Table 1-1. List of crustacean photoreceptor λmax from the literature and from this study. All measurements are from adults, unless the species name is followed by an N (nauplius), L (larvae), M (megalopa) or Z (zoea). More than one λmax indicate species where multiple pigments have been characterized. For stomatopod visual pigments, λmax values from different portions of the retina are listed in the following order: peripheral retina rhabdoms, midband row 1 distal rhabdom, midband row 1 proximal rhabdom, midband row 2 distal rhabdom, midband row 2 proximal rhabdom, midband row 3 distal rhabdom, midband row 3 proximal rhabdom, midband row 4 distal rhabdom, midband row 4 proximal rhabdom, midband rows 5 and 6 rhabdoms. Where depth ranges are not available, habitat abbreviations are: ST – subtidal; IT – intertidal; C – coastal; P – pelagic; MP – mesopelagic; BP – bathypelagic; DB – deep benthic; EST – estuarine; BW – brackish water; FW – freshwater; sTR – semi-terrestrial; TR - terrestrial. The abbreviations used for the method of measuring λmax are as follows: BP – behavioral phototaxis; EON – extracellular/optic nerve; ERG – intercellular electrophysiology; EX – spectrophotometry of pigment extract; IC – intracellular electrophysiology; MSP – microspectrophotometry; VC – voltage clamp. Genbank accession numbers (http://www.ncbi.nlm.nih.gov/) are given for those species where visual pigments have also been characterized genetically. Sequences similar to opsin isolated from expressed sequence tag libraries are indicated by (EST) after the accession number.

	Habitat	method	λ_{max}	λ_{max} reference	Accession #
BRANCHIOPODA					
Anostraca					
Artemiidae					
Artemia franciscana					BQ605261 (EST)
Artemia salina		EON	410	(Hertel 1972)	
Diplostraca					
Daphniidae					
Daphnia magna		VC	348, 434, 525, 608	(Smith and Macagno 1990)	
MAXILLOPODA					
Copepoda					
Acartiidae					
Acartia tonsa		BP	450-520	(Stearns and Forward 1984)	
Cirripedia					
Balanidae					
Balanus amphitrite		ERG	532	(Hillman et al. 1973)	

Balanus amphitrite		MSP	532	(Minke and Kirschfield 1978)	
Balanus balanoides (N)		BP	510-530	(Barnes and Klepal 1972)	
Balanus eburneus		ERG	532	(Hillman et al. 1973)	
Balanus eburneus		MSP	532	(Minke and Kirschfield 1978)	
OSTRACODA					
Myodocopida					
Cypridinidae					
Skogsbergia lerneri					AF353374-AF353339
Vargula hilgendorfi					AF353338-AF353331
MALACOSTRACA					
Stomatopoda					
Squilloidea					
Coronis scolopendra	ST	MSP	494, 407, 436, 489, 518, 529, 533, 441, 468, 517	(Cronin et al. 1993)	
Lysiosqullia sulcata	5-25m	MSP	499, 397, 434, 492, 516, 517, 538, 416, 461, 500	(Cronin et al. 1993)	
Pullosquilla litoralis	sIT	MSP	509, 404, 425, 469, 509, 527, 540, 446, 455, 482	(Jutte et al. 1998b)	
Pullosquilla litoralis (L)		MSP	446	(Jutte et al. 1998a)	
Pullosquilla thomassini	1-37m	MSP	467, 405,	(Jutte et al. 1998b)	

			445, 489, 509, ???, ???, 456, 452, 483	
Pullosquilla thomassini (L)		MSP	447	(Jutte et al. 1998a)
Gonodactyloidea				
Gonodactylellus affinis	3-30m	MSP	500, 400, 424, 496, 521, 546, 541, 454, 474, 509	(Cronin et al. 2002)
Gonodactylaceus falcatus		MSP	510, 400, 443, 513, 527, 532, 553, 443, 475, 518	(Cronin et al. 2000; Cronin et al. 1995)
Gonodactylaceus falcatus (L)		MSP	499	(Cronin et al. 1995)
Gonodactylus smithii	IT	MSP	517, 400, 440, 505, 528, 536, 552, 436, 469, 512	(Chiao et al. 2000)
Gonodactylopsis spongicola	5-60m	MSP	506, 401, 444, 505, 525, 536, ???, 448, 474, 507	(Cronin et al. 2002)
Neogonodactylus curacaoensis	2-20m	MSP	467, 400, 434, 494, 520, ???, ???, 435,	(Cronin et al. 1996)

			467, 511		
Neogonodactylus oertstedii	IT-3m	MSP	528, 400, 430, 505, 525, 520, 551, 429, 460, 489	(Cronin and Marshall 1989)	(Brown 1996)
Hemisquilla ensigera	10-15m	MSP	501, 414, 451, 499, 510, 510, 535, 443, 473, 500	(Cronin et al. 1994a)	
Haptosquilla trispinosa	ST-25m	MSP	499, 400, 433, 508, 537, 539, 558, 422, 462, 510	(Cronin et al. 2002)	
Pseudosquilla ciliata	ST-25m	MSP	498, 400, 433, 498, 517, 535, 539, 425, 452, 510	(Cronin and Marshall 1989)	
Odontodactylus brevirostris	10-25m	MSP	490, 402, 457, 495, 524, 511, 535, 452, 460, 589	(Cronin et al. 1994a; Cronin et al. 1996)	
Odontodactylus 'havanensis'	20-35m	MSP	475, 407, 446, 485, 520, ???, ???,428, 459, 501	(Cronin et al. 1996)	

Odontodactylus scyllarus	1-30m	MSP	503, 400, 430, 487, 509, 528, 546, 429, 451, 506	(Cronin et al. 1994a; Cronin et al. 1996)
Squilloidea				
Squilla empusa	1-150m	MSP	517	(Cronin 1985; Cronin et al. 1993)
Squilla empusa		MSP	507	(Cronin and Jinks 2001)
Squilla empusa (L)		MSP	509	(Cronin and Jinks 2001)
Cloridopsis dubia	IT	MSP	510	(Cronin et al. 1993)
Lophogastrida				
Lophogastridae				
Gnathophausia ingens	>400m	ERG	490, 520	(Frank and Case 1988b)
Mysida				
Mysidae				
Archaeomysis grebnitzkii		MSP	496	**this study**
Bowmaniella sp.		MSP	SW, 502	**this study**
Hemimysis anomala		ERG	393, 500	(Lindström 2000)
Heteromysis formosa		MSP	499	**this study**
Holmesimysis costata		MSP	512	**this study**
Neomysis americana		MSP	520	**this study**
Neomysis integer		ERG	525-535	(Lindström 2000)
Neomysis mercedis	FW/BW	MSP	521	**this study**
Mysis mixta		ERG	505-520	(Lindström 2000)
Mysis relicta sp.I		ERG	550-570	(Lindström 2000)
Mysis relicta sp.II		ERG	505-520	(Lindström 2000)
Mysis relicta sp.IV	FW	MSP	520	(Gal et al. 1999)
Mysis relicta sp.IV	FW	MSP	505, 520*	**this study**, (Jokela-Määttä et al. 2005)
Praunus inermis		ERG	520-530	(Lindström 2000)

Praunus flexuosus		ERG	505-515	(Lindström 2000)	
Amphipoda					
Hyperiidae					
Phronima sedenteria	MP	ERG	470	(Frank and Widder 1999)	
Isopoda					
Cirolanidae					
Eurydice pulchra					CO869196-CO157253 (EST)
Ligiidae					
Ligia exotica	TR	ERG	340, 460, 520	(Hariyama and Tsukahara 1993)	
Talitridae					
Talitrus saltator	sTR	ERG	450	(Mezzetti and Scapini 1995)	
Euphausiacea					
Euphausiidae					
Euphausia superba	MP	ERG	487	(Frank and Widder 1999)	
Euphausia superba	MP	EX	485	(Denys and Brown 1982)	
Euphausia pacifica	MP		462	(Kampa 1955)**	
Meganyctiphanes norvegica	MP	ERG	490	(Frank and Widder 1999)	
Meganyctiphanes norvegica	MP	EX	460-465	(Fisher and Goldie 1959)**	
Meganyctiphanes norvegica	MP		462	(Fisher 1967)**	
Meganyctiphanes norvegica	MP	ERG	460, 490, 515	(Boden et al. 1961)	
Meganyctiphanes norvegica	MP	MSP	488	(Denys and Brown 1982)	
Nematobrachion boopis	MP	ERG	488	(Frank and Widder 1999)	
Nematobrachion sexspinosus	MP	ERG	478	(Frank and Widder 1999)	
Stylocheiron maximum	MP	ERG	479	(Frank and Widder 1999)	
Stylocheiron maximum	MP	EX	470	(Fisher and Goldie 1961)**	
Nematoscelis megalops	MP	EX	465	(Fisher and Goldie 1961)**	
Thysanopoda acutifrons	MP	EX	480	(Fisher and Goldie 1961)**	
Thysanopoda orientalis	MP	ERG	478	(Frank and Widder 1999)	

Thysanoessa raschii	MP	EX	460-465	(Fisher and Goldie 1961)**	
Decapoda					
Dendrobranchiata					
Aristeidae					
Plesiopenaeus armatus	P	MSP	493	(Kent 1997)	
Benthesicymidae					
Bentheogennema intermedia	P	MSP	494	(Kent 1997)	
Bentheogennema pasithea	P	MSP	500	(Kent 1997)	
Gennadas sp.	P	MSP	495	(Kent 1997)	
Gennadas valens	P	MSP	495	(Kent 1997)	
Penaeidae					
Funchalia villosa	P	ERG	489	(Frank and Widder 1999)	
Penaeus duororum	C	EX	516	(Fernandez 1965)	
Penaeus monodon					AI770282, AI770242, AI770226, AI253885 (EST)
Penaeus penicillatus	C	ERG	480, 570	(Minjuan and Shujun 1990)	
Sergestidae					
Sergestes arcticus	MP	ERG	495	(Frank and Widder 1999)	
Sergestes arcticus	MP	extract	475	(Fisher and Goldie 1961)	
Sergestes corniculum	MP	ERG	500	(Frank and Widder 1999)	
Sergestes curvatus	P	MSP	493	(Kent 1997)	
Sergestes similis	P	MSP	495	(Kent 1997)	
Sergestes similis	MP	MSP	495	(Lindsay et al. 1999)	
Sergestes tenuiremis	P	MSP	495	(Hiller-Adams et al. 1988)	
Sergia grandis	MP	ERG	500	(Frank and Widder 1999)	
Sergia maximus	P	MSP	495	(Kent 1997)	
Sergia phorcus	P	MSP	495	(Kent 1997)	
Sergia robustus	P	MSP	496	(Kent 1997)	
Sergia splendens	P	MSP	497	(Kent 1997)	

Pleocyemata				
Caridea				
Bresiliidae				
Rimicaris exoculata	DB	ERG	500	(Johnson et al. 2002)
Rimicaris exoculata	DB	EX	500	(Van Dover et al. 1989)
Crangonidae				
Crangon allmani	C	ERG	415, 525	(Johnson et al. 2002)
Palaemonidae				
Palaemonetes paladosus	EST	EX	539	(Fernandez 1965)
Palaemonetes vulgaris	EST	ERG	390, 540	(Wald and Seldin 1968)
Palaemonetes vulgaris	EST	MSP	496, 555	(Goldsmith et al. 1968)
Pandalidae				
Pandalus montagui	C	ERG	515	(Johnson et al. 2002)
Plesionika martia	P	MSP	499	(Kent 1997)
Stylopandalus richardi	P	MSP	491	(Kent 1997)
Pasiphaeidae				
Parapasiphaea sulcatifrons	P	MSP	501	(Kent 1997)
Pasiphaea chacei	P	MSP	509	(Kent 1997)
Pasiphaea emarginata	P	MSP	497	(Kent 1997)
Pasiphaea multidentata	P	ERG	497	(Frank and Widder 1999)
Pasiphaea suspirosum	P	MSP	501	(Kent 1997)
Oplophoridae				
Acanthephyra curtirostris	P	ERG	510	(Frank and Case 1988a)
Acanthephyra curtirostris	P	MSP	485	(Hiller-Adams et al. 1988)
Acanthephyra curtirostris	P	MSP	485	(Kent 1997)
Acanthephyra microphthalma	P	MSP	482	(Kent 1997)
Acanthephyra purpurea	P	MSP	492	(Kent 1997)
Acanthephyra smithi	P	ERG	510	(Frank and Case 1988a)
Acanthephyra smithi	P	MSP	491	(Hiller-Adams et al. 1988)
Acanthephyra stylorostratis	P	MSP	489	(Kent 1997)
Hymenodora frontalis	P	MSP	495	(Kent 1997)

Hymenodora glacialis	P	MSP	500	(Kent 1997)
Janicella spinacauda	P	ERG	400, 500	(Frank and Case 1988a)
Meningodora miccyla	P	MSP	486	(Kent 1997)
Meningodora vesca	P	MSP	487	(Kent 1997)
Notostomus elegans	P	ERG	490	(Frank and Case 1988a)
Notostomus gibbosus	P	ERG	480	(Frank and Case 1988a)
Oplophorus gracilirostris	P	ERG	400, 500	(Frank and Case 1988a)
Oplophorus spinosus	P	ERG	400, 500	(Frank and Case 1988a)
Oplophorus spinosus	P	MSP	492	(Kent 1997)
Systellaspis braueri	P	MSP	411, 500	(Kent 1997)
Systellaspis cristata	P	MSP	414, 498	(Kent 1997)
Systellaspis debilis	P	MSP	400, 498	(Cronin and Frank 1996)
Systellaspis debilis	P	ERG	400, 500	(Frank and Case 1988a)
Systellaspis debilis	P	MSP	493	(Hiller-Adams et al. 1988)
Systellaspis debilis	P	MSP	417, 497	(Kent 1997)
Achelata				
Palinuridae				
Jasus edwardsii	C	ERG	472, 536	(Meyer-Rochow and Tiang 1984)
Panulirus argus	C	ERG	379, 510	(Cummins et al. 1984)
Anomala				
Diogenidae				
Clibanarius vittatus	EST	MSP	510	(Cronin and Forward 1988)
Dardanus fucosus	C	MSP	511	(Cronin and Forward 1988)
Petrolisthes diogenes	C	MSP	508	(Cronin and Forward 1988)
Coenobitidae				
Coenobita clypeatus	TR	MSP	508	(Cronin and Forward 1988)
Coenobita rugosa	TR	MSP	491	(Cronin and Forward 1988)
Paguridae				
Pagurus annulipes		MSP	493	(Cronin and Forward 1988)
Pagurus longicarpus	EST	MSP	515	(Cronin and Forward 1988)
Pagurus pollicaris	C	MSP	515	(Cronin and Forward 1988)

Pagurus pollicaris	C	MSP	516	(Lipetz and Cronin 1988)	
Galatheidae					
Pleuroncodes planipes	P	EX	523	(Fernandez 1973)	
Porcellanidae					
Petrolisthes elongates	C	ERG	536	(Ziedins and Meyer-Rochow 1990)	
Astacidea					
Astacidae					
Astacus fluviatus	FW	MSP	530	(Hamacher and Kohl 1981)	
Astacus leptodactylus	FW	MSP	530	(Hamacher and Stieve 1984)	
Cambaridae					
Cambarus hubrichti	FW			(Crandall and Hillis 1997)	AF005385
Cambarus maculatus	FW			(Crandall and Hillis 1997)	AF005386
Cambarellus schufeldtii	FW	MSP	526	(Crandall and Cronin 1997)	AF003544
Cambarellus ludovicianus	FW	MSP	529	(Crandall and Cronin 1997)	AF003543
Orconectes australis					AF005387
Orconectes virilis					AF003545
Orconectes rusticus	FW	MSP	530-535	(Cronin and Goldsmith 1982; Goldsmith 1978)	
Procambarus clarkii	FW	MSP	530-533	(Goldsmith 1978; Zeiger and Goldsmith 1994)	S53494
Procambarus clarkii	FW	MSP	440	(Cummins and Goldsmith 1981)	
Procambarus milleri	FW	MSP	522	(Crandall and Cronin 1997; Cronin and Goldsmith 1982)	AF003546
Procambarus orcinus					AF005389
Procambarus seminolae					AF005388
Parastacidae					
Engaeus cunicularius	FW	MSP	522	(Crandall and Cronin 1997)	
Nephropidae					
Homarus americanus	C	MSP	515	(Bruno et al. 1977)	CN853478, CN854434 (ESTs)
Homarus gammarus	C	MSP	515	(Kent 1997)	

Nephrops norvegicus	C	MSP	498	(Kent 1997)
Nephrops norvegicus	C	MSP	498	(Lowe 1976)
Nephrops norvegicus	C	ERG	425?, 515	(Johnson et al. 2002)
Brachyura				
Bythograeidae				
Bythograea thermydron	DB	MSP	489	(Cronin and Jinks 2001)
Bythograea thermydron (L)		MSP	447	(Cronin and Jinks 2001)
Bythograea thermydron	BP	MSP	489	(Jinks et al. 2002)
Bythograea thermydron (M)	BP	MSP	479	(Jinks et al. 2002)
Bythograea thermydron (Z)	MP	MSP	447	(Jinks et al. 2002)
Calappidae				
Calappa flammea	C	MSP	486	(Cronin and Forward 1988)
Calappa flammea		MSP	483	(Lipetz and Cronin 1988)
Hepatus epheliticus	C	MSP	487	(Cronin and Forward 1988)
Cancridae				
Cancer irroratus	C	MSP	496	(Cronin and Forward 1988)
Gecarcinidae				
Gecarcinus lateralis	TR	MSP	487	(Cronin and Forward 1988)
Gecarcinus lateralis	TR	ERG	510	(Lall and Cronin 1987)
Geryonidae				
Chaceon affinis	DB	ERG	380?, 480	(Johnson et al. 2002)
Geryon quinquedens	DB	MSP	473	(Cronin and Forward 1988)
Geryon quinquedens	DB	MSP	470	(Lipetz and Cronin 1988)
Grapsidae				
Leptograpsus variegatus	EST	IC	484	(Stowe 1980)
Sesarma cinereum	EST	MSP	492	(Cronin and Forward 1988)
Sesarma reticulatum	EST	MSP	493	(Cronin and Forward 1988)
Sesarma reticulatum	EST	IC	508	(Scott and Mote 1974)
Homolidae				
Paromola cuvieri	DB	ERG	?, 470	(Johnson et al. 2002)
Majidae				

Libinia dubia	EST	MSP	489	(Cronin and Forward 1988)	
Libinia dubia		MSP	486	(Lipetz and Cronin 1988)	
Libinia emarginata	EST	MSP	493	(Hays and Goldsmith 1969)	
Ocypodidae					
Uca pugilator	TR	IC	508	(Scott and Mote 1974)	
Uca pugilator	TR	ERG	510	(Scott and Mote 1974)	
Uca pugilator	TR	EX	480	(Goldsmith 1972)	
Uca pugnax	TR	ERG	510	(Scott and Mote 1974)	
Uca pugnax	TR	IC	508	(Scott and Mote 1974)	
Uca thayeri	TR	ERG	430, 500-540	(Horch et al. 2002)	
Portunidae					
Arenaeus cribrarius	C	MSP	498	(Cronin and Forward 1988)	
Callinectes ornatus	C	MSP	501	(Cronin and Forward 1988)	
Callinectes sapidus	EST	MSP	503	(Cronin and Forward 1988)	CV224458 (EST)
Callinectes sapidus	EST	IC	440, 508	(Martin and Mote 1982)	
Callinectes sapidus	C	MSP	504	(Cronin et al. 1995)	
Callinectes sapidus (M)	C	MSP	504	(Cronin et al. 1995)	
Carcinus maenas	EST	MSP	508	(Bruno and Goldsmith 1974)	
Carcinus maenas	EST	IC	440, 508	(Martin and Mote 1982)	
Ovipales stephensoni	C	MSP	505	(Cronin and Forward 1988)	
Portunus spinimanis	C	MSP	483	(Cronin and Forward 1988)	
Portunus spinimanus		MSP	479	(Lipetz and Cronin 1988)	
Portunus trituberculatus	C	ERG	513	(Weiyun and Minjuan 1990)	
Scylla serrata	EST	MSP	490	(Leggett 1979)	
Varunidae					
Hemigrapsus edwardsii	EST	EX	513	(Briggs 1961)	
Hemigrapsus sanguinensis			480	(Sakamoto et al. 1996)	D50583- D50584
Hemigrapsus sanguinensis	EST	ERG	360, 480	(Shukolyukov et al. 1984)	
Xanthidae					
Eurypanopeus depressus	EST	MSP	480	(Cronin and Forward 1988)	

Menippe mercenaria	EST	MSP	494	(Cronin and Forward 1988)
Panopeus herbtii	EST	MSP	493	(Fernandez 1973)
Panopeus herbstii	EST	MSP	491	(Lipetz and Cronin 1988)
Panopeus obesus	EST	MSP	492	(Cronin and Forward 1988)
Pilumnus sayi	C	MSP	489	(Cronin and Forward 1988)
Rhithropanopeus harrisii	EST	MSP	495	(Cronin and Forward 1988)

* - λ_{max} based on porphyropsin template; ** - λ_{max} may be contaminated by ommochrome pigments (Denys and Brown 1982)

REFERENCES CITED

Abele, L. G. 1991. Comparison of morphological and molecular phylogeny of the Decapoda. Memoirs of the Queensland Museum 31:101-108.

Abele, L. G., and B. E. Felgenhauer. 1986. Phylogenetic and phenetic relationships among the lower Decapoda. Journal of Crustacean Biology 6:385-400.

Adachi, J., and M. Hasegawa. 1996. MOLPHY version 2.3: Programs for molecular phylogenetics based in maximum likelihood. Comput. Sci. Monogr. 28:1-150.

Amati, L., R. M. Feldmann, and J.-P. Zonneveld. 2004. A new family of Triassic lobsters (Decapoda: Astacidea) from British Columbio and its phylogenetic context. Journal of Paleontology 78:150-168.

Andersson, S. G. E., A. Zomorodipour, J. O. Andersson, T. Sicheritz-Ponten, U. C. M. Alsmark, R. M. Podowski, A. K. Naslund, A. S. Eriksson, H. H. Winkler, and C. G. Kurland. 1998. The genome sequence of *Ricksettsia prowazekii* and the origin of mitochondria. Nature 133:133-143.

Andresen, M. C., and A. M. Brown. 1979. Photoresponses of a sensitive extraretinal photoreceptor in *Aplysia*. J. Physiol 287:267-282.

Anisimova, M., J. P. Bielawski, and Z. Yang. 2002. Accuracy and power of Bayes prediction of amino acid sites under positive selection. Molecular Biology and Evolution 19:950-958.

Ardendt, D., K. Tessmar-Raible, H. Snyman, A. W. Dorresteijn, and J. Wittbrodt. 2004. Ciliary photoreceptors with a vertebrate-type opsin in an invertebrate brain. Science 306:869-871.

Argos, P., M. G. Rossmann, U. M. Grau, H. Zuber, G. Frank, and J. D. Tratschin. 1979. Thermal stability and protein structure. Biochemistry 18:5698-5703.

Arikawa, K., K. Inokuma, and E. Eguchi. 1987. Pentachromatic visual system in a butterfly. Naturwissenschaften 74:297-298.

Arikawa, K., D. G. W. Scholten, M. Kinoshita, and D. G. Stavenga. 1999. Tuning of photoreceptor spectral sensitivities by red and yellow pigmens in the butterfly *Papilio xuthus*. Zool. Sci. 16:17-24.

Aris-Brosou, S., and Z. Yang. 2002. Effects of models of rate evolution on estimation of divergence dates with special reference to the metazoan 18S ribosomal RNA phylogeny. Systematic Biology 51:703-714.

Asenjo, A. B., J. Rim, and D. D. Oprian. 1994. Molecular determinants of red/green color discrimination. Neuron 12:1131-1138.

Babcock, L. E., M. F. Miller, J. L. Isbell, J. W. Collinson, and S. T. Hasiotis. 1998. Paleozoic-Mesozoic crayfish from Antarctica: Earliest evidence of freshwater decapod crustaceans. Geology 26:539-542.

Bargmann, C. 1998. Neurobiology of the *Caenorhabditis elegans* genome. Science 282:2028-2033.

Barnes, H., and W. Klepal. 1972. Phototaxis in stage I nauplius larvae of two cirripedes. J. Exp. Mar. Ecol. 10:267-273.

Beaudet, L., and C. W. Hawryshyn. 1999. Ecological aspects of vertebrate visual ontogeny. Pp. 413-437 *in* S. N. Archer, M. B. A. Djamgoz, E. R. Loew, J. C. Partridge and S. Vallerga, eds. Adaptive mechanisms in the ecology of vision. Kluwer Academic Publishers, Great Britain.

Bellingham, J., A. Morris, and D. M. Hunt. 1998. The rhodopsin gene of the cuttlefish *Sepia officinalis*: sequence and spectral tuning. The Journal of Experimental Biology 201:2299-2306.
Bellingham, J., D. J. Wells, and R. G. Foster. 2003. *In silico* characterisation and chromosomal localisation of human *RRH* (peropsin) - implications for opsin evolution. BMC Genomics 4, article 3, 8pp.
Bielawski, J. P., and Z. Yang. 2004. A maximum likelihood method for detecting functional divergence at individual codon sites, with application to gene family evolution. Journal of Molecular Evolution 59:121-132.
Blackshaw, S., and S. Snyder. 1997. Parapinopsin, a novel catfish opsin localized in the parapineal organ, defines a new gene family. J. Neurosci. 17:8083-8092.
Blackshaw, S., and S. H. Snyder. 1999. Encephalopsin: a novel mammalian extraretinal opsin discretely localized in the brain. J. Neurosci. 19:3681-3690.
Boas, J. E. V. 1880. Studier over Decapodernes Slaegtskabsforhold. Danske vidensk. Selsk. Skr., (Nat.) 6:25-210.
Boas, J. E. V. 1883. Studien über die Verwandtschaftsbeziehungen der Malakostraken. Morph. Jahrb. 8:485-579.
Bobkova, M., P. Grève, V. B. Meyer-Rochow, and G. Martin. 2003. Description of intracerebral ocelli in two species of North American crayfish: *Orconectes limosus* (Cambaridae) and *Pacifasticus leniusculus* (Astacidae). Invertebrate Biology 122:158-165.
Boden, B. P., E. M. Kampa, and B. C. Abbott. 1961. Photoreception of a planktonic crustacean in relation to light penetration in the sea. Pp. 189-196 *in* B. Christensen and B. Buchman, eds. Progress in photobiology. Elsevier, New York.
Borowsky, R., and H. Wilkens. 2002. Mapping a cave fish genome: Polygenic systems and regressive evolution. Journal of Heredity 93:19-21.
Borradaile, L. A. 1907. On the classification of the decapod crustaceans. Annals and Magazine of Natural History 7:457-486.
Bowmaker, J. K. 1995. The visual pigments of fish. Prog. Retinal Eye Res. 15:1-31.
Bowmaker, J. K. 1998. Evolution of colour vision in vertebrates. Eye 12:541-547.
Bowmaker, J. K., S. Astell, D. M. Hunt, and J. D. Mollon. 1991. Photosensitive and photostable pigments in the retinae of old world monkeys. Journal of Experimental Biology 156:1-19.
Bowmaker, J. K., V. I. Govardovskii, S. A. Shukolyukov, L. V. Zueva, D. M. Hunt, V. G. Sideleva, and O. G. Smirnova. 1994. Visual pigments and the photic environment: the cottoid fish of Lake Baikal. Visual Research 34:591-605.
Bowman, T. E., and L. G. Abele. 1982. Classification of the recent Crustacea. Pp. 1-27 *in* L. G. Abele, ed. The biology of the Crustacea. Academic Press, New York.
Bravi, S., and A. Garassino. 1998. 'Plattenkalk' of the Lower Cretaceous (Albian) of Petina, in the Alburni Mounts (Campania, S. Italy), and its decapod crustacean assemblage. Atti Societa italiana Scienze naturali Museo civico Storia naturale Milano 138:89-118.
Briggs, M. H. 1961. Visual pigments of grapsiod crabs. Nature 190:784-786.
Briscoe, A. D. 1998. Molecular diversity of visual pigments in the butterfly *Papilio glaucus*. Naturwissenschaften 85:33-35.

Briscoe, A. D. 2000. Six opsins from the butterfly *Papilio glaucus*: Molecular phylogenetic evidence for paralogous origins of red-sensitive visual pigments in insects. Journal of Molecular Evolution 51:110-121.
Briscoe, A. D. 2001. Functional diversification of Lepidopteran opsins following gene duplication. Molecular Biology and Evolution 18:2270-2279.
Briscoe, A. D. 2002. Homology modeling suggests a functional role for parallel amino acid substitutions between bee and butterfly red- and green-sensitive opsins. Molecular Biology and Evolution 19:983-986.
Briscoe, A. D., G. D. Bernard, A. S. Szeto, L. M. Nagy, and R. H. White. 2003. Not all butterfly eyes are created equal: rhodopsin absorption spectra, molecular identification, and localization of ultraviolet-, blue-, and green-sensitive rhodopsin-encoding mRNAs in the retina of *Vanessa cardui*. The Journal of Comparative Neurology 458:334-349.
Briscoe, A. D., and L. Chitkka. 2001. The evolution of color vision in insects. Annual Review of Entomology 46:471-510.
Briscoe, A. D., and R. H. White. 2005. Adult stemmata of the butterfly *Vanessa cardui* express UV and green opsin mRNAs. Cell Tissue Res 319:175-179.
Britt, S. G., R. Feiler, K. Kirschfeld, and C. S. Zuker. 1993. Spectral tuning of rhodopsin and metarhodopsin in vivo. Neuron 11:29-39.
Broek, J. V. 2001. Insect G protein-coupled receptors and signal transduction. Archives of Insect Biochemistry and Physiology 48:1-12.
Brown, A. J. H. 1996. Isolation and characterisation of visual pigment genes from the stomatopod crustacean *Gonodactylus oerstedii*. Pp. 192. University of Sussex.
Brown, A. M., and H. M. Brown. 1973. Light response of a giant *Aplysia* neuron. J Gen Physiol 62:239-254.
Brown, P. K., and P. S. Brown. 1958. Visual pigments of the octopus and cuttlefish. Nature 182:1288-1290.
Bruno, M. S., S. N. Barnes, and T. H. Goldsmith. 1977. The visual pigment and visual cycle of the lobster, *Homarus*. Journal of Comparative Physiology A 120:123-142.
Bruno, M. S., and T. H. Goldsmith. 1974. Rhodopsin of the blue crab *Callinectes*: evidence for absorption differences in vitro, in vivo. Vision Research 14:653-658.
Bruno, M. S., and D. Kennedy. 1962. Spectral sensitivitiy of photoreceptor neurons in sixth ganglion of crayfish. Comp. Biochem. Physiol. 6:41-&.
Buckley, T. R. 2002. Model misspecification and probablistic test of topology: Evidence from empirical data sets. Systematic Biology 51:509-523.
Burch, C. L., and L. Chao. 1999. Evolution by small steps and rugged landscapes in the RNA virus ϕ6. Genetics 151:921-927.
Burkenroad, M. D. 1963. The Evolution of the Eucarida (Crustacea, Eumalacostraca), in Relation to the Fossil Record. Tulane Stud. Geol. 2:1-17.
Burkenroad, M. D. 1981. The higher taxonomy and evolution of decapoda (Crustacea). Trans. San Diego Soc. Nat. Hist. 19:251-268.
Carleton, K. L., and T. D. Kocher. 2001. Cone opsin genes of African cichlid fishes: Tuning spectral sensitivity by differential gene expression. Molecular Biology and Evolution 18:1540-1550.

Carulli, J. P., D.-M. Chen, W. S. Stark, and D. L. Hartl. 1994. Phylogeny and physiology of *Drosophila* opsins. Journal of Molecular Evolution 38:250-262.
Carulli, J. P., and D. L. Hartl. 1992. Variable rates of evolution among Drosophila opsin genes. Genetics 132:193-204.
Casanova, B., L. De Jong, and X. Moreau. 2002. Carapace and mandibles ontogeny in the Dendrobranchiata (Decapoda), Euphausiacea, and Mysidacea (Crustacea): a phylogenetic interest. Candian Journal of Zoology 80:296-306.
Castresana, J. 2000. Selection of conserved blocks from multiple alignments for their use in phylogenetic analysis. Molecular Biology and Evolution 17:540-552.
Chan, T., M. Lee, and T. P. Sakmar. 1992. Introduction of hydroxyl bearing residues causes bathochromic spectral shifts in rhodopsin. J. Biol. Chem. 267:9478-9480.
Chang, B. S. W., D. Ayers, W. C. Smith, and N. E. Pierce. 1996. Cloning of the gene encoding honeybee long-wavelength rhodopsin: A new class of insect visual pigments. Gene 173:215-219.
Chang, B. S. W., K. A. Crandall, J. P. Carulli, and D. L. Hartl. 1995. Opsin phylogeny and evolution: A model for blue shift in wavelength regulation. Molecular Phylogenetics and Evolution 4:31-43.
Chase, M. R., P. R. Bennett, and R. H. White. 1997. Three opsin-encoding cDNAs from the compound eye of *Manduca sexta*. The Journal of Experimental Biology 200:2469-2478.
Cheroske, A. G., T. W. Cronin, and R. L. Caldwell. 2003. Adaptive color vision in *Pullosquilla litoralis* (Stomatopoda, Lysiosquilloidea) associated with spectral and intensity changes in light environment. The Journal of Experimental Biology 206:373-379.
Chiao, C. C., T. W. Cronin, and N. J. Marshall. 2000. Eye design and color signaling in a stomatopod crustacean, *Gonodactylus smithii*. Brain, Behavior and Evolution 56:107-122.
Chitkka, L. 1996. Does bee color vision predate the evolution of flower color? Naturwissenschaften 83:136-138.
Chitkka, L. 1997. Bee color vision is optimal for coding flower color, but flower colors are not optimal for being coded - why? Israel Journal of Plant Sciences 45:115-127.
Christoffersen, M. L. 1988. Phylogenetic systematics of the Eucarida (Crustacea Malacostraca). Revista Brasileira de Zoologia 5:325-351.
Colgar, D. J., A. McLauchlan, G. D. F. Wilson, S. P. Livingston, G. D. Edgecombe, J. Macaranas, G. Cassis, and M. R. Gray. 1998. Histone H3 and U2 snRNA DNA sequences and arthropod molecular evolution. Aust. J. Zool. 46:419-437.
Colless, D. H. 1980. Congruence between morphometric and allozyme data for *Menidia* species: A reappraisal. Systematic Zoology 29:288-299.
Cowing, J. A., S. Poopalasundaram, S. E. Wilkie, J. K. Bowmaker, and D. M. Hunt. 2002a. Spectral tuning and evolution of short wave-sensitive cone pigments in cottoid fish from Lake Baikal. Biochemistry 41:6019-6025.
Cowing, J. A., S. Poopalasundaram, S. E. Wilkie, P. R. Robinson, J. K. Bowmaker, and D. M. Hunt. 2002b. The molecular mechanism for the spectral shifts between vertebrate ultraviolet- and violet- sensitive cone visual pigments. Biochemical Journal 367:129-135.

Crandall, K. A. 2002. Encyclopedia of Evolution. Oxford University Press.
Crandall, K. A., and T. W. Cronin. 1997. The molecular evolution of visual pigments of freshwater crayfishes (Decapoda: Cambaridae). Journal of Molecular Evolution 45:524-534.
Crandall, K. A., and J. F. Fitzpatrick Jr. 1996. Crayfish molecular systematics: Using a combination of procedures to estimate phylogeny. Systematic Biology 45:1-26.
Crandall, K. A., D. J. Harris, and J. W. J. Fetzner. 2000. The monophyletic origin of freshwater crayfish estimated from nuclear and mitochondrial DNA sequences. Proceedings of the Royal Society of London B 267:1679-1686.
Crandall, K. A., and D. M. Hillis. 1997. Rhodopsin evolution in the dark. Nature 387:667-668.
Crescitelli, F., M. McFall-Ngai, and J. Horwitz. 1985. The visual pigment sensitivity hypothesis: further evidence from fishes of varying habitats. Journal of Comarative Physiology A 157:323-333.
Crill, W. D., H. A. Wichman, and J. J. Bull. 2000. Evolutionary reversals during viral adaptation to alternating hosts. Genetics 154:27-37.
Cronin, T. W. 1985. The visual pigment of a stomatopod crustacean, *Squilla empusa*. Journal of Comparative Physiology A 156:679-687.
Cronin, T. W. 1986. Optical design and evolutionary adaptation in crustacean compound eyes. Journal of Crustacean Biology 6:1-23.
Cronin, T. W. 2005. Invertebrate vision in water. In: Invertebrate Vision (E. Warrant and D. E. Nilsson, eds.). Cambridge University Press, Cambridge UK (in press).
Cronin, T. W., R. L. Caldwell, and M. V. Erdmann. 2002. Tuning of photoreceptor function in three mantis shrimp species that inhabit a range of depths. I. Visual pigments. Journal of Comparative Physiology A 188:179-186.
Cronin, T. W., R. L. Caldwell, and N. J. Marshall. 2001. Tunable colour vision in a mantis shrimp. Nature 411:547.
Cronin, T. W., and R. B. Forward. 1988. The visual pigments of crabs - I. Spectral characteristics. Journal of Comparative Physiology A 162:463-478.
Cronin, T. W., and T. M. Frank. 1996. A short-wavelength photoreceptor class in deep-sea shrimp. Proceedings of the Royal Society of London B 263:861-865.
Cronin, T. W., and T. H. Goldsmith. 1982. Photosensitivity spectrum of crayfish rhodopsin measured using fluorescence of metarhodopsin. J. Gen. Physiol. 79:313-332.
Cronin, T. W., and R. N. Jinks. 2001. Ontogeny of vision in marine crustaceans. Amer. Zool. 41:1098-1107.
Cronin, T. W., and N. J. Marshall. 1989. Multiple spectral classes of photoreceptors in the retinaes of gonodactyloid stomatopod crustaceans. Journal of Comparative Physiology A 166:267-275.
Cronin, T. W., and N. J. Marshall. 2004. The unique visual world of mantis shrimps. Pp. 239-268 *in* F. Prete, ed. Complex Worlds from Simple Nervous Systems. MIT Press, Cambridge MA.
Cronin, T. W., N. J. Marshall, and R. L. Caldwell. 1993. Photoreceptor spectral diversity in the retinas of squilloid and lysiosquilloid stomatopod crustaceans. Journal of Comarative Physiology A 172:339-350.

Cronin, T. W., N. J. Marshall, and R. L. Caldwell. 1994a. The retinas of mantis shrimp from low-light environments (Crustacea; Stomatopoda; Gonodactylidae). Journal of Comparative Physiology A 174:607-619.
Cronin, T. W., N. J. Marshall, and R. L. Caldwell. 1996. Visual pigment diversity in two genera of mantis shrimps implies rapid evolution (Crustacea: Stomatopoda). Journal of Comparative Physiology A 179:371-384.
Cronin, T. W., N. J. Marshall, and R. L. Caldwell. 2000. Spectral tuning and the visual ecology of mantis shrimps. Philosophical Transactions of the Royal Society Series B 355:1263-1267.
Cronin, T. W., N. J. Marshall, R. L. Caldwell, and D. Pales. 1995. Compound eyes and ocular pigments of crustacean larvae (Stomatopoda and Decapod Brachyura). Mar Fresh Behav Physiol 26:219-231.
Cronin, T. W., N. J. Marshall, R. L. Caldwell, and N. Shashar. 1994b. Specialization of retinal function in the compound eyes of mantis shrimps. Vision Research 34:2639-2656.
Cronin, T. W., N. J. Marshall, C. A. Quinn, and C. A. King. 1994c. Ultraviolet photoreceptors in mantis shrimp. Vision Research 34:1443-1452.
Culver, D. C., L. L. Master, M. C. Christman, and H. H. I. Hobbs. 2000. Obligate cave fauna of the 48 contiguous United States. Conservation Biology 14:386-401.
Culver, D. C., and H. Wilkens. 2000. Critical review of the relevant theories of the evolution of subterranean animals. Pp. 381-398 *in* H. Wilkens, D. C. Culver and W. F. Humphreys, eds. Subterranean Ecosystems. Elsevier Science, Amsterdam, The Netherlands.
Cummins, D. R., D.-M. Chen, and T. H. Goldsmith. 1984. Spectral sensitivity of the spiny lobster *Panulirus argus*. Biol. Bull. 16:269-276.
Cummins, D. R., and T. H. Goldsmith. 1981. Cellular identification of the violet receptor in the crayfish eye. Journal of Comarative Physiology 42:199-202.
Cunningham, C. W., K. E. Omland, and T. H. Oakley. 1998. Reconstructing ancestral character states: a critical reappraisal. Trends in Ecology and Evolution 13:361-366.
Darwin, C. 1859. On the Origin of Species. John Murray
De Jong, L., S. Jean, and X. Moreau. 2004. The digestive system of *Euphausia krohni* (Crustacea, Euphausiacea): functional morphology and phylogenetic relevance. Cahiers de biologie marine 45:71-82.
De Jong-Moreau, L., and J.-P. Casanova. 2001. The foreguts of the primitive families of the Mysida (Crustacea, Peracarida): a transitional link between those of the Lophogastrida (Crustacea, Mysidacea) and the most evolved Mysida. Acta Zoologica 82:137-147.
Denys, C. J., and P. K. Brown. 1982. Euphausiid visual pigments. The rhodopsins of *Euphausia superba* and *Meganyctiphanes norvegicus*. J. Gen. Physiol. 80:451-472.
DePamphilis, C. W., N. D. Young, and A. D. Wolfe. 1997. Evolution of plastid gene *rps2* in a lineage of hemiparasitic and holoparasitic plants: Many losses of photosynthesis and complex patterns of rate variation. Proceedings of the National Academy of Science USA 94:7367-7372.

Dixon, C. J., S. T. Ahyong, and F. R. Schram. 2003. A new hypothesis of decapod phylogeny. Crustaceana 76:935-975.
Douglas, R. H., and N. J. Marshall. 1999. A review of vertebrate and invertebrate ocular filters. Pp. 95-162 *in* S. N. Archer, E. R. Loew, J. C. Partridge and S. Vallarta, eds. Adaptive mechanisms in the ecology of vision. Kluwer Academic Publishers, Dordrecht.
Douglas, R. H., and J. C. Partridge. 1997. On the visual pigments of deep-sea fish. Journal of Fish Biology 50:68-85.
Douglas, R. H., J. C. Partridge, and N. J. Marshall. 1998. The eyes of deep-sea fish I. Lens pigmentation, tapeta, visual pigments. Prog. Retinal Eye Res. 17:597-636.
Dowling, T. E., D. P. Martasian, and W. R. Jeffery. 2002. Evidence for multiple genetic forms with similar eyeless phenotypes in the blind cavefish, Astyanax mexicanus. Molecular Biology and Evolution 19:446-455.
Eguchi, E., K. Watanabe, T. Hariyama, and K. Yamamoto. 1982. A comparison of electrophysiologically determined spectral responses in 35 species of Lepidoptera. Journal of Insect Physiology 28:675-682.
Elena, S. F., and R. E. Lenski. 2001. Epistasis between new mutations and genetic background and a test of genetic canalization. Evolution 55:1746-1752.
Emlen, D. J. 2001. Costs and the diversification of exaggerated animal structures. Science 291:1534-1536.
Fasick, J. I., M. L. Applebury, and D. D. Oprian. 2002. Spectral tuning in the mammalian shortwavelength sensitive cone pigments. Biochemistry 41:6860-6865.
Fasick, J. I., and P. R. Robinson. 1998. Mechanism of spectral tuning in the dolphin visual pigments. Biochemistry 37:432-438.
Feiler, R., R. Bjornson, K. Kirschfeld, D. Mismer, G. M. Rubin, D. P. Smith, M. Socolich, and C. S. Zuker. 1992. Ectopic expression of ultraviolet-rhodopsins in the blue photoreceptor cells of *Drosophila*: visual physiology and photochemistry of transgenic animals. Journal of Neuroscience 12:3862-3868.
Feiler, R., W. A. Harris, K. Kirschfeld, C. Wehrhahn, and C. S. Zuker. 1988. Targeted misexpression of a *Drosophila* opsin gene leads to altered visual function. Nature 333:737-741.
Feldmann, R. M. 2003. The Decapoda: New initiatives and novel approaches. Journal of Paleontology 77:1021-1038.
Feldmann, R. M., F. J. Vega, S. P. Applegate, and G. A. Bishop. 1998. Early Cretaceous arthropods from the Tlayua formation at Tepexi de Rodriguez, Puebla, Mexico. Journal of Paleontology 72:79-90.
Felgenhauer, B. E., and L. G. Abele. 1983. Phylogenetic relationships among shrimp-like decapods. Crustacean Issues 1:291-311.
Felsenstein, J. 1981. Evolutionary trees from DNA sequences: A maximum likelihood approach. Journal of Molecular Evolution 17:368-376.
Felsenstein, J. 1985. Confidence limits on phylogenies: An approach using the bootstrap. Evolution 39:783-791.
Felsenstein, J. 2003. Phylip (Phylogenetic Inference Package). distributed by the author, Dept. of Genetics, University of Washington, Seattle.

Fenton, G. E. 1985. Ecology and taxonomy of mysids (Mysidacea: Crustacea). Pp. 412. Dept. of Zoology. University of Tasmania.
Fernandez, H. R. 1965. A survey of the visual pigments of decapod crustaceans of S Florida. University of Miami, Miami, Florida.
Fernandez, H. R. 1973. Spectral sensitivity and visual pigment of the compound eye of the galatheid crab *Pleuroncodes planipes*. Marine Biology 20:148-153.
Filipek, S., R. Stenkamp, D. C. Teller, and K. Palczewski. 2003a. G protein-coupled receptor rhodopsin: A prospectus. Ann. Rev. Physiol. 65:851-79.
Filipek, S., D. C. Teller, K. Palczewski, and R. Stenkamp. 2003b. The crystallographic model of rhodopsin and its use in studies of other G protein-coupled receptors. Annual Review of Biophys. Biomol. Struct. 32:375-397.
Fisher, L. R. 1967. Pigments of euphausiid eyes. J. Mar. Biol. Assoc. India:1074-1080.
Fisher, L. R., and E. H. Goldie. 1959. The eye pigments of a euphausiid crustacean, *Meganyctiphanes norvegica* (M. Sars). Proc. XV Intern. Congr. Zool., London 533-535.
Fisher, L. R., and E. H. Goldie. 1961. Pigments of compound eyes. Pp. 153-154 *in* B. Christensen and B. Buchman, eds. Progress in photobiology. Elsevier, Amsterdam.
Flower, D. R. 1999. Modelling G-protein-coupled receptors for drug design. Biochem Biophys Acta 1422:207-234.
Forsberg, R., and F. B. Christiansen. 2003. A codon-based model of host-specific selection in parasites, with an application to the influenza A virus. Molecular Biology and Evolution 20:1252-1259.
Forsell, J., P. Ekström, I. Novales Flamarique, and B. Holmqvist. 2001. Expression of pineal ultraviolet- and green-like opsins in the pineal organ and retina of teleosts. Journal of Experimental Biology 204:2517-2525.
Frank, T. M., and J. F. Case. 1988a. Visual spectral sensitivities of bioluminscent deep-sea crustaceans. Biol. Bull. 175:261-273.
Frank, T. M., and J. F. Case. 1988b. Visual spectral sensitivity of the bioluminescent deep-sea mysid, *Gnathophausia ingens*. Biological Bulletin 175:274-283.
Frank, T. M., and E. A. Widder. 1999. Comparative study of the spectral sensitivities of mesopelagic crustaceans. Journal of Comparative Physiology a-Neuroethology Sensory Neural and Behavioral Physiology 185:255-265.
Fredriksson, R., M. C. Lagerström, L.-G. Lundin, and H. B. Schiöth. 2003. The G-protein-couled receptros in the human genome form five main families. Phylogeneitc analysis, paralogon groups, and fingerprints. Molecular Pharmacology 63:1256-1272.
Frêlon-Raimond, M., V. B. Meyer-Rochow, A. Ugolini, and G. Martin. 2002. First cytological description of intracerebral ocelli in an amphipod: the extraretinal photoreceptors of the sandhopper *Talitrus saltator* (Crustacea, Amphipoda). Invert Neurosci 121:1-12.
Fryxell, K. J., and E. M. Meyerowitz. 1991. The evolution of rhodopsins and neurotransmitter receptors. Journal of Molecular Evolution 33:367-378.
Gal, G., E. R. Loew, L. G. Rudstam, and A. M. Mohammadian. 1999. Light and diel vertical migration: spectral sensitivity and light avoidance by *Mysis relicta*. Can. J. Fish. Aquat. Sci. 56:311-322.

Garassino, A., and S. Bravi. 2003. Palaemon antonellae new species (Crustacea, Decapoda, Caridea) from the Lower Cretaceous 'Platydolomite' of Profeti (Caserta, Italy). Journal of Paleontology 77:589-592.
Gartner, W., and P. Towner. 1995. Invertebrate visual pigments. Photochem Photobiol 62:1-16.
Gatesy, J., P. O'Grady, and R. H. Baker. 1999. Corroboration among data sets in simultaneous analysis: Hidden support for phylogenetic relationships among higher level artiodactyl taxa. Cladistics 15:271-314.
Gil, R., B. Sabater-Munoz, A. Latorre, F. J. Silva, and A. Moya. 2002. Extreme genome reduction in *Buchneria* spp.: Toward the minimal genome needed for symbiotic life. Proceedings of the National Academy of Science USA 99:4454-4458.
Giribet, G., S. Richter, G. D. Edgecombe, and W. C. Wheeler. 2004. The position of crustaceans within the Arthropoda - Evidence from nine molecular loci and morphology. Crustacean Issues 16:307-352.
Glaessner, M. F. 1969. Decapoda. Pp. R651 *in* R. C. Moore, ed. Treatise on Invertebrate Paleontology, Part R. Arthropoda 4. University of Kansas, Geological Society of America, Lawerence.
Goldman, L. J., S. N. Barnes, and T. H. Goldsmith. 1975. Microspectrophotometry of rhodopsin and metarhodopsin in the moth *Galleria*. Journal of General Physiology 66:383-404.
Goldman, N., J. P. Anderson, and A. G. Rodrigo. 2000. Likelihood-based tests of topologies in phylogenetics. Systematic Biology 49:652-670.
Goldsmith, T. H. 1972. The natural history of invertebrate visual pigments. Pp. 727-742 *in* H. J. A. Dartnall, ed. Handbook of sensory physiology. Springer, Berlin.
Goldsmith, T. H. 1978. The spectral absorption of crayfish rhabdoms: pigment, photoproduct and pH sensitivity. Vision Research 18:463-473.
Goldsmith, T. H., A. E. Dizon, and H. R. Fernandez. 1968. Microspectrophotometry of photoreceptor organelles from eyes of the prawn Palaemonetes. Science 161:468-470.
Gotow, T. 1989. Photoresponses of an extraocular photoreceptor associated with a decrease in membrane conductance in a opisthobranch mollusc. Brain Res 479:120-129.
Graur, D., and W. Martin. 2004. Reading the entrails of chickens: molecular timescales of evolution and the illusion of precision. Trends in Genetics 20:80-86.
Gromiha, M. M., and P. K. Ponnuswamy. 1993. Relationship between amino acid properties and protein compressibility. Journal of Theoretical Biology 165:87-100.
Guex, N., and M. C. Peitsch. 1997. SWISS-MODEL and the Swiss-Pdb Viewer: an environment for comparative protein modeling. Electrophoresis 18:2714-2723.
Guindon, S., and O. Gascuel. 2003. A simple, fast, and accurate algorithm to estimate large phylogenies by maximum likelihood. Systematic Biology 52:696-704.
Hafner, G. S., R. L. Martin, and T. R. Tokarski. 2003. Photopigment gene expression and rhabdom formation in the crayfish (*Procambarus clarkii*). Cell Tissue Res. 311:99-105.
Hall, M. D., M. A. Hoon, N. J. Ryba, J. D. Pottinger, J. N. Keen, H. R. Saibil, and J. B. Findlay. 1991. Molecular cloning and primary structure of squid (*Loligo forbesi*)

rhodopsin, a phospholipase C-directed G-protein linked receptor. Biochemical Journal 274:35-40.
Hamacher, H., and H. Stieve. 1984. Spectral properties of the rhodopsin-system of the crayfish *Astacus leptodactylus*. Photochem Photobiol 39:379-390.
Hamacher, K. J., and K. D. Kohl. 1981. Spectroscopical studies of the *Astacus* visual pigment. Biophysics of Structure and Mechanism 7:338.
Hao, W., and H. K. Fong. 1996. Blue and ultraviolet light-absorbing opsin from the retinal pigment epithelium. Biochemistry 35:6251-6256.
Hariyama, T., K. Ozaki, F. Tokunaga, and Y. Tsukahara. 1993. Primary structure of crayfish visual pigment deduced from cDNA. FEBS Letters 315:287-292.
Hariyama, T., and Y. Tsukahara. 1993. Spectral responses, including a UV-sensitive cell type, in the eye of the isopod *Ligia exotica*. Naturwissenschaften 80:233-235.
Hasegawa, M. 1990. Mitochondrial DNA evolution in primates: Transition rates has been extremely low in the lemur. Journal of Molecular Evolution 31:113-121.
Hasiotis, S. T. 2002. Where is the fossil evidence for Gondwanan crayfish? Gondwana Research: International Geoscience Journal 5:872-878.
Hasiotis, S. T., and C. E. Mitchell. 1993. A comparison of crayfish burrow morphologies: Triassic and Holocene fossil, paleo- and neo-ichnological evidence, and the identification of their burrowing signatures. Ichnos 2:291-314.
Hattar, S., H.-W. Liao, M. Takao, D. M. Berson, and K.-W. Yau. 2002. Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity. Science 295:1065-1070.
Hays, D., and T. H. Goldsmith. 1969. Microspectrophotometry of the visual pigment of the spider crab *Libinia emarginata*. Zeitschrift fur Vergleichende Physiologie 65:218-232.
Hertel, H. 1972. Aspekte zur photorezeption von *Artemia salina*. Verh. dtsch. Ges. Zool. Erlangen
Higgs, P. G. 1998. Compensatory neutral mutations and the evolution of RNA. Genetica 102:91-101.
Hill, C. A., A. N. Fox, R. J. Pitts, L. B. Kent, P. L. Tan, M. A. Chrystal, A. Cravchik, F. H. Collins, H. M. Robertson, and L. J. Zwiebel. 2002. G protein-coupled receptors in *Anopheles gambiae*. Science 298:176-178.
Hiller-Adams, P., E. A. Widder, and J. F. Case. 1988. The visual pigments of four deep-sea crustacean species. Journal of Comarative Physiology A 163:63-72.
Hillis, D. M., and T. M. Dixon. 1991. Ribsomal DNA: Molecular evolution and phylogenetic inference. Q. Rev. Biol. 66:411-453.
Hillman, P., F. A. Dodge, S. Hochstein, B. W. Knight, and B. Minke. 1973. Rapid dark recovery of the invertebrate early receptor potential. Journal of General Physiology 62:77-86.
Holmquist, C. 1981. The genus *Acanthomysis* Czerniavsky, 1882 (Crustacea, Mysidacea). Zool. Jb. Syst. 108:386-415.
Horch, K., M. Salmon, and R. Forward. 2002. Evidence for a two pigment visual system in the fiddler crab, *Uca thayeri*. Journal of Comarative Physiology A 188:493-499.
Hubbard, R., and R. C. C. St. George. 1958. The rhodopsin system of the squid. J. Gen. Physiol. 41:510-528.

Hubbard, R., and G. Wald. 1960. Nature 186:212-215.
Hueffer, K., J. S. L. Parker, W. S. Weichert, R. E. Geisel, J. Y. Sgro, and C. R. Parrish. 2003. The natural host range shift and subsequent evolution of canine parvovirus resulted from virus-specific canine transferrin receptor. Journal of Virology 77:1718-1726.
Huelsenbeck, J. P., and K. A. Crandall. 1997. Phylogeny estimation and hypothesis testing using maximum likelihood. Annual Review of Ecology and Systematics 28:437-466.
Huelsenbeck, J. P., and N. S. Imennov. 2002. Geographic origin of human mitochondrial DNA: Accomodating phylogenetic uncertainty and model comparison. Systematic Biology 51:673-688.
Huelsenbeck, J. P., B. Larget, R. E. Miller, and F. Ronquist. 2002. Potential applications and pitfalls of Bayesian inference phylogeny. Systematic Biology 51:673-688.
Hunt, D. M., J. A. Cowing, S. E. Wilkie, J. W. L. Parry, S. Poopalasundaram, and J. K. Bowmaker. 2004. Divergent mechanisms for tuning of shortwave sensitive visual pigments in vertebrates. Photochemical and Photobiological Sciences: and International Journal 3:713-720.
Huxley, T. H. 1880. The crayfish. C. Kegan Paul and Co., London.
Ichikawa, T., and H. Tateda. 1982. Distribution of color receptors in the larval eyes of four species of Lepidoptera. Journal of Comparative Physiology A 149:317-324.
Ikeda, Y., M. Mochizuki, R. Naito, K. Nakamura, T. Miyazawa, T. Mikami, and E. Takahashi. 2000. Predominance of canine parvovirus (CPV) in unvaccinated cat populations and emergence of new antigenic types of CPV in cats. Virology 278:13-19.
Ikeda, Y., K. Nakamura, T. Miyazawa, E. Takahashi, and M. Mochizuki. 2002. Feline host range of canine parvovirus: recent emergence of new antigenic types in cats. Emerging Infectious Diseases 8:341-346.
Imaizumi, R. 1938. Fossil crayfishes from Jehol. Science Reports of the Tokyo Imperial University, Sendal, Japan, Second Series 19:173-179.
Janz, J. M., J. F. Fay, and D. L. Farrens. 2003. Stability of dark state rhodopsin is mediated by a conserved ion pair in intradiscal loop E-2. J. Biol. Chem. 278:16982-16991.
Jarman, S. N., S. Nicol, N. G. Elliott, and A. McMinn. 2000. 28S evolution in the Eumalacostraca and the phylogenetic position of krill. Molecular Phylogenetics and Evolution 17:26-36.
Jeffery, W. R. 2001. Cavefish as a model system in evolutionary developmental biology. Developmental Biology 231:1-12.
Jeffery, W. R., and D. P. Martasian. 1998. Evolution of eye regression in the cavefish Astyanax: Apoptosis and the Pax-6 gene. American Zoologist 38:685-696.
Jinks, R. N., T. L. Markley, E. E. Taylor, G. Perovich, A. I. Dittel, C. E. Epifanio, and T. W. Cronin. 2002. Adaptive visual metamorphosis in a deep-sea hydrothermal vent crab. Nature 420:68-70.
Johnson, M. L., E. Gaten, and P. M. J. Shelton. 2002. Spectral sensitivities of five marine decapod crustaceans and a review of spectral sensitivity variation in relation to habitat. J. Mar. Biol. Ass. UK 82:835-842.

Jokela-Määttä, M., J. Pahlberg, M. Lindström, P. Zak, M. L. Porter, M. Ostrovskii, T. Cronin, and K. Donner. 2005. Visual pigment absorbance and spectral sensitivity of *Mysis relicta* (Crustacea, Mysidae) in different light environments. Journal of Comarative Physiology A. in press.

Jutte, P. A., T. W. Cronin, and R. L. Caldwell. 1998a. Retinal function in the planktonic larvae of two species of *Pullosquilla* a lysiosquilloid stomatopod crustacean. Journal of Experimental Biology 201:2481-2487.

Jutte, P. A., T. W. Cronin, and R. L. Caldwell. 1998b. Vision in two sympatric species of *Pullosquilla* (Stomatopoda, Lysiosquilloidea) living in different depth ranges. Marine Freshwater Behavior and Physiology 31:231-250.

Kampa, E. M. 1955. Euphausiopsin, a new photosensitive pigment from the eyes of euphausiid crustaceans. Nature 175:996-998.

Kass, R. E., and A. E. Raftery. 1995. Bayes factors. J. Am. Stat. Assoc. 90:773-795.

Kawamura, S., and S. Yokoyama. 1996. Molecular characterization of the pigeon P-opsin gene. Gene 182:213-214.

Kawamura, S., and S. Yokoyama. 1997. Expression of visual and nonvisual opsins in American chameleon. Vision Research 37:1867-1871.

Kent, J. 1997. The visual pigments of deep-sea crustaceans. University of Bristol, UK.

Kim, W., and L. G. Abele. 1990. Molecular phylogeny of selected decapod crustaceans based on 18s rRNA nucleotide sequences. Journal of Crustacean Biology 10

King, R. C., and W. D. Stansfield. 1997. A dictionary of genetics. Oxford University Press

Kishino, H., J. L. Thorne, and W. J. Bruno. 2001. Performance of a divergence time estimation method under a probabilistic model of rate evolution. Molecular Biology and Evolution 18:352-361.

Kitamoto, J. K., K. Sakamoto, K. Ozaki, Y. Mishina, and K. Arikawa. 1998. Two visual pigments in a single photoreceptor cell: identification and histological localization of three mRNAs encoding visual pigment opsins in the retina of the butterfly *Papilio xuthus*. Journal of Experimental Biology 201:1255-1261.

Kito, Y., T. Seki, T. Suzuki, and I. Uchiyama. 1986. 3-Dehydroretinal in the eye of a bioluminescent squid, *Watsenia scintillans*. Vision Research 26:275-279.

Kobusch, W. 1998. The foregut of the Mysida (Crustacea, Peracarida) and its phylogenetic relevance. Philosophical Transactions of the Royal Society of London B 353:559-581.

Kojima, D., H. Mano, and Y. Fukada. 2000. Vertebrate ancient-long opsin: A green-sensitive photoreceptor molecule present in zebrafish deep brain retinal horizontal cells. J. Neurosci. 20:2845-2851.

Koutalos, Y., T. G. Ebrey, M. Tsuda, K. Odashima, T. Lien, M. H. Park, N. Shimizu, F. Derguini, K. Nakanishi, H. R. Gilson, and B. Honig. 1989. Regeneration of bovine and octopus opsins in situ with natural and artificial retinals. Biochemistry 28:2732-2739.

Kroeze, W. K., D. J. Sheffler, and B. L. Roth. 2003. G-protein-coupled receptors at a glance. Journal of Cell Science 116:4867-4869.

Lall, A. B., and T. W. Cronin. 1987. Spectral sensitivity of the compound eyes in the purple land crab, *Geocarcinus lateralis*. Biological Bulletin 173:398-406.

Land, M. F. 1981. Optics and vision in invertebrates. Pp. 471-592 *in* H. Autrum, ed. Handbook of sensory physiology. Springer-Verlag, New York.
Langer, H., B. Haumann, and C. C. Meinecki. 1979. Tetrachromatic visual system in the moth *Spodoptera exempta* (Insecta: Noctuidae). Journal of Comparative Physiology A 129:235-239.
Larimer, J. L. 1966. A functional caudal photoreceptor in blind cavernicolous crayfish. Nature 210:204-205.
Lee, M. S. Y. 1999. Molecular clock calibrations and metazoan diversity. Journal of Molecular Evolution 49:385.
Leggett, L. M. W. 1979. A retinal substrate for colour discrimination in crabs. Journal of Comparative Physiology A 133:159-166.
Levin, B. R., V. Perrot, and N. Walker. 2000. Compensatory mutations, antibiotic resistance and the population genetics of adaptive evolution in bacteria. Genetics 154:985-997.
Lindsay, S. M., T. M. Frank, J. Kent, J. C. Partridge, and M. I. Latz. 1999. Spectral sensitivity of vision and bioluminescence in the midwater shrimp *Sergestes similis*. Biol. Bull. 197:348-360.
Lindström, M. 2000. Eye function of Mysidacea (Crustacea) in the northern Baltic Sea. Journal of Experimental and Marine Biology and Ecoloty 246:85-101.
Lipetz, L. E., and T. W. Cronin. 1988. Application of an invariant spectral form to the visual pigments of crustaceans: Implications regarding the binding of the chromophore. Vision Research 28:1083-1093.
Lohan, A. J., and K. H. Wolfe. 1998. A subset of conserved tRNA genes in plastid DNA of nongreen plants. Genetics 150:425-433.
Lowe, E. R. 1976. Light and photoreceptor degeneration in the Norway lobster, *Nephrops norvegicus*. Proceedings of the Royal Society of London B 193:31-44.
Lythgoe, J. N. 1972. The adaptation of visual pigments to the photic environment. Pp. 566-603 *in* H. J. A. Dartnall, ed. Handbook of sensory physiology. Springer, Berlin.
Lythgoe, J. N. 1980. Vision in fish: ecological adapatations. Pp. 431-445 *in* M. A. Ali, ed. Environmental physiology of fishes. Plenum Press, New York.
Lyu, P. C., M. I. Liff, L. A. Marky, and N. R. Kallenback. 1990. Side chain contributions to the stability of alpha helical structure in peptides. Science 250:669-673.
Maddison, W. P., and D. R. Maddison. 2003. MacClade: Analysis of phylogeny and character evolution. Sinauer Associates, Sunderland, MA.
Maisnier-Patin, S., O. G. Berg, L. Liljas, and D. I. Andersson. 2002. Compensatory adaptation to the deleterious effect of anitbiotic resistance in *Salmonella typhimurium*. Molecular Microbiology 46:355-366.
Marshall, N. J., T. W. Cronin, and T. N. Frank. 2003. Visual adaptations in Crustaceans: Chromatic, developmental, and temporal aspects. Pp. 343-372 *in* S. Collins and N. J. Marshall, eds. Sensory Processing in the Aquatic Environment. Springer-Verlag, Berlin.
Marshall, N. J., J. Kent, and T. W. Cronin. 1999. Visual adaptations in crustaceans: Spectral sensitivity in diverse habitats. Pp. 285-327 *in* S. N. Archer, M. B. A.

Djamgoz, E. R. Loew, J. C. Partridge and S. Vallerga, eds. Adaptive mechanisms in the ecology of vision. Kluwer Academic, Great Britain.
Marshall, N. J., and M. F. Land. 1993. Some optical features of the eyes of stomatopods. II. Ommatidial design, sensitivity and habitat. Journal of Comparative Physiology A 173:583-594.
Martin, G. 1971. Etude préliminaire d'une structure photosensible dans la région centrale du protocérébron de *Porcellio dilatatus* (Brandt), Crustacé, Isopode, Oniscoide. Comp. rend. Acad. Sc. Paris 272:269-271.
Martin, G. 1976. Mise en évidence et étude ultrastructurale des ocelles médians chez les crustacés isopodes. Ann. Sci. Nat. Zool. Paris 18:405-436.
Martin, G., and M. I. Mote. 1982. Color receptors in marine crustaceans: a second spectral class of retinular cell in the compound eyes of *Callinectes* and *Carcinus*. Journal of Comarative Physiology 145:549-554.
Martin, J. W., and G. E. Davis. 2001. An updated classification of the recent Crustacea. Natural History Museum of Los Angeles Cy. Sci. Ser. 39:1-124.
Martinez-Torres, D., C. Buades, A. Latorre, and A. Moya. 2001. Molecular systematics of aphids and their primary endosymbionts. Molecular Phylogenetics and Evolution 20:437-449.
Massey, R. C., A. Buckling, and S. J. Peacock. 2001. Phenotypic switching of antibiotic resistance circumvents permanent costs in *Staphylococcus aureus*. Current Biology 11:1810-1814.
Matsui, S., M. Seidou, I. Uchiyama, N. Sekiya, K. Hiraki, K. Yoshihara, and Y. Kito. 1988. 4-Hydroxyretinal, a new visual pigment chromophore found in bioluminescent squid, *Watasenia scintillans*. Biochemica et Biophysica Acta 966:370-374.
Max, M., P. J. McKinnon, K. J. Seidenman, R. K. Barrett, M. L. Applebury, J. S. Takahashi, and R. F. Margolskee. 1995. Pineal opsin: a nonvisual opsin expressed in chick pineal. Science 267:1502-1506.
McClellan, D. A. 2000. The codon-degeneracy model of molecular evolution. Journal of Molecular Evolution 50:131-140.
McClellan, D. A., and K. G. McCracken. 2001. Estimating the influence of selection on the variable amino acid sites of the cytochrome *b* protein functional domains. Molecular Biology and Evolution 18:917-925.
McClellan, D. A., E. J. Palfreyman, M. J. Smith, J. L. Moss, R. G. Christensen, and J. K. Sailsbery. 2004. Physiocochemical evolution and molecular adaptation of the Cetacean and Artiodactyl cytochrome *b* proteins. Molecular Biology and Evolution 22:437-455.
McFarland, W. N., and E. R. Loew. 1994. Ultraviolet visual pigments in marine fishes of the family pomacentridae. Vision Research 34:1393-1396.
Meland, K. 2004. Species diversity and phylogeny of the deep-sea genus *Pseudomma* (Crustacea: Mysida). Zootaxa 649:1-30.
Meland, K., and E. Willassen. 2004. Molecular phylogeny and biogeography of the genus *Pseudomma* (Peracarida: Mysida). Journal of Crustacean Biology 24:541-557.
Merbs, S. L., and J. Nathans. 1992. Absorption spectra of hybrid pigments responsible for anomalous color vision. Science 258:464-466.

Meyer-Rochow, V. B. 2001. The crustacean eye: Dark/Light adaptation, polarization, sensitivity, flicker fusion frequency, and photoreceptor damage. Zoological Science 18:1175-1197.
Meyer-Rochow, V. B., and K. M. Tiang. 1984. The eye of *Jasus edwardsii* (Crustacea, Decapoda): electrophysiology, histologoy, and behaviour. Zoologica 45:1-61.
Mezzetti, M. C., and F. Scapini. 1995. Aspects of spectral sensitivity in Talitrus saltator (Montagu) (Crustacea-Amphipoda). Marine and Freshwater Behaviour and Physiology 26:35-45.
Minjuan, C., and L. Shujun. 1990. The spectral sensitivity of receptor system in the compound eye of *Penaeus penicillatus*. Oceanologia et Limnologia Sinica 21:160-165.
Minke, B., and K. Kirschfield. 1978. Microspectrophotometric evidence for two photo-interconvertible states of visual pigment in the barnacle lateral eye. Journal of General Physiology 71:37-45.
Mirzadegan, T., G. Benko, S. Filipek, and K. Palczewski. 2003. Biochemistry 42:2759-2767.
Montell, C., K. Jones, C. S. Zuker, and G. M. Rubin. 1987. A second opsin gene expressed in the ultraviolet-sensitive R7 photoreceptor cells of *Drosophila melanogaster*. J. Neurosci. 7:1558-1566.
Moran, N. A., M. A. Munson, P. Baumann, and H. Ishikawa. 1993. A molecular clock in endosymbiotic bacteria is calibrated using the insect host. Proceedings of the Royal Society of London B 253:167-171.
Moran, N. A., and J. J. Wernegreen. 2000. Lifestyle evolution in symbiotic bacteria: insights from genomics. Trends in Ecology and Evolution 15:321-326.
Morris, A., J. K. Bowmaker, and D. M. Hunt. 1993. The molecular basis of a spectral shift in the rhodopsins of two species of squid from different photic environments. Proceedings of the Royal Society of London B 254:233-240.
Moutsaki, P., J. Bellingham, B. G. Soni, Z. K. David-Gray, and R. G. Foster. 2000. Sequence, genomic structure and tissue expression of carp (*Cyprinus carpio* L.) vertebrate ancient (VA) opsin. FEBS Letters 473:316-322.
Muachline, J. 1980. The biology of mysids and euphausiids. Academic Press, London.
Muller, G. B. 2002. Encyclopedia of Evolution. Oxford University Press
Müller, O. F. 1776. Zoologiae Danicae prodromus, seu animalium Daniae et Norvegiae indigenarum: characteres, nomina, et synonyma imprimis popularium. (Typis Hallageriis, Havniae [Copenhagen]) i-xxxii:1-282.
Naito, T., K. Nashima-Hayama, K. Ohtsu, and Y. Kito. 1981. Photoreactions of cephalopod rhodopsin. Vision Research 21:935-941.
Nakagawa, M., T. Iwasa, S. Kikkawa, M. Tsuda, and T. G. Ebrey. 1999. How verterbrate and invertebrate visual pigments differ in their mechanism of photoactivation. Proceedings of the National Academy of Science USA 96:6189-6192.
Nakayama, T. A. 1991. Mapping of the amino acids in membrane-embedded helices that interact with the retinal chromophore in bovine rhodopsin. J. Biol. Chem. 266:4269-4275.
Nathans, J. 1987. Molecular biology of visual pigments. Ann. Rev Neurosci 10:163-94.

Nathans, J. 1990a. Deteriminants of visual pigment absorbance: identification of the retinylidene Schiff's base counterion in bovine rhodopsin. Biochemistry 29:9746-9752.
Nathans, J. 1990b. Determinants of visual pigment absorbance: role of charged amino acids in putative transmembrane segments. Biochemistry 29:937-942.
Nathans, J., C. M. Davenport, I. H. Maumenee, R. A. Lewis, J. F. Hejtmancik, M. Litt, E. Lovrien, R. Weleber, B. Bachynski, F. Zwas, R. Klingaman, and G. Fishman. 1989. Molecular genetics of human blue cone monochromacy. Science 245:831-838.
Nathans, J., and D. S. Hogness. 1983. Isolation, sequence analysis, and intron-exon arrangement of the gene encoding bovine rhodopsin. Cell 34:807-814.
Neitz, M., J. Neitz, and G. H. Jacobs. 1991. Spectral tuning of pigments underlying red-green colour vision. Science 252:971-974.
Nevo, E. 1999. Mosaic evolution of subterranean mammals: Regression, progression, and global convergence. Oxford University Press, Oxford.
Nielsen, H. S., M. B. Oleksiewicz, R. Forsberg, T. Stadejek, A. Botner, and T. Storgaard. 2001. Reversion of a live porcine reproductive and respiratory syndrome virus vaccine investigated by parallel mutations. Journal of General Virology 82:1263-1272.
Nielsen, R., and Z. Yang. 1998. Likelihood models for detecting positively delected amino acid sites and applications to the HIV-1 envelope gene. Genetics 134:1271-1276.
Nilsson, D.-E. 1989. Optics and evolution of the compound eye. Pp. 30-73 *in* D. G. Stavenga and R. C. Hardie, eds. Facets of vision. Springer-Verlag, Berlin.
Nolte, J., and J. E. Brown. 1972. J. Gen. Physiol. 59:186-200.
Norell, M. 1992. Taxic origin and temporal diversity: The effect of phylogeny. Pp. 89-118 *in* N. J. Novacek and Q. D. Wheeler, eds. Extinction and phylogeny. Columbia University Press, New York.
Nylander, J. A. A., F. Ronquist, J. P. Huelsenbeck, and J. L. Nieves-Aldrey. 2004. Bayesian phylogenetic analysis of combinded data. Systematic Biology 53:47-67.
Oakley, T. H., and D. R. Huber. 2004. Differential expression of duplicated opsin genes in two eye types of ostracod crustaceans. Journal of Molecular Evolution 59:239-249.
Ochman, H., and N. A. Moran. 2001. Genes lost and genes found: Evolution of bacterial pathogenesis and symbiosis. Science 292:1096-1098.
Okano, T., T. Yoshizawa, and Y. Fukada. 1994. Pinopsin is a chicken pineal photoreceptive molecule. Nature 372:94-97.
Oliveira, L., T. Hulsen, D. L. Hulsik, A. C. M. Paiva, and G. Vriend. 2004. Heavier-than-air flying machines are impossible. FEBS Letters 564:269-273.
Omland, K. E. 1997. Examining two standard assumptions of ancestral reconstructions: repeated loss of dichromatism in dabbling ducks (Anatini). Evolution 51:1636-1646.
Omland, K. E., and S. M. Lanyon. 2000. Reconstructing plumage evolution in orioles (Icterus): Repeated convergence and reversal in patterns. Evolution 54:2119-2133.

O'Neil, K. T., and W. F. DeGrado. 1990. A thermodynamic scale for the helix forming tendencies of the commonly occurring amino acids. Science 250:646-650.
O'Tousa, J. E., W. Baehr, R. L. Martin, J. Hirsh, W. L. Pak, and M. L. Applebury. 1985. The Drosophila *ninaE* gene encodes an opsin. Cell 40:839-850.
Padmanabhan, S., S. Marqusee, T. Ridgeway, T. M. Laue, and R. L. Baldwin. 1990. Relative helix forming tendencies of nonpolar amino acids. Nature 344:268-270.
Pagel, M., and A. Meade. 2004. A phylogenetic mixture model for detecting pattern-heterogeneity in gene sequence of character-state data. Systematic Biology 53:571-581.
Palczewski, K., T. Kumasaka, T. Hori, and e. a. co-authors). 2000. Crystal structure of rhodopsin: a G protein coupled receptor. Science 289:739-745.
Pandey, S., J. C. Blanks, C. Spee, M. Jiang, and H. K. Fong. 1994. Cytoplasmic retinal localization of an evolutionary homolog of the visual pigments. Exp Eye Res 58:605-613.
Partridge, J. C. 1989. Visual pigments of deep-sea fishes: ecophysiology and molecular biology. Prog. Underwater Sci. 14:17-31.
Partridge, J. C., S. N. Archer, and J. N. Lythgoe. 1988. Visual pigments in the individual rods of deep-sea fishes. Journal of Comarative Physiology A 162:543-550.
Partridge, J. C., S. N. Archer, and J. Van Oostrum. 1992. Single and multiple visual pigments in deep-sea fishes. J Mar Biol Ass UK 72:113-130.
Partridge, J. C., J. Shand, S. N. Archer, J. N. Lythgoe, and W. A. H. M. van Groningen-Luyben. 1989. Interspecific variation in the visual pigments of deep-sea fishes. Journal of Comarative Physiology A 164:513-529.
Paul, R., A. Steiner, and R. Gemperlein. 1986. Spectral sensitivity of *Calliphora erythrocephala* and other insect species studien with Fourier interferometric stimulation (FIS). Journal of Comarative Physiology A 158:669-680.
Peitsch, D., A. Feitz, H. Hertel, J. de Souza, D. F. Ventura, and R. Menzel. 1992. The spectral input systems of hymenopteran insects and their receptor-based colour vision. Journal of Comarative Physiology A 170:23-40.
Pérez-Losada, M., J. T. Hoeg, and K. A. Crandall. 2004. Unraveling the evolutionary radiation of the Thoracican barnacles using molecular and morphological evidence: A comparison of several divergence time estimation approaches. Systematic Biology 53:244-264.
Philp, A. R., J. M. Garcia-Fernandez, B. G. Soni, R. J. Lucas, J. Bellingham, and R. G. Foster. 2000. Vertebrate ancient (VA) opsin and extraretinal photoreception in the Atlantic salmon (*Salmo salar*). Journal of Experimental Biology 203:1925-1936.
Pichaud, F., A. Briscoe, and C. Desplan. 1999. Evolution of color vision. Current Opinion in Neurobiology 9:622-627.
Pinker, R. J., L. Lin, G. D. Rose, and N. R. Kallenbach. 1993. Effects of alanine substitution in alpha-helices of sperm whale myoglobin on protein stability. Protein Science 2:1099-1105.
Pol, D. 2004. Empirical problems of the hierarchical likelihood ratio test for model selection. Systematic Biology 53:949-962.

Popp, M. P., R. Grisshammer, P. A. Hargrave, and W. C. Smith. 1996. Ant opsins: sequences from the Saharan silver ant and the carpenter ant. Invert Neurosci 1:323-329.
Posada, D., and T. R. Buckley. 2004. Model selection and model averaging in phylogenetics: Advantages of Akaike information criterion and Bayesian approaches over Likelihood ratio tests. Systematic Biology 53:793-808.
Posada, D., and K. A. Crandall. 1998. Modeltest: Testing the model of DNA substitution. Bioinformatics 14:817-818.
Posada, D. P., and K. A. Crandall. 2001. Intraspecific gene genealogies: trees grafting into networks. Trends in Ecology and Evolution 16:37-44.
Ptitsyn, O. B. 1992. Secondary structure formation and stability. Current Opinion in Structural Biology 2:13-20.
Rambaut, A., and L. Broham. 1998. Estimating divergence data from molecular sequences. Molecular Biology and Evolution 15:442-448.
Rambaut, A., and A. J. Drummond. 2003. Tracer v1.2, available from http:\\evolve.zoo.ox.ac.uk\.
Remerie, T., B. Bulckaen, J. Calderon, T. Deprez, J. Mees, J. Vanfleteren, A. Vanreusel, A. Vierstraete, M. Vincx, K. J. Wittmann, and T. Wooldridge. 2004. Phylogenetic relationships within the Mysidae (Crustacea, Peracarida, Mysida) based on nuclear 18S ribosomal RNA sequences. Molecular Phylogenetics and Evolution 32:770-777.
Richter, S., and G. Scholtz. 2001. Phylogenetic analysis of the Malacostraca (Crustacea). J. Zool. Syst. Evol. Research 39:113-136.
Riek, R. P., I. Rigoutsos, J. Novotny, and R. M. Graham. 2001. Non-alpha-helical elements modulate polytopic membrane protein architecture. Journal of Molecular Evolution 306:349-362.
Robas, N., M. O'Reilly, S. Katugampola, and M. Fidock. 2003. Maximizing serendipity: strategies for identifying ligands for orphan G-protein-coupled receptors. Current Opinion in Pharmacology 3:121-126.
Rode, A. L., and L. E. Babcock. 2003. Phylogeny of fossil and extant freshwater crayfish and some closely related Nephropid lobsters. Journal of Crustacean Biology 23:418-435.
Rokyta, D., M. R. Badgett, I. J. Molineux, and J. J. Bull. 2002. Experimental genomic evolution: Extensive compensation for loss of DNA ligase activity in a virus. Molecular Biology and Evolution 19:230-238.
Ronquist, F., and J. P. Huelsenbeck. 2003. MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19:1572-1574.
Rossel, S. 1979. Regional differences in photoreceptor performance in the eye of the praying mantis (*Tenodera australasiae*). Journal of Comarative Physiology 131:95-112.
Saiki, R., D. H. Gelfand, S. Stofell, S. J. Scharf, R. Higuchi, G. T. Horn, K. B. Mullis, and H. A. Erlich. 1988. Primer-directed enzymatic amplification of DNA with a thermosotable DNA polymerase. Science 239:487-491.
Sakamoto, K., O. Hisatomi, F. Tokunaga, and E. Eguchi. 1996. Two opsins from the compound eye of the crab *Hemigrapsus sanguineus*. The Journal of Experimental Biology 199:441-450.

Sakmar, T. P., R. R. Franke, and H. G. Khorana. 1989. Glutamic acid-113 serves as the retinylidene Schiff basee counterion in bovine rhodopsin. Proceedings of the National Academy of Science USA 86:8309-8313.
Salcedo, E., A. Huber, S. Henrich, L. V. Chadwell, W.-H. Chou, R. Paulsen, and S. G. Britt. 1999. Blue- and green-absorbing visual pigments of *Drosophila*: ectopic expression and physiological characterization of the R8 photoreceptor cell-specific Rh5 and Rh6 rhodopsins. Journal of Neuroscience 19:10716-10726.
Salcedo, E., L. Zheng, M. Phistry, E. E. Bagg., and S. G. Britt. 2003. Molecular basis for ultraviolet vision in invertebrates. The Journal of Neuroscience 23:10873-10878.
Sandeman, D. C., R. E. Sandeman, and H. G. DeCouet. 1990. Extraretinal photoreceptors in the brain of the crayfish *Cherax destructor*. Journal of Neurobiology 21:619-629.
Sanderson, M. J. 1997. A nonparametric approach to estimating divergence times in the absence of rate constancy. Molecular Biology and Evolution 19:101-109.
Sanderson, M. J. 2002. Estimating absolute rates of molecular evolution and divergence times: A penalized likelihood approach. Molecular Biology and Evolution 14:1218-1231.
Savill, N. J., D. C. Hoyle, and D. G. Higgins. 2001. RNA sequence evolution with secondary structure constraints: Comparison of substitution rate models using maximum likelihood methods. Genetics 157:399-411.
Schiff, H., and M. E. Hendrickx. 1997. An introductory survey of ecology and sensory receptors of tropical eastern Pacific crustaceans. Italian Journal of Zoology 64:13-30.
Scholtz, G., and S. Richter. 1995. Phylogenetic systematics of the reptantian Decapoda (Crustacea, Malacostraca). Zool. Jour. Linn. Soc. 113:289-328.
Schöniger, M., and A. von Haeseler. 1994. A stochastic model for the evolution of autocorrelated DNA sequences. Molecular Phylogenetics and Evolution 3:240-247.
Schrag, S., V. Perrot, and B. R. Levin. 1997. Adaptation to the fitness costs of antibiotic resistance in *Escherichia coli*. Proceedings of the Royal Society of London B 264:1287-1291.
Schram, F. R. 1984. Relationships within eumalacostracan Crustacea. Trans. San Diego Soc. Nat. Hist. 20:301-312.
Schram, F. R. 1986. Crustacea. Oxford University Press, New York.
Schram, F. R. 2000. Phylogeny of decapods. Studi e Ricerche, Assoc. Amici Mus. civ. 'G. Zannato', Montecchio Maggiore , 61.
Schram, F. R. 2001. Phylogeny of decapods: moving towards a consensus. Hydrobiologia 449:1-20.
Schram, F. R., and C. J. Dixon. 2003. Fossils and decapod phylogeny. Contributions to Zoology 72:169-172.
Schram, F. R., R. M. Feldmann, and M. J. Copeland. 1978. The late Devonian Palaeopalaemonidae and the earliest decapod crustaceans. Jour. Paleo 52:1375-1387.

Schram, F. R., and C. J. Hof. 1998. Fossils and the interrelationships of major Crustacean groups. Pp. 233-302 *in* G. D. Edgecombe, ed. Arthropod Fossils and Phylogeny. Columbia University Press, New York.

Schweitzer, C. E., R. M. Feldmann, G. Gonzales-Barba, and F. J. Vega. 2002. New crabs from the Eocene and Oligocene of Baja California Sur, Mexico and an assessment of the evolutionary and paleobiogeographic implications of Mexican fossil decapods. The Paleontological Society Memoir 59:1-43.

Scott, S., and M. I. Mote. 1974. Spectral sensitivity in some marine crustacea. Vision Research 14:659-663.

Seki, T., and K. Vogt. 1998. Evolutionary aspects of the diversity of visual pigment chromophores in the class Insecta. Comp. Biochem. Physiol. B 119:53-64.

Shand, J. 1993. Changes in the spectral absorption of cone visual pigments during the settlement of the goatfish *Upeneus tragula*: the loss of red sensitivity as a benthic existence begins. Journal of Comarative Physiology A 173:115-121.

Shand, J. 1994. Changes in retinal structure during development and settlement of the goatfish *Upeneus tragula*. Brain Behav Evol 43:51-60.

Shand, J., J. C. Partridge, S. N. Archer, G. W. Potts, and J. N. Lythgoe. 1988. Spectral absorbance changes in the violet/blue sensitive cones of the juvenile pollack, *Pollachius pollachius*. Journal of Comarative Physiology A 163:699-703.

Shen, D., M. Jiang, W. Hao, L. Tao, M. Salazar, and H. K. Fong. 1994. A human opsin-related gene that encodes a retinaldehyde-binding protein. Biochemistry 33:13117-13125.

Shi, Y., F. B. Radlwimmer, and S. Yokoyama. 2001. Molecular genetics and the evolution of ultraviolet vision in vertebrates. Proceedings of the National Academy of Science USA 98:11731-11736.

Shi, Y., and S. Yokoyama. 2003. Molecular analysis of the evolutionary significance of ultraviolet vision in verebrates. Proceedings of the National Academy of Science USA 100:8308-8313.

Shigenobu, S., H. Watanabe, M. Hattori, Y. Sakaki, and H. Ishikawa. 2000. Genome sequence of the endocellular bacterial symbiont of aphids *Buchnera* sp. APS. Nature 407:81-86.

Shimizu, I., Y. Yamakawa, Y. Shimazaki, and T. Iwasa. 2001. Molecular cloning of *Bombyx* cerebral opsin (Boceropsin) and cellular localization of its expression in the silkworm brain. Biochem. Biophys. Res. Commun. 287:27-34.

Shimodaira, H. 2001. Multiple comparisons of log-likelihoods and combining nonnested models with applications to phylogenetic tree selection. Commun. Stat. Theory Methods 30:1751-1772.

Shimodaira, H. 2002. An approximately unbiased test of phylogenetic tree selection. Systematic Biology 51:492-508.

Shimodaira, H., and M. Hasegawa. 1999a. An approximately.:

Shimodaira, H., and M. Hasegawa. 1999b. Multiple comparisons of log-likelihoods with applications to phylogenetic inference. Molecular Biology and Evolution 16:1114-1234.

Shukolyukov, S. A., O. Kalishevich, A. D. Polyanovsky, and F. G. Gribakin. 1984. Vision in the crab *Hemigrapsus sanguineus*: spectral sensitivity and ommatidium fine structure. Marine Biology 2:53-59.

Simpson, A. A., V. Chandrasekar, B. Hebert, G. M. Sullivan, M. G. Rossmann, and C. R. Parrish. 2000. Host range and variability of calcium binding by surface loops in the capsids of canine and feline parvoviruses. Journal of Molecular Biology 300:597-610.

Smith, A. B. 1994. Systematics and the fossil record. Blackwell, Oxford, UK.

Smith, K. C., and E. R. Macagno. 1990. UV photoreceptors in the compound eye of *Daphnia magna* (Crustacea, Branchiopoda) - a 4th spectral class in single ommatidia. Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology 166:597-606.

Smith, W. C., D. M. Ayers, M. P. Popp, and P. A. Hargrave. 1997. Short wavelength-sensitive opsins from the Saharan silver and carpenter ants. Invert Neurosci 3:49-56.

Smith, W. C., D. A. Price, R. M. Greenberg, and B.-A. Battelle. 1993. Opsins from the lateral eyes and ocelli of the horseshoe crab, *Limulus polyphemus*. Proceedings of the National Academy of Science USA 90:6150-6154.

Soltis, P. S., D. E. Soltis, V. Savolainen, P. R. Crane, and T. G. Barraclough. 2002. Rate heterogeneity among lineages of tracheophytes: Integration of molecular and fossil data and evidence for molecular living fossils. Proceedings of the National Academy of Science USA 99:4430-4435.

Soni, B. G., and R. G. Foster. 1997. A novel and ancient vertebrate opsin. FEBS Letters 406:279-283.

Soni, B. G., A. R. Philp, R. G. Foster, and B. E. Knox. 1998. Novel retinal photoreceptors. Nature 394:27-28.

Spaethe, J., and A. D. Briscoe. 2004. Early duplication and functional diversification of the opsin gene family in insects. Molecular Biology and Evolution???????

Stavenga, D. G., R. P. Smits, and B. J. Hoenders. 1993. Simple exponential functions describing the absorbance bands of visual pigment spectra. Vision Research 33:1011-1017.

Stearns, D. E., and R. B. J. Forward. 1984. Photosensitivity of the calanoid copepod, *Acartia tonsa*. Marine Biology 82:85-90.

Stowe, S. 1980. Spectral sensitivity, retinal pigment movement in the crab *Leptograpsus variegatus* (Fabricus). Journal of Experimental Biology 87:73-98.

Strickler, A. G., K. Famuditimi, and W. R. Jeffery. 2002. Retinal homeobox genes and the role of cell proliferation in cavefish eye degeneration. International Journal of Developmental Biology 46:285-294.

Strickler, A. G., Y. Yamamoto, and W. R. Jeffery. 2001. Early and late changes in Pax6 expression accompany eye degeneration during cavefish development. Development Genes and Evolution 211:138-144.

Strimmer, K., and A. Rambaut. 2002. Inferring confidence sets of possible misspecified gene trees. Proceedings of the Royal Society of London B 269:137-142.

Struwe, G. 1972. Spectral sensitivity of the compound eye in butterflies (*Heliconius*). Journal of Comarative Physiology A 79:191-196.

Sun, H., D. J. Gilbert, N. G. Copeland, N. A. Jenkins, and J. Nathans. 1997. Peropsin, a novel visual pigment-like protein located in the apical microvilli of the retinal pigment epithelium. Proceedings of the National Academy of Science USA 94:9893-9898.

Suzuki, T., K. Arikawa, and E. Eguchi. 1985. The effects of light and temperature on the rhodopsin-porphyropsin visual system of the crayfish, *Procambarus clarkii*. Zoological Science 2:455-461.

Suzuki, T., and E. Eguchi. 1987. Survey of 3-dehydroretinal as as visual pigment chromophore in various species of crayfish and other freshwater crustaceans. Experientia 43:1111-1113.

Suzuki, T., M. Makino-Tasaka, and E. Eguchi. 1984. 3-Dehydroretