	460		497 438 413					1620				str. S 9	<a href="#">Tetrahedron Lett. 1999, 40(13), 2645-2648</a>		
402.		E-	330 $\epsilon$ 48700	325	373		NO									in HEPES buffer fluorescence emission spectra $\lambda_{f \max}$ 435, 459(sh)	<a href="#">Photochem Photobiol 2003, 78(5), 503-510.</a>		
403.		all-E-	364 $\epsilon$ 50200	362	421		440					1025		stable $\tau_{\text{repl}}$ 340 min	in HEPES buffer $\tau_{\text{rec}} \sim 20$ min fluorescence emission spectra $\lambda_{f \max}$ 550, 421(sh) nm No fluorescence emission in pigment	<a href="#">Photochem Photobiol 2003, 78(5), 503-510.</a>			
404.		all-E-	355 $\epsilon$ 49100	347	405		NO									in HEPES buffer fluorescence emission spectra $\lambda_{f \max}$ 500 nm	<a href="#">Photochem Photobiol 2003, 78(5), 503-510.</a>		
405.		all-E-	383 $\epsilon$ 38500	379	409		452					660		stable $\tau_{\text{repl}}$ 300 min	in HEPES buffer $\tau_{\text{rec}} \sim 20$ min fluorescence emission spectra $\lambda_{f \max}$ 603 nm No fluorescence emission in pigment	<a href="#">Photochem Photobiol 2003, 78(5), 503-510.</a>			

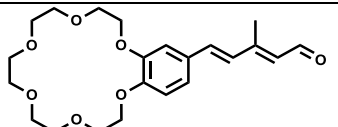
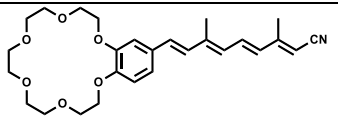
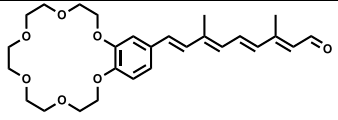
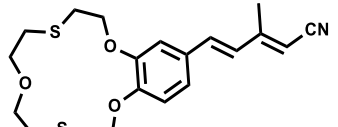
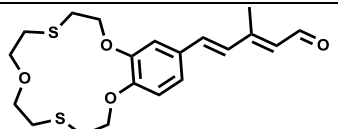
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
406.		E-          E-	229 $\epsilon$ 14500, 284 $\epsilon$ 18200, 449 $\epsilon$ 22500	436	465		458				+		-330		stable 1h % <sub>repl</sub> after 24h – 26%		str. R <sub>1</sub> M <sub>1</sub> 10 mM TrisHCl buffer pH 5, $\tau_{1/2\text{rec}} \sim 7\text{min}$ Fluorescence behavior	<a href="#">JACS</a> <a href="#">1996</a> <a href="#">118(26)</a> <a href="#">6185-</a> <a href="#">6191</a>
			412				458											<a href="#">Org.</a> <a href="#">Biomol.</a> <a href="#">Chem.</a> <a href="#">2020, V.</a> <a href="#">18, P.</a> <a href="#">6312 –</a> <a href="#">6327</a>
407.		E-          E-	253 $\epsilon$ 5382 313 $\epsilon$ 10928, 461 $\epsilon$ 18836	446	504		597				+		3090		stable 1h % <sub>repl</sub> after 24h -15%		str. R <sub>1</sub> M <sub>1</sub> 10 mM TrisHCl buffer pH 5, $\tau_{1/2\text{rec}} \sim 11\text{min}$ Fluorescence behavior	<a href="#">JACS</a> <a href="#">1996</a> <a href="#">118(26)</a> <a href="#">6185-</a> <a href="#">6191</a>
			387				462											<a href="#">Org.</a> <a href="#">Biomol.</a> <a href="#">Chem.</a> <a href="#">2020, V.</a> <a href="#">18, P.</a> <a href="#">6312 –</a> <a href="#">6327</a>
408.		E-	251 $\epsilon$ 7422, 310 $\epsilon$ 8698, 450 $\epsilon$ 17460	434	484		485				NO		40		stable 1h % <sub>repl</sub> after 24h -80%		str. R <sub>1</sub> M <sub>1</sub> 10 mM TrisHCl buffer pH 5, $\tau_{1/2\text{rec}} \sim 1\text{min}$ Fluorescence behavior	<a href="#">JACS</a> <a href="#">1996</a> <a href="#">118(26)</a> <a href="#">6185-</a> <a href="#">6191</a>

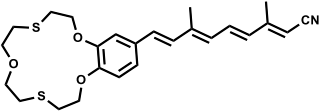
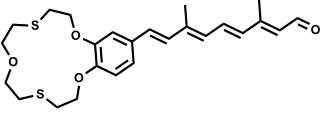
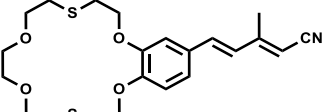
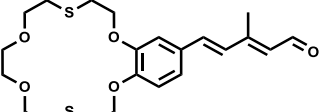
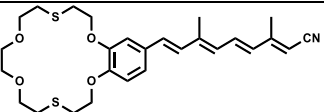
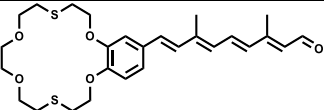
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{ cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
409.		all-E-	340 <sup>h</sup> $\epsilon$ 32400					NO									str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
410.		all-E-	356 <sup>h</sup> $\epsilon$ 32600					450-460									str. ET1001, 5mM MES, pH 6.0 $\tau_{\text{rec}} \sim 20$ min	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
411.		all-E-	383 <sup>h</sup> $\epsilon$ 45000					NO									str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
412.		all-E-	400 <sup>h</sup> $\epsilon$ 52000						495			23					str. ET1001, 5mM MES, pH 6.0 $\tau_{\text{rec}} \sim 2$ h	<a href="#">Mol. Cryst. Liq. Cryst. 2005, 431, 209-214</a> <a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a> <a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
413.		all-E-	342 <sup>h</sup> $\epsilon$ 34000					NO									str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	

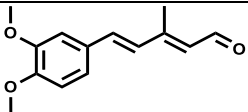
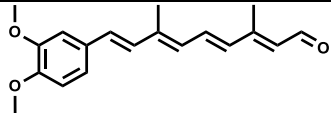
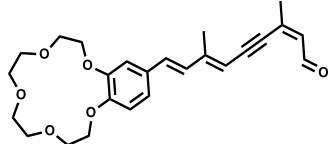
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
414.		all-E-	359 <sup>h</sup> $\epsilon$ 28000				450-460										str. ET1001, 5mM MES, pH 6.0 $\tau_{rec}$ ~20 min	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
415.		all-E-	387 <sup>h</sup> $\epsilon$ 44000				NO										str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
416.		all-E-	400 <sup>h</sup> $\epsilon$ 50000					495		22							str. ET1001, 5mM MES, pH 6.0 $\tau_{rec}$ ~2 h	<a href="#">Mol. Cryst. Liq. Cryst. 2005, 431, 209-214</a> <a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a> <a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
417.		all-E-	341 <sup>h</sup> $\epsilon$ 32000				NO										str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	
418.		all-E-	354 <sup>h</sup> $\epsilon$ 27000				450-460										str. ET1001, 5mM MES, pH 6.0 $\tau_{rec}$ ~20 min	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>	

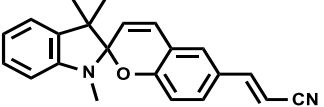
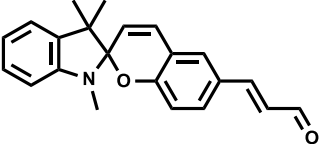
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
419.		all-E-	379 <sup>h</sup> $\epsilon$ 44500					NO									str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
420.		all-E-	396 <sup>h</sup> $\epsilon$ 51000						497								str. ET1001, 5mM MES, pH 6.0 $\tau_{rec} \sim 2$ h	<a href="#">Mol. Cryst. Liq. Cryst. 2005, 431, 209-214</a> <a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a> <a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
421.		all-E-	339 <sup>h</sup> $\epsilon$ 23000					NO									str. ET1001, 5mM MES, pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
422.		all-E-	359 <sup>h</sup> $\epsilon$ 29000					450-460									str. ET1001, 5mM MES, pH 6.0 $\tau_{rec} \sim 20$ min	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
423.		all-E-	379 <sup>h</sup> $\epsilon$ 42000					NO									str. ET1001 pH 6.0	<a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
424.		all-E-	396 <sup>h</sup> $\epsilon$ 55000						497								str. ET1001, 5mM MES, pH 6.0 $\tau_{rec} \sim 2$ h	<a href="#">Mol. Cryst. Liq. Cryst.</a>

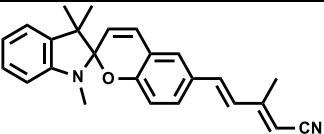
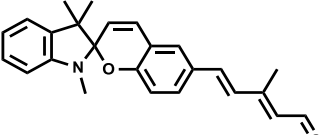
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} cm^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $cm^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		2005, 431, 209-214 Vestnik MITHT, 2011, 6(2), 15-36 Lukin A. Yu. Ph.D. thesis, 2004	
425.		all-E-	358 $\epsilon$ 34000				450-460										str. ET1001, 5mM MES, pH 6.0 $\tau_{rec} \sim 20$ min	Lukin A. Yu. Ph.D. thesis, 2004	
426.		all-E-	400 $\epsilon$ 40000 402 <sup>h</sup>				500			+		35					str. ET1001, 5mM MES, pH 6.0 $\tau_{rec} \sim 1$ h	Mol. Cryst. Liq. Cryst. 2005, 431, 209-214 Vestnik MITHT, 2011, 6(2), 15-36 Lukin A. Yu. Ph.D. thesis, 2004	
427.		all-E-	364 $\epsilon$ 35000	356	436		460			+		3.5-4		1200			str. ET1001 pH 6.0	Mol. Cryst. Liq. Cryst. 2000, 345 15.	

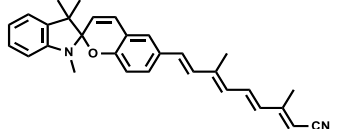
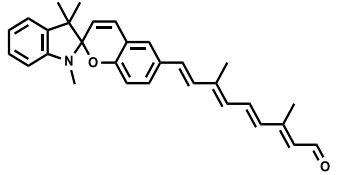
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		20. <a href="#">Biochem M 2001 66(1): 1323-1333</a>  <a href="#">Mol. Cryst. Liq. Cryst. 2005, 431, 209-214</a>  <a href="#">Vestnik MITHT. 2011, 6(2), 15-36</a>  <a href="#">Lukin A.Yu. Ph.D. thesis, 2004</a>
428.		E-	320 $\epsilon$ 25100			-	NO										str. ET1001 pH 6.5	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, № 2, 252-260</a>  <a href="#">Laptev A.V. Ph.D. thesis, 2008</a>
429.		E-	340 $\epsilon$ 26300			-	NO										str. ET1001 pH 6.5	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, № 2, 252-260</a>

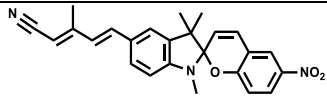
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others		
							(P)	DA	LA										
430.		all-E-	340 $\epsilon$ 35480	-	-	-	NO											str. ET1001 pH 6.5	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, No 2, 252-260</a> <a href="#">Laptev A.V., Ph.D. thesis, 2008</a>
431.		all-E-	365 $\epsilon$ 37160	338	384	-	440					3310					str. ET1001 pH 6.5 $\tau_{\text{rec}} \sim 3$ days	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, No 2, 252-260</a> <a href="#">DyesPigments</a>	

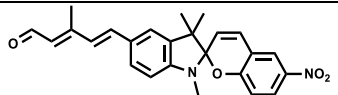
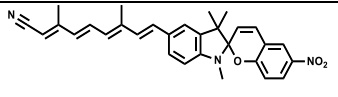
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		<a href="#">2012 92</a> <a href="#">831-837</a>  <a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a>  <a href="#">JPhotochemPhoto biol A 2012 231(1) 41-44</a>  <a href="#">Laptev A.V., Ph.D. thesis, 2008</a>
432.		all-E-	390 $\epsilon$ 44670	-	-	400	NO										str. ET1001 pH 6.5	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, № 2, 252-260</a>  <a href="#">Laptev A.V., Ph.D. thesis, 2008</a>
433.		all-E-	411 $\epsilon$ 51290	391	470	455	495					850					str. ET1001 pH 6.5 $\tau_{\text{rec}} \sim 3$ days	<a href="#">Rus J. Bioorgan Chem., 2008, V. 34, № 2, 252-260</a>  <a href="#">DyesPigments 2012 92 831-837</a>

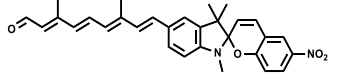
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a> <a href="#">JPhotochemPhoto biol A 2011, 222(1), 16-24</a> <a href="#">Laptev A.V., Ph.D. thesis, 2008</a>	
434.		all-E-	367 $\epsilon$ 45700	-	-		NO									str. ET1001 pH 6.5	<a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a> <a href="#">JPhotochemPhoto biol A 2011, 222(1), 16-24</a> <a href="#">HighEnergyChem 2008, 42(7), 601-603</a> <a href="#">Laptev A.V., Ph.D. thesis, 2008</a>		

### Properties of artificial bacteriorhodopsin analogs

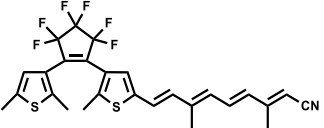
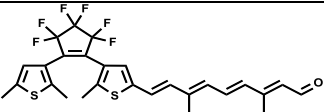
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh cm <sup>-1</sup>	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
435.		all-E-	385 $\epsilon$ 47860	345		-	605										str. ET1001 pH 6.5 $\tau_{\text{rec}} \sim 4$ days	<a href="#">DyesPigments</a> <a href="#">2012</a> , <a href="#">92</a> , <a href="#">831-837</a>  <a href="#">Vestnik</a> <a href="#">MITHT.</a> <a href="#">2011.</a> <a href="#">6(2)</a> , 15- <a href="#">36</a>  <a href="#">JPhotochemPhoto</a> <a href="#">biol. A</a> <a href="#">2011</a> , <a href="#">222(1)</a> , <a href="#">16-24</a>  <a href="#">HighEnergyChem</a> <a href="#">2008</a> , <a href="#">42(7)</a> , <a href="#">601-603</a>  <a href="#">Laptev</a> <a href="#">A.V.</a> , <a href="#">Ph.D.</a> <a href="#">thesis</a> , <a href="#">2008</a>
436.		all-E-	405 $\epsilon$ 48980	-	-		NO										str. ET1001, pH 6.5	<a href="#">Vestnik</a> <a href="#">MITHT.</a> <a href="#">2011.</a> <a href="#">6(2)</a> , 15- <a href="#">36</a>  <a href="#">JPhotochemPhoto</a> <a href="#">biol. A</a> <a href="#">2011</a> , <a href="#">222(1)</a> , <a href="#">16-24</a>  <a href="#">HighEnergyChem</a> <a href="#">2008</a>

### Properties of artificial bacteriorhodopsin analogs

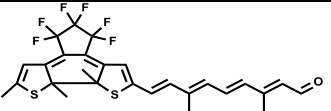
No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		<a href="#">42(7)</a> <a href="#">601-603</a>  <a href="#">Laptev A.V. Ph.D. thesis, 2008</a>
437.		all-E-	266 324 410 <sup>a</sup> $\epsilon$ 50120			480	500										str. ET1001, pH 6.5 $\tau_{\text{rec}} \sim 7$ days	<a href="#">Dyes Pigments 2012 92 831-837</a>  <a href="#">Vestnik MITHT. 2011. 6(2). 15-36</a>  <a href="#">JPhotochemPhoto biol A 2011 222(1) 16-24</a>  <a href="#">HighEnergyChem 2008. 42(7) 601-603</a>  <a href="#">Laptev A.V. Ph.D. thesis, 2008</a>  <a href="#">Colorants, 2023, V. 2, P. 264 - 404</a>



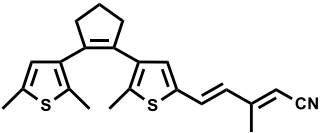
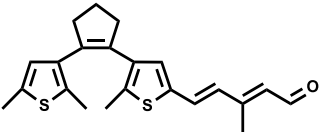
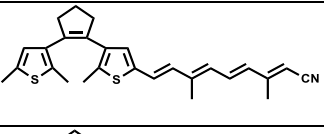
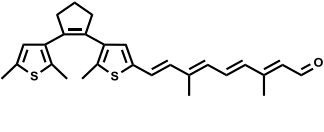
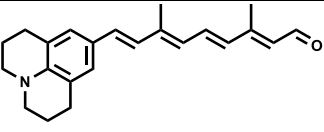
### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		2012 92 831-837  Vestnik MITHT, 2011, 6(2), 15- 36
440.		all-E-					NO										str. ET1001, 5mM MES, 100mM NaCl pH 6.0	DyesPig ments 2012 92 831-837  Belikov N.E., Ph.D. thesis, 2011
441.		all-E-	390, 402	368	460		510						2130				str. ET1001, 5mM MES, 100mM NaCl pH 6.0 $\tau_{\text{rec}} \sim 4$ days	JPhotoch emPhoto biol_A 2008 196(2-3) 262-267  Belikov N.E., Ph.D. thesis, 2011  DyesPig ments 2012 92 831-837  Vestnik MITHT, 2011, 6(2), 15- 36

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.	
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments							M	NH <sub>2</sub> OH	all-E-RET	CD		others
							(P)	DA	LA										
																		<a href="#">Biochemical physics today, Ch. 26, P. 509 - 525, 2024</a> <a href="#">Rus. J. Phys. Chem., 2019, V. 38, №12, P. 44 - 47</a>	
442.		all-E-	392, 409, 579				NO										str. ET1001, 5mM MES, 100mM NaCl pH 6.0 Incubation of closed cyclized form during ~48 days no ABR formation!!!  <a href="#">Belikov N.E., Ph.D. thesis, 2011</a> <a href="#">Dyes Pigments 2012 92 831-837</a>  <a href="#">Vestnik MITHT, 2011, 6(2), 15-36</a>  <a href="#">Biochemical physics today, Ch. 26, P. 509 - 525, 2024</a>  <a href="#">Rus. J. Phys.</a>		

### Properties of artificial bacteriorhodopsin analogs

No	Structure	Isomer	$\lambda_{\max}$ (nm); $\epsilon$ ( $M^{-1} \text{cm}^{-1}$ )						Photocycle		H <sup>+</sup> -pump %	Isomer ratio all-E/13Z-	OS BRh $\text{cm}^{-1}$	Reactions with		Remarks		Ref.
			"CHO"	SB	SBH <sup>+</sup>	NC	Pigments			M				NH <sub>2</sub> OH	all-E-RET	CD	others	
							(P)	DA	LA									
																		<a href="#">Chem., 2019, V. 38, №12, P. 44 - 47</a>
443.		all-E-	313 365 <sup>a</sup>				NO										str. ET1001, 5mM MES, 100mM NaCl pH 6.0	<a href="#">Belikov N.E., Ph.D. thesis, 2011</a>
444.		all-E-	330sh 390	365	444		450						300				str. ET1001, 5mM MES, 100mM NaCl pH 6.0 $\tau_{\text{rec}} \sim 7$ days Ret and ABR analogs destroyed under illumination.	<a href="#">Belikov N.E., Ph.D. thesis, 2011</a>
445.		all-E-					NO										str. ET1001, 5mM MES, 100mM NaCl pH 6.0	<a href="#">Belikov N.E., Ph.D. thesis, 2011</a>
446.		all-E-	397sh 420	400	500		535						1310				str. ET1001, 5mM MES, 100mM NaCl pH 6.0 $\tau_{\text{rec}} \sim 7$ days Ret and ABR analogs destroyed under illumination.	<a href="#">Belikov N.E., Ph.D. thesis, 2011</a>
447.		all-E-	338, 460 $\epsilon$ 48000	329, 430, 620sh	358sh, 387, 592		595	595						unstable, $\tau_{1/2} \sim 30$ min	stable		str. <i>H. salinarum</i> ВКПМ В-9451, pH 6.5, 20°C $\tau_{1/2 \text{ form}} 60$ min NaBH <sub>4</sub> : the pigment absorption band gradually disappears	<a href="#">Biochemical physics: proceedings of the XXII Conference, Moscow, 2023, P. 142 - 144</a>

Notes:

<sup>1</sup>\* Abbreviations: BRh - bacteriorhodopsin; ABR - bacteriorhodopsin analog; BO - bacterioopsin; AM –apomembranes; PM – purple membranes; OS - opsin shift; SB - the Schiff base; SBH<sup>+</sup> - protonated form of the Schiff base; P - pigment (covalent complex, containing protonated aldimine bond); NC - noncovalent complex; pK<sub>a</sub> - pK of aldimine group of retinal or its analog in SBH<sup>+</sup> and in ABR. Usually, synthesis of retinal analogs and study of their properties are carried out at pH close to neutral (pH 6-7); if pH and temperature at which the reaction of BO with polyenal and other measurements were performed are given in the publication, these values are presented in “Remarks” column. In the same column, data on transitional spectral forms from their photocycles and their transitions in alkaline medium as well as some other non-standart properties of pigments (times of pigments formation, if ones differ substantially from natural BRh parametres, CD-; X-rays or ESR-data, etc.) are presented.

(+) - quality without quantitative assesment; (-) or (NO) - lack of quality; (blank) - no data; sh - shoulder.

<sup>2</sup>\* Polyenals' structures are only given for *all-E*-isomers as their *6-s-cis*-forms, except analogs (1b).

<sup>3</sup>\*  $\lambda_{\max}$  values for compounds (CHO, SB, SBH<sup>+</sup>) are given for solutions in methanol (no index), ethanol (a), isopropanol (b), hexane (c), micells with octadecylamine (d), aldimine prepared with monoethanolamine (the others, with n-butylamine) (e), cyclohexane (f), – acetonitrile (h), – water (g), aldimine prepared with piperidine (k), aldimine prepared with t-Bu-NH<sub>2</sub> protonation by CF<sub>3</sub>COOH/EtOH (l).

<sup>4</sup>\* States of pigments, considered in the table: L - light-adapted; D - dark-adapted; (P) - pigment of which is not known to what form (dark or light) the  $\lambda_{\max}$  value relates or the preparation was obtained in the dark, but this is definitely a non-equilibrium form to which reversion occurs in the dark after illumination or upon long-term storage of the sample.

<sup>5</sup>\* (OS) =  $1/\lambda(\text{SBH}^+) - 1/\lambda(\text{pigment})$  [[33](#),[34](#)]

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