Archaeal Transmembrane Receptor Af1503

T1100 in CASP14

Andrei N. Lupas

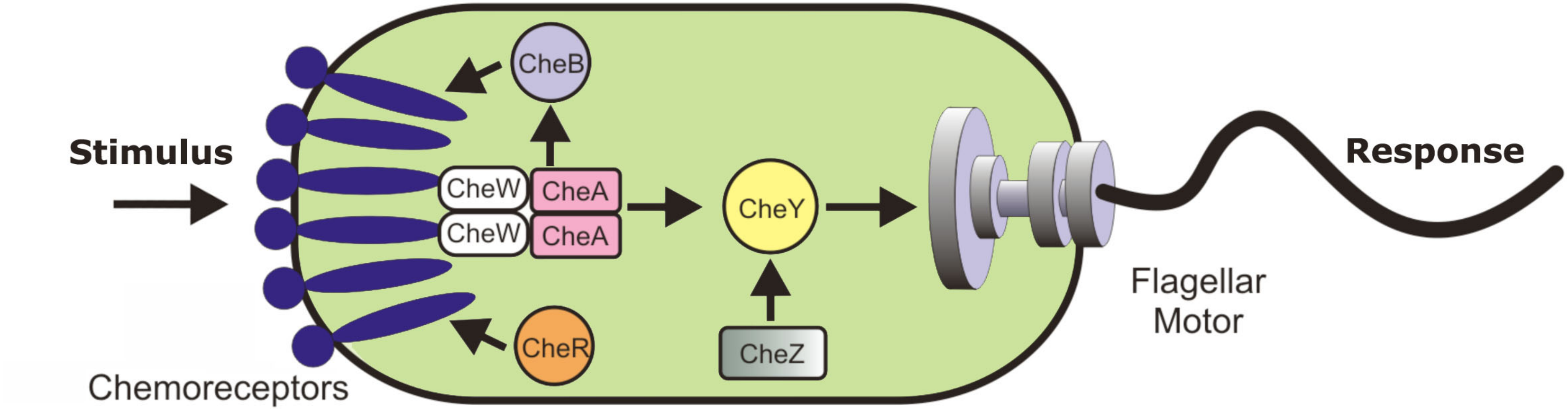
and the Department of Protein Evolution,

particularly **Reinhard Albrecht** (protein biochemistry and crystallization), **Marcus Hartmann** (crystallography) and **Murray Coles** (NMR)

Max Planck Institute for Developmental Biology

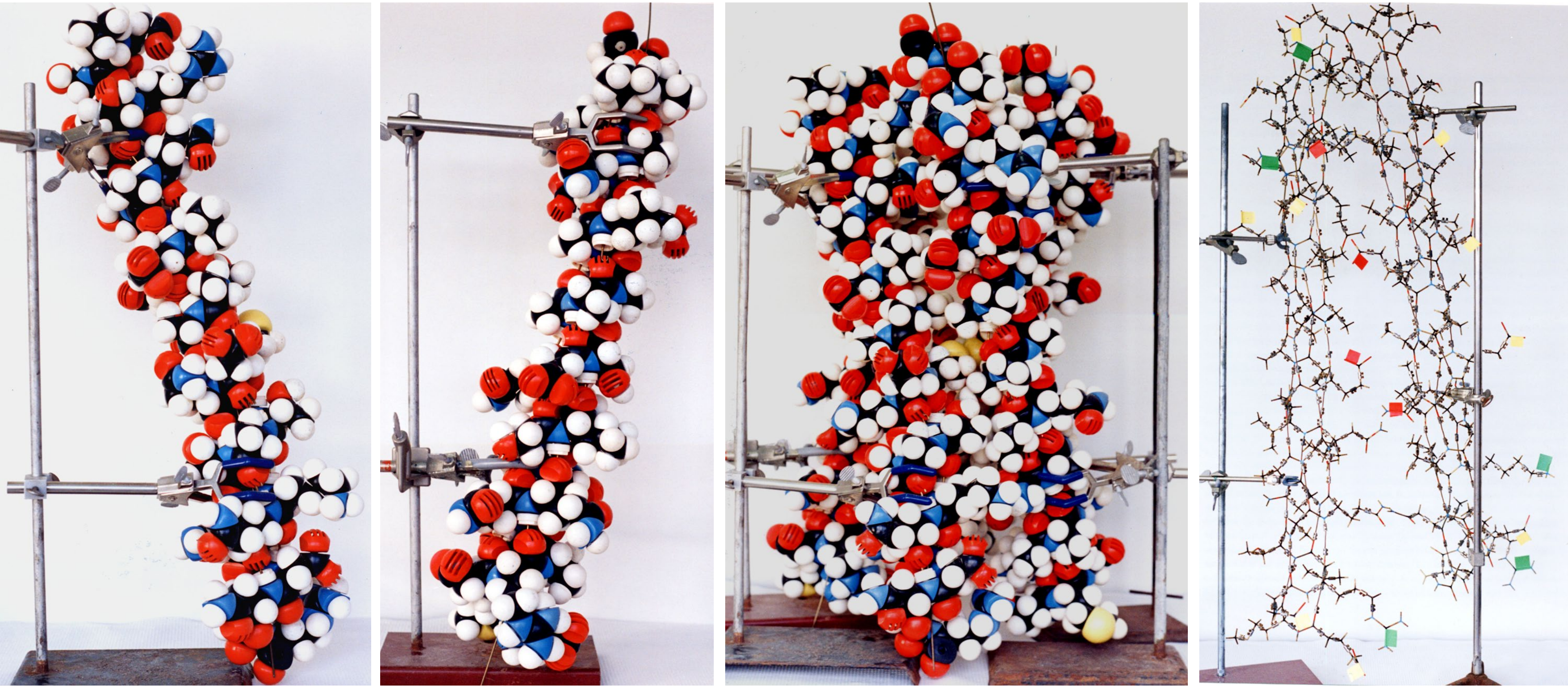
Ancient History

1986-1990 – PhD thesis: Mechanisms of signal transduction in bacterial chemotaxis



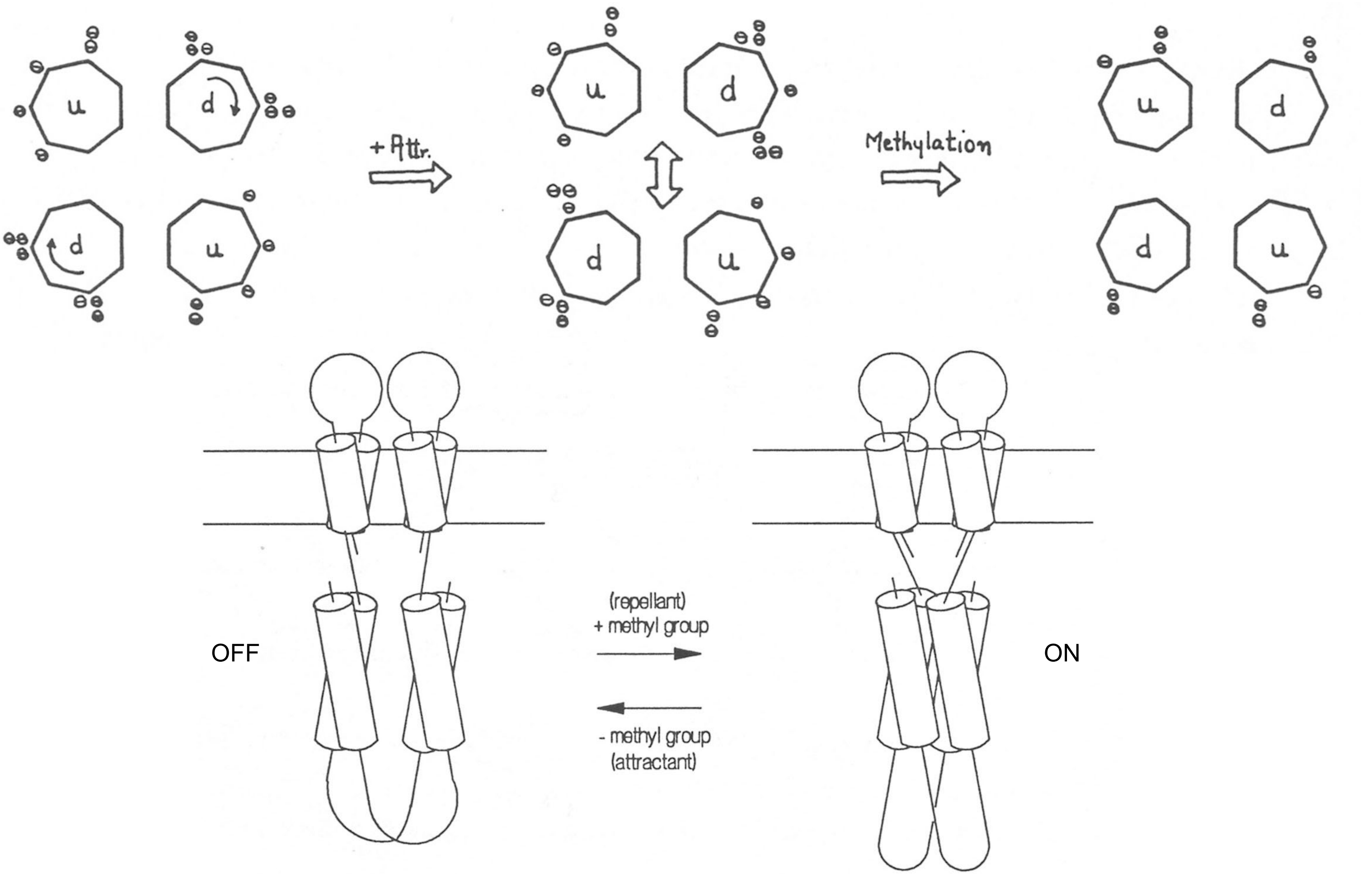
How do signals cross the membrane?

Molecular modeling 30 years ago



How do signals cross the membrane?

A model for signal transduction based on axial helix rotation



How do signals cross the membrane?

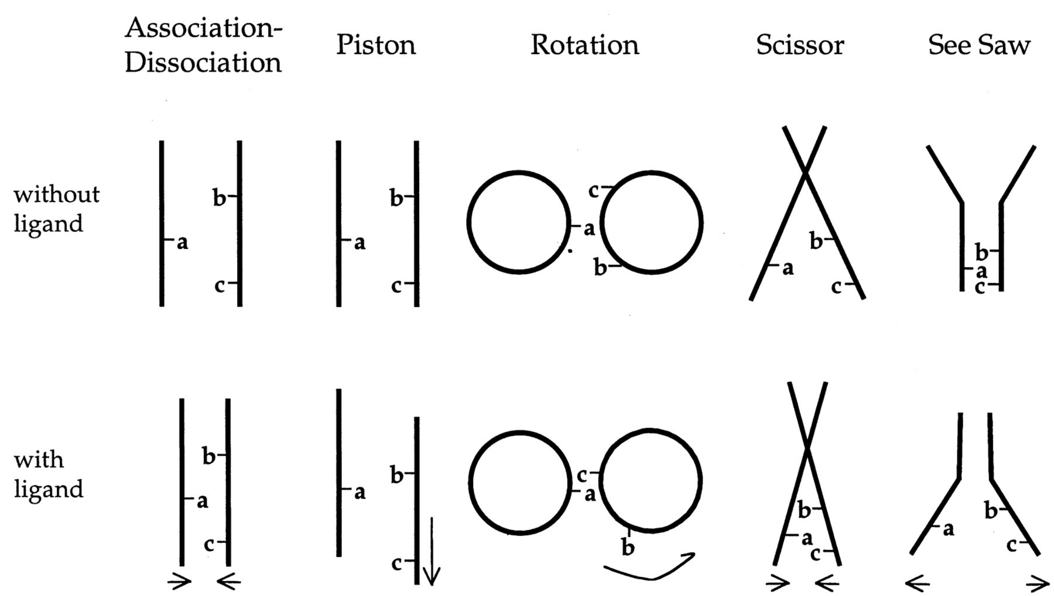
The piston model

SCIENCE VOL 285 10 SEPTEMBER 1999 1751

A Piston Model for Transmembrane Signaling of the Aspartate Receptor

Karen M. Ottemann,[1*†] Wenzhong Xiao,[2*] Yeon-Kyun Shin,[2‡] Daniel E. Koshland Jr.[1‡]

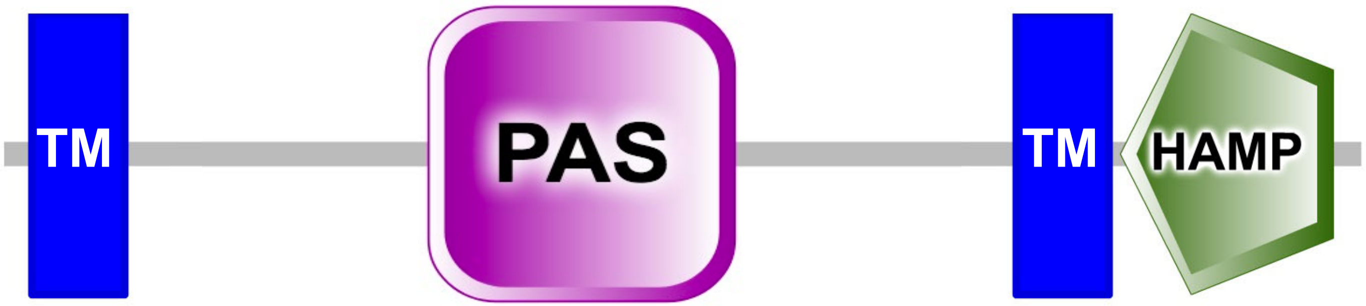
To characterize the mechanism by which receptors propagate conformational changes across membranes, nitroxide spin labels were attached at strategic positions in the bacterial aspartate receptor. By collecting the electron paramagnetic resonance spectra of these labeled receptors in the presence and absence of the ligand aspartate, ligand binding was shown to generate an ~1 angstrom intrasubunit piston-type movement of one transmembrane helix downward relative to the other transmembrane helix. The receptor-associated phosphorylation cascade proteins CheA and CheW did not alter the ligand-induced movement. Because the piston movement is very small, the ability of receptors to produce large outcomes in response to stimuli is caused by the ability of the receptor-coupled enzymes to detect small changes in the conformation of the receptor.



A new model system for structural studies

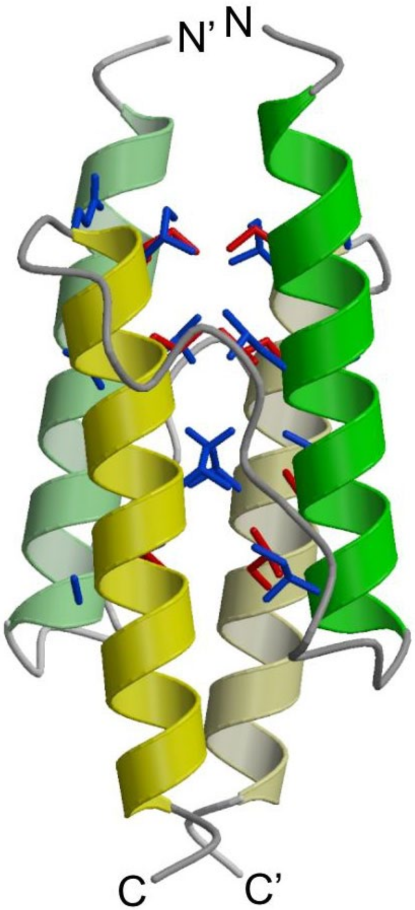
A minimal-size, hyperthermostable receptor:

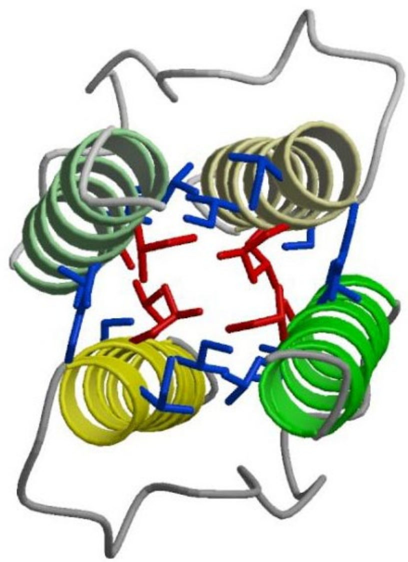
Af1503 of *Archaeoglobus fulgidus*

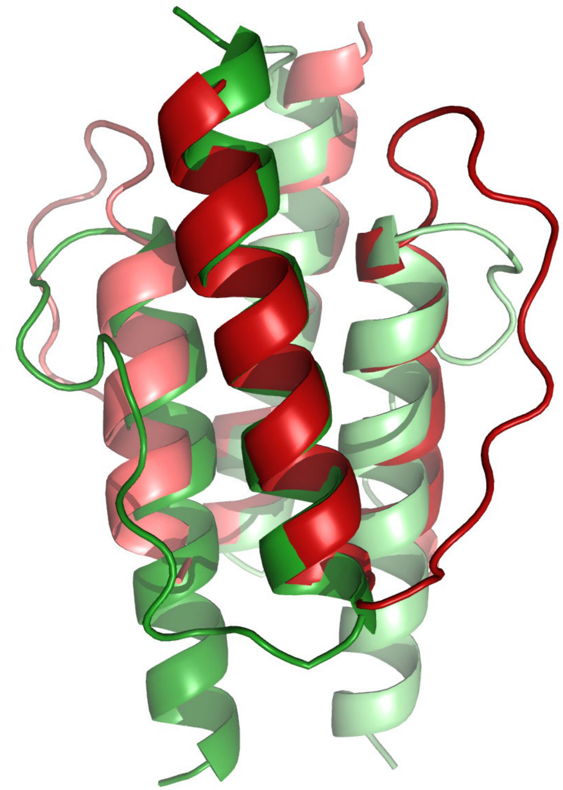


A new model system for structural studies

Af1503 HAMP structure – not a canonical coiled coil



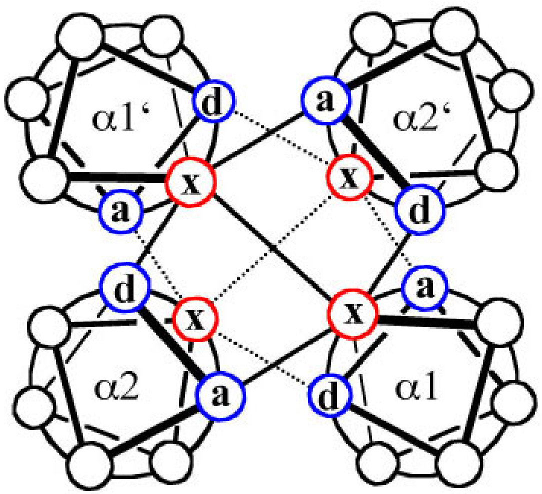




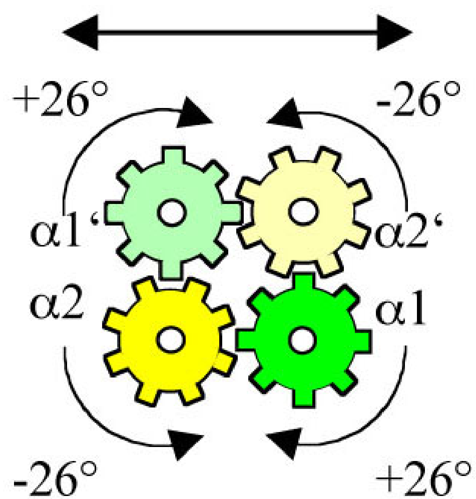
superposition of structure (green) and model (red)

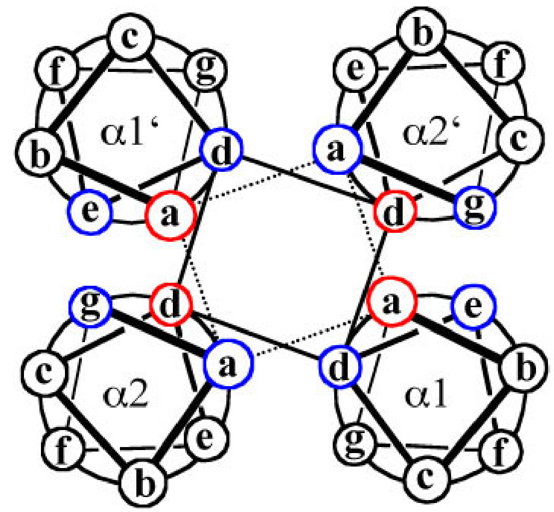
A new model system for structural studies

The axial helix rotation model for signal transduction revisited



complementary *x-da*
ON





knobs-into-holes
OFF

Making functional receptor chimeras

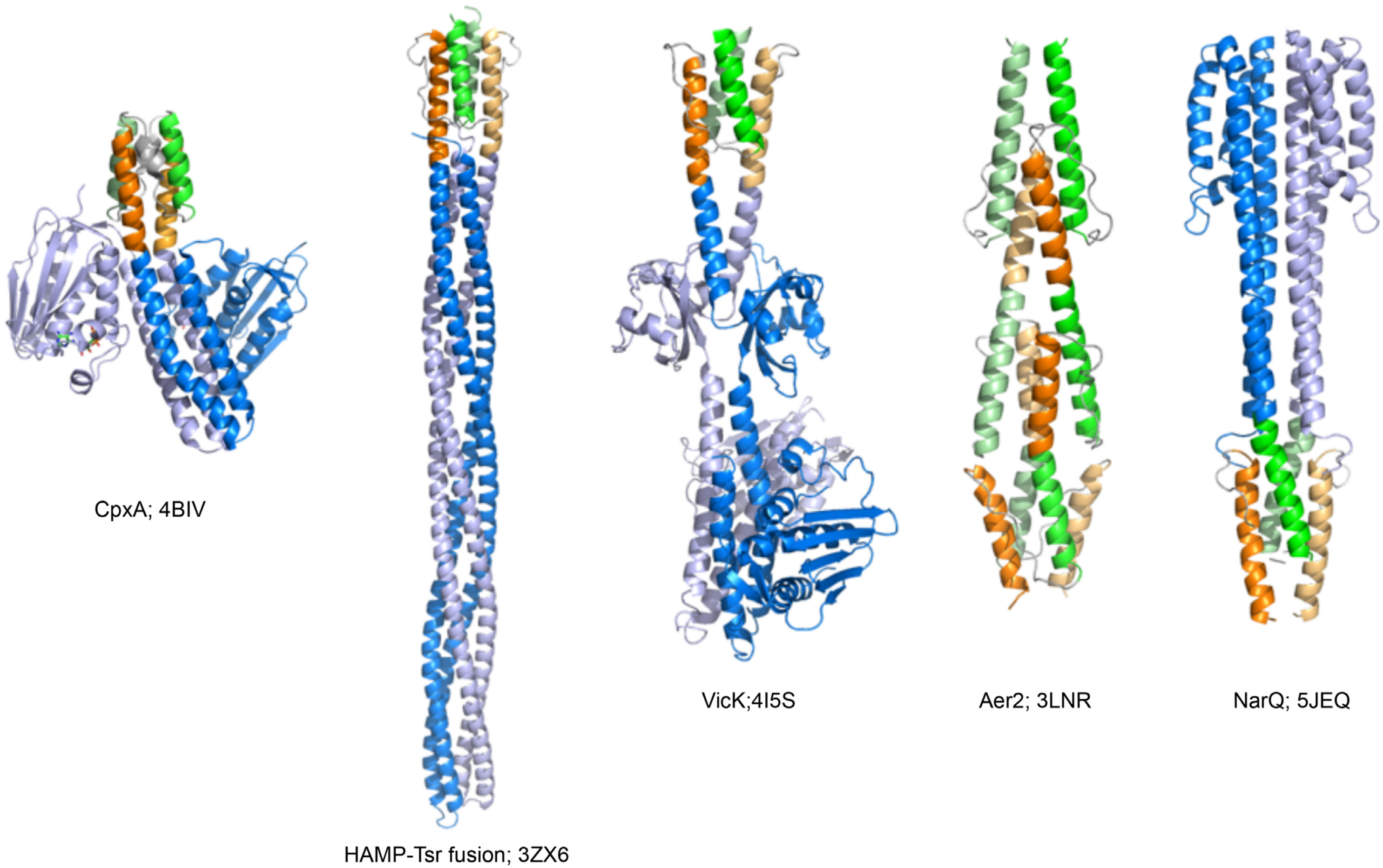
But still no structure of a complete receptor

Solving the structure of individual domains leaves open the question how entire, functional receptors transduce the signal

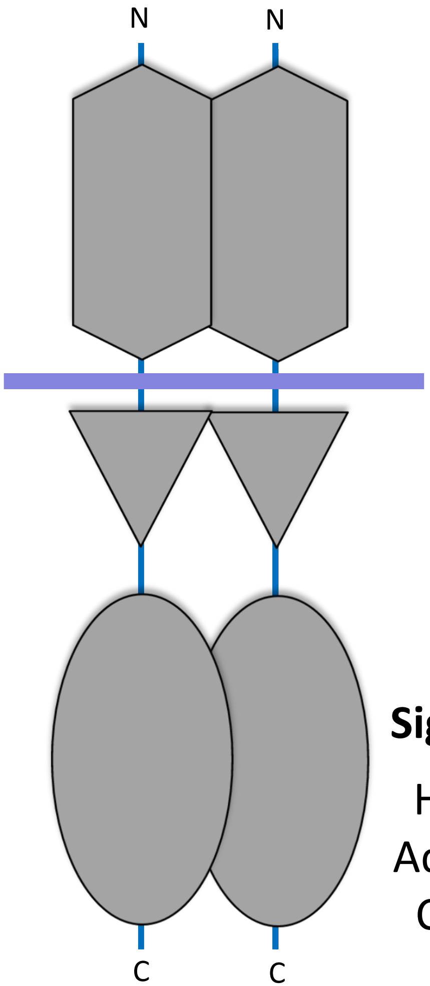
New approach: **build functional chimeras with Af1503 as a transmembrane model protein and well understood intracellular effector domains**

Making functional receptor chimeras

Dimeric receptors with one (eukaryotes) or two (prokaryotes) transmembrane helices per monomer are organized along a coiled-coil backbone:



Making functional receptor chimeras



Input domains

GAF

PAS

CACHE

CHASE2

...

Membrane

Transducers

S-helix

HAMP

...

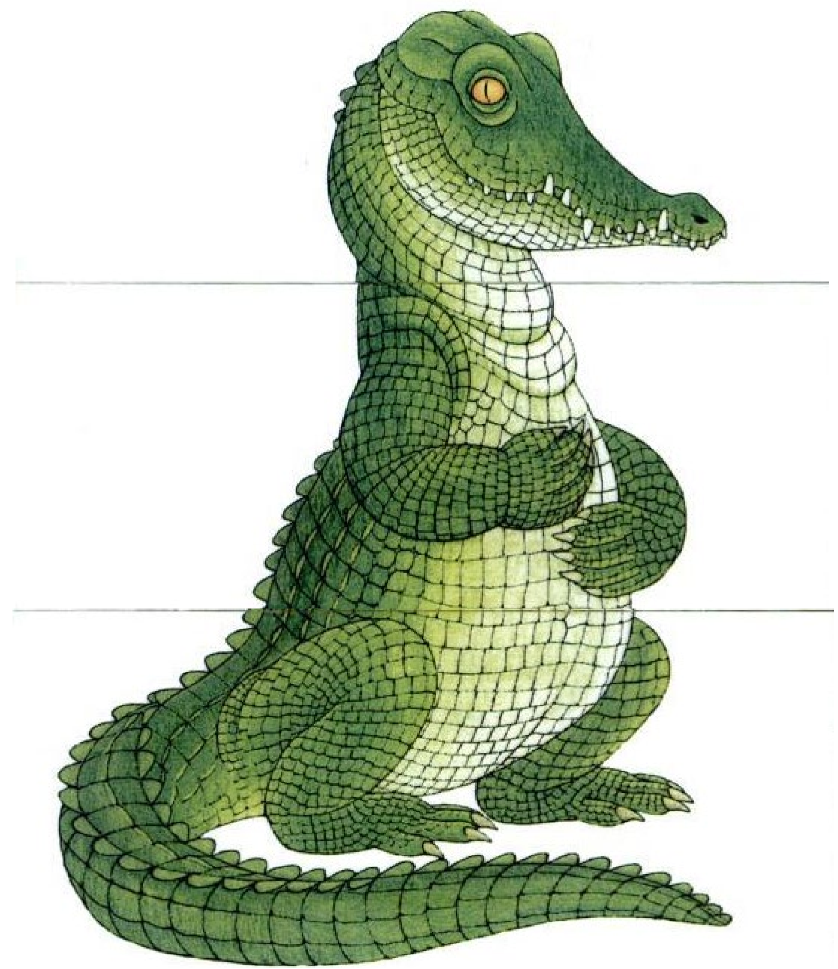
Signal Generators

Histidine Kinase

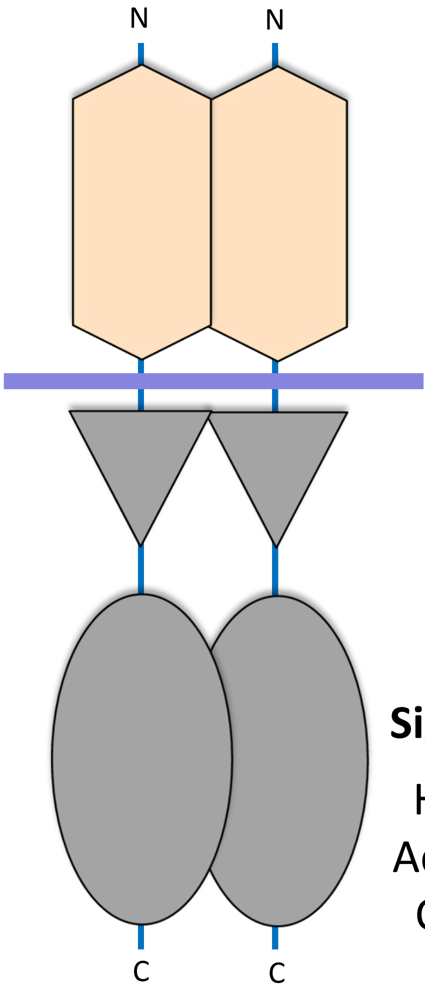
Adenylate Cyclase

Chemoreceptor

...



Making functional receptor chimeras



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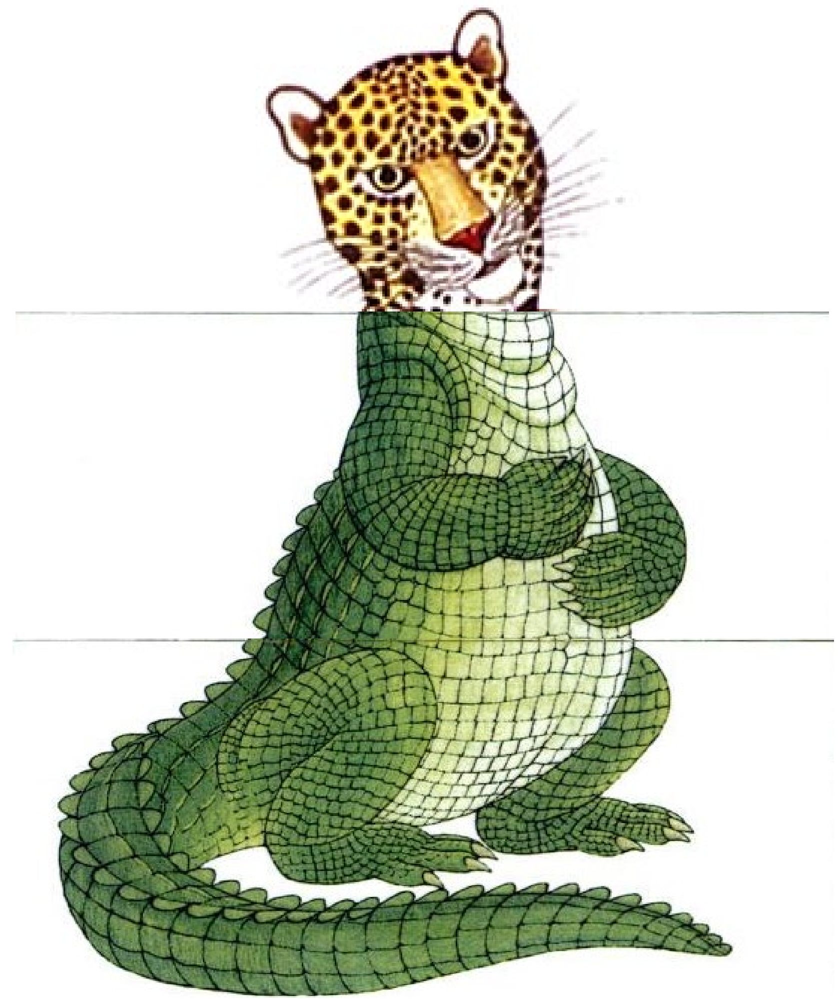

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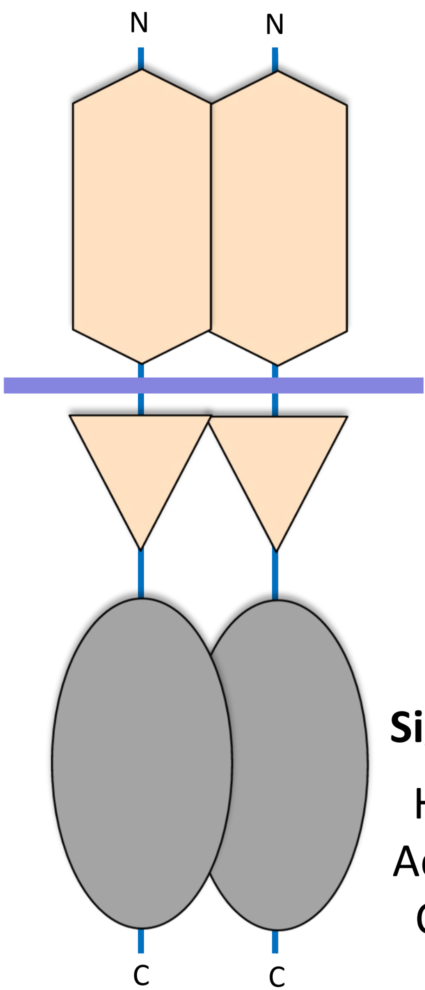

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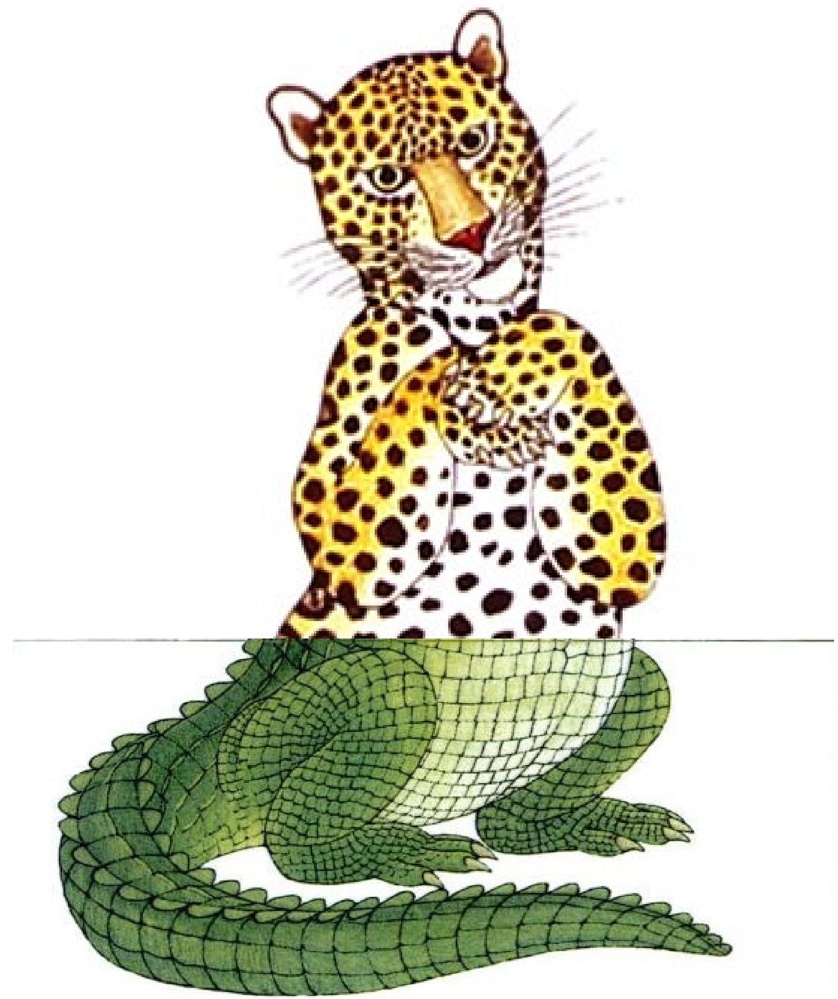
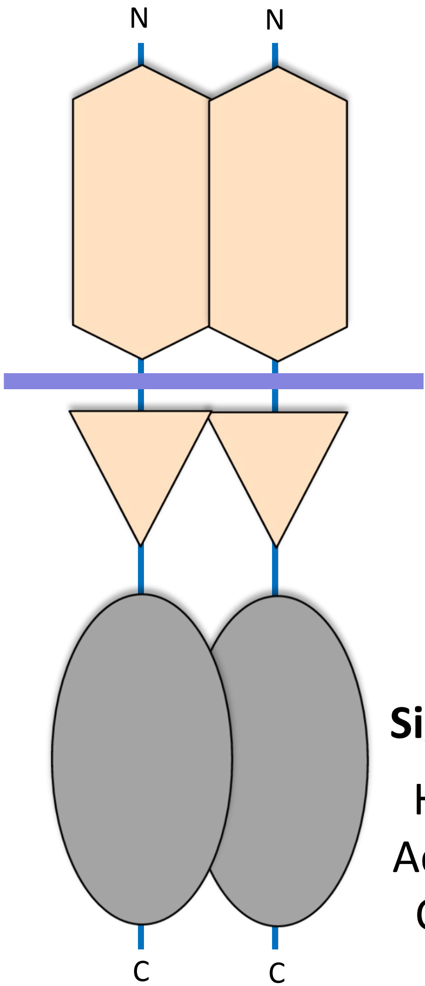


Making functional receptor chimeras



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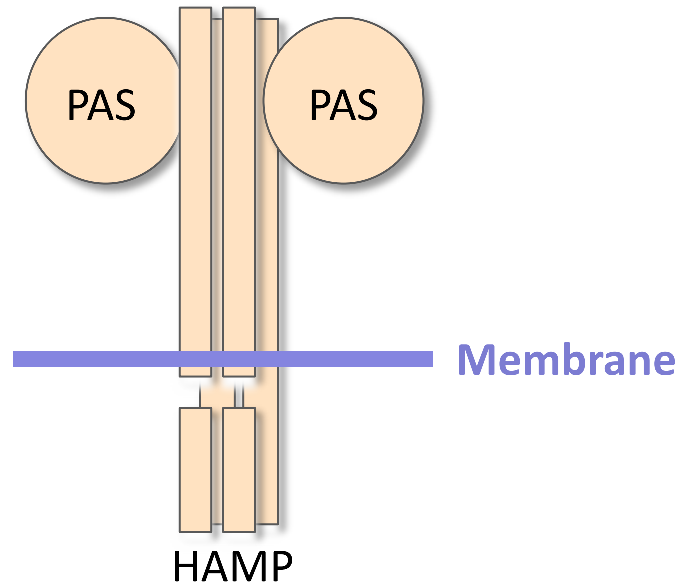
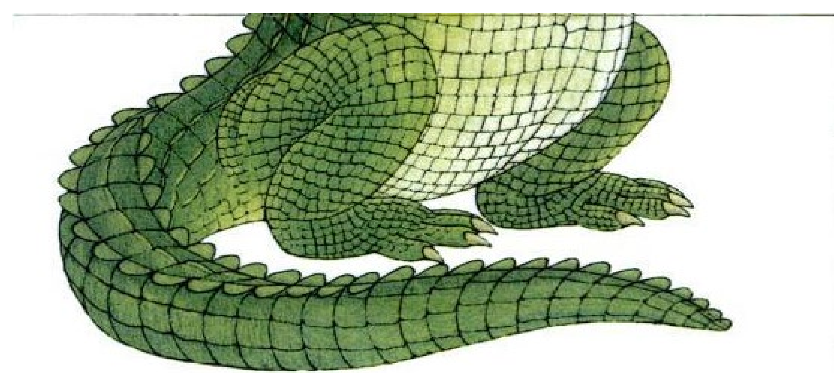




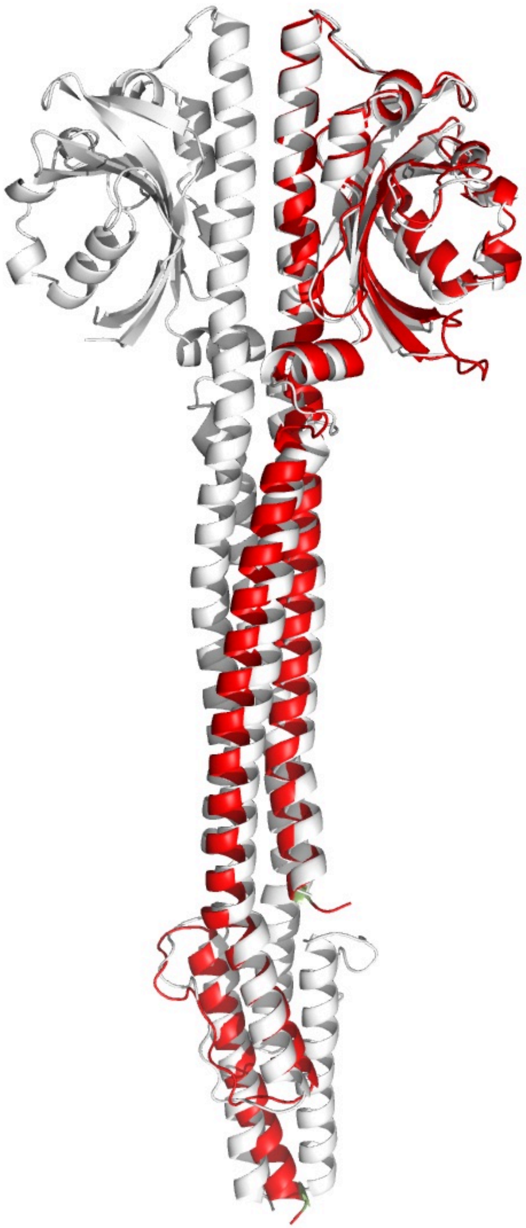
Making functional receptor chimeras

Diffraction data to 3.5 Å by 2010 (full receptor in detergent)

Could not solve the phasing problem by any approach, including solution of individual domains by NMR and molecular replacement

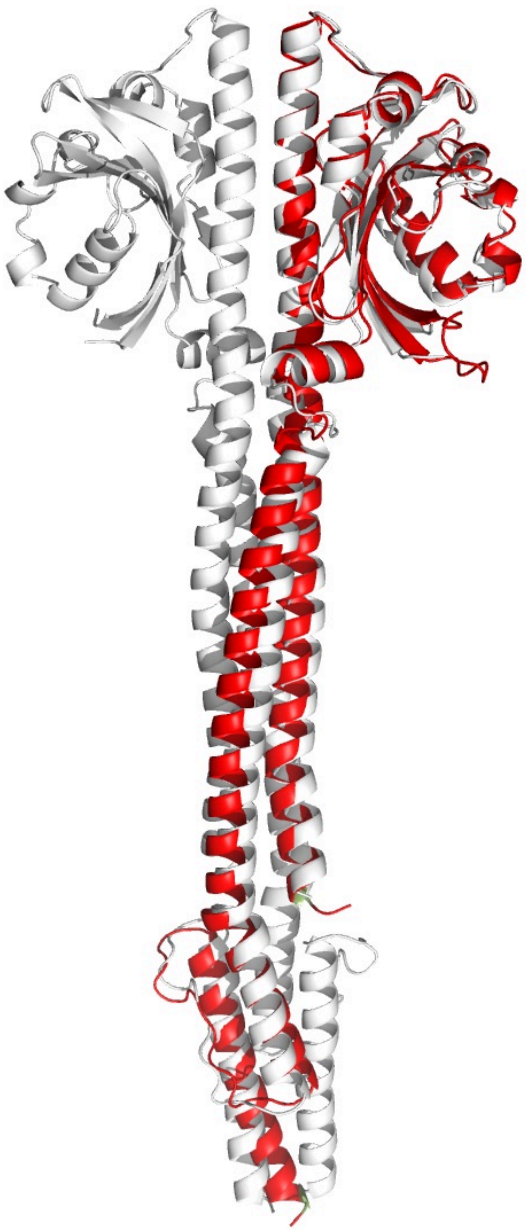
Submitted the protein as T1100 to CASP14 in the hope that a computational model would work for molecular replacement

Solving the Af1503 structure by MR



model 2 of AlphaFold2 superimposed to the Af1503 structure solved by molecular replacement (the model was computed as a monomer!)

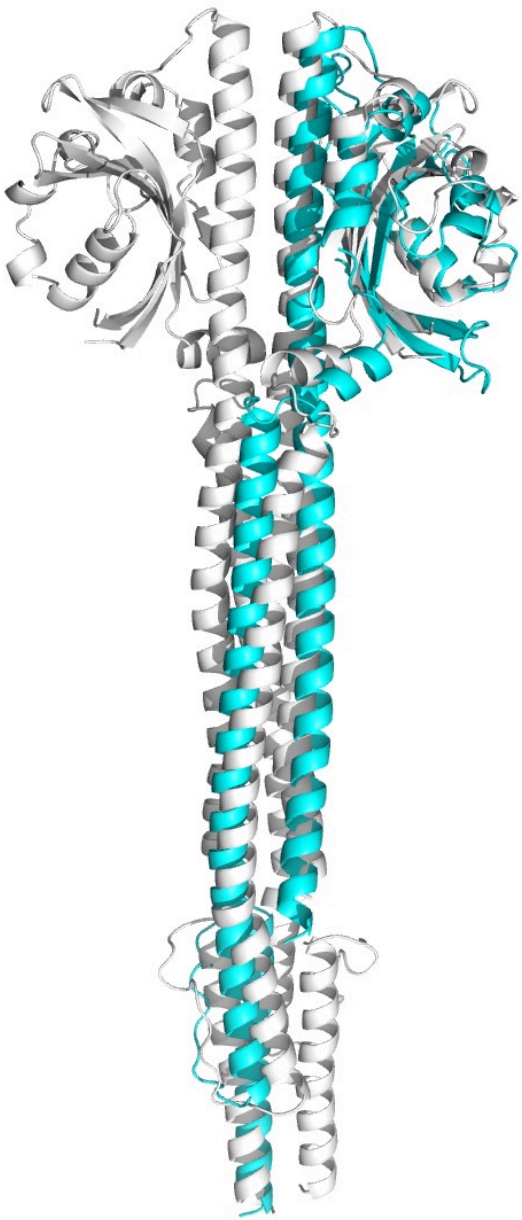
Solving the Af1503 structure by MR



AlphaFold2

Model	GR#	GR_name	GDT_TS	GDT_HA	S_geom_ casp14
T1100TS427_2	427	ALPHAFOLD2	81.67	63.88	2.82
T1100TS339_4	339	PROQ3D	54.83	32.74	1.15
T1100TS257_4	257	P3DE	54.83	32.74	1.13
T1100TS498_2	498	VOROMQA-SELECT	54.83	32.74	1.12
T1100TS067_5	67	PROQ2	54.83	32.74	1.11
T1100TS473_1	473	BAKER	55.14	34.51	1.02
T1100TS420_3	420	MULTICOM	54.98	32.74	1.02
T1100TS379_3	379	WALLNER	52.61	29.83	0.94
T1100TS403_5	403	BAKER-EXPERIMENTAL	54.06	31.82	0.94
T1100TS334_3	334	FEIG-R3	47.78	27.68	0.90
T1100TS362_3	362	SEOK-REFINE	54.83	33.36	0.87
T1100TS129_1	129	ZHANG	50.23	28.07	0.83
T1100TS193_4	193	SEOK	50.77	29.52	0.83
T1100TS071_5	71	KIHARALAB	54.06	32.13	0.83
T1100TS039_4	39	ROPIUSOQA	54.83	32.74	0.82
T1100TS314_5	314	FEIG-R1	51.38	29.83	0.81
T1100TS005_3	5	SEDER2020	54.83	32.74	0.78
T1100TS183_1	183s	TFOLD-CAT	54.83	32.74	0.78
T1100TS288_1	288	DATE	54.83	32.74	0.78
T1100TS343_1	343	VOROCNN-SELECT	54.83	32.74	0.78

Solving the Af1503 structure by MR



TFOLD-CAT

Model	GR#	GR_name	GDT_TS	GDT_HA	S_geom_casp14
T1100TS427_2	427	ALPHAFOLD2	81.67	63.88	2.82
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T1100TS343_1	343	VOROCNN-SELECT	54.83	32.74	0.78

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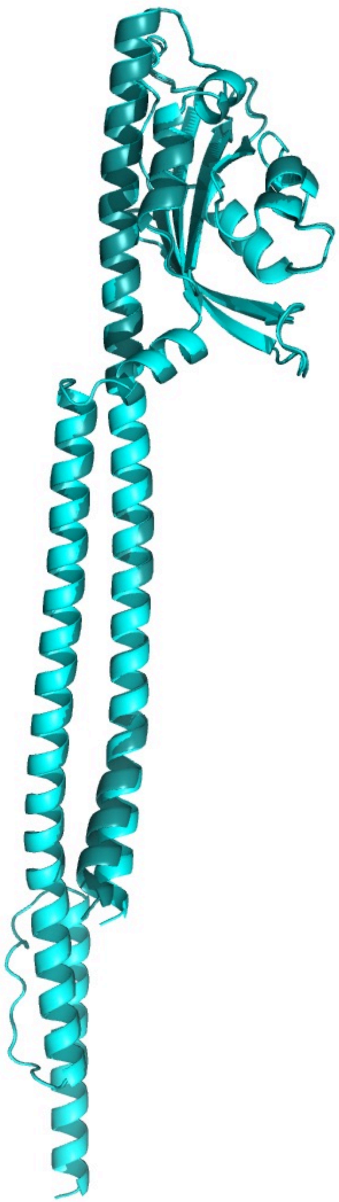

KIHARALAB superimposed to **TFOLD-CAT**

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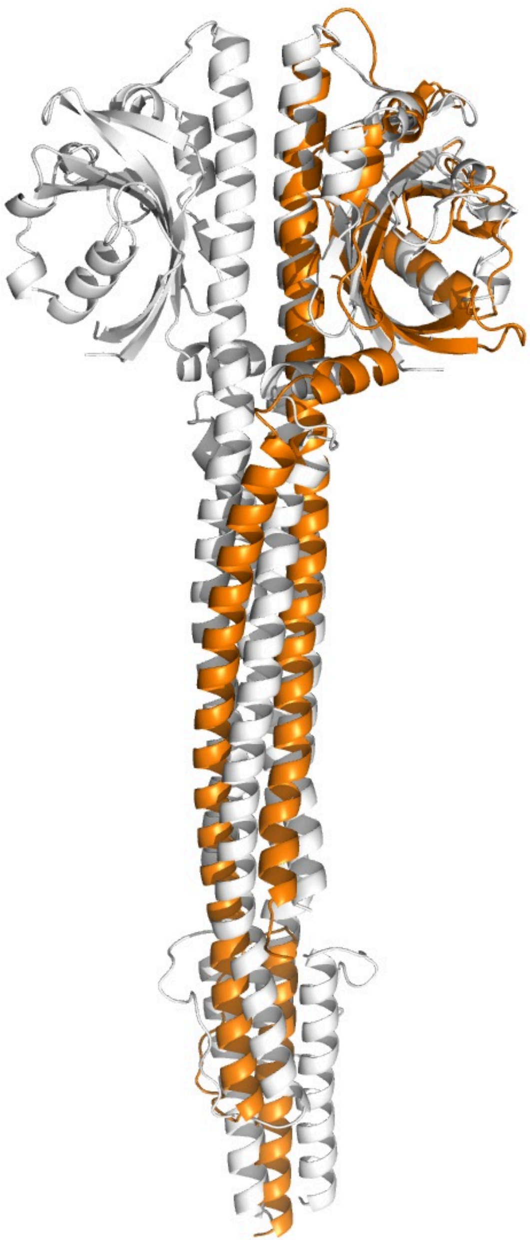
Solving the Af1503 structure by MR



Baker

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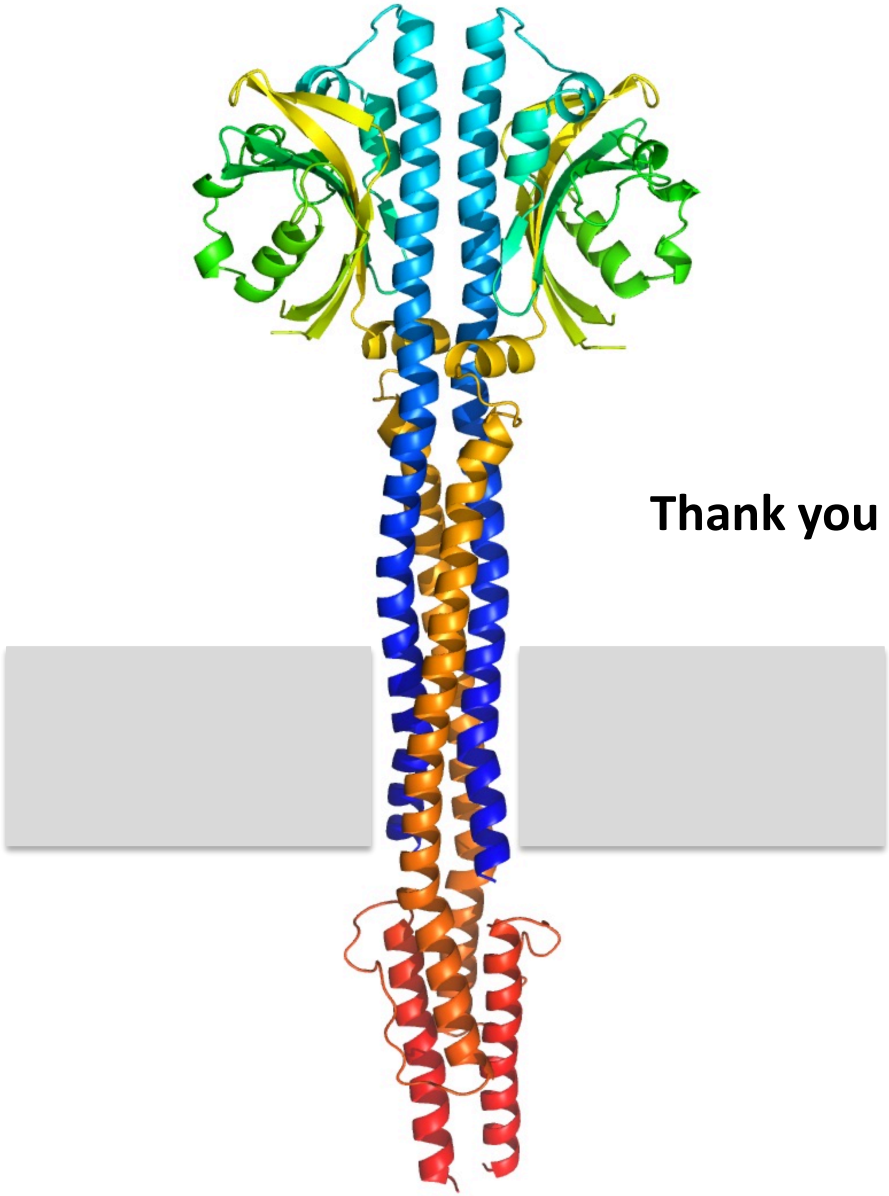
Solving the Af1503 structure by MR



Thank you for this structure!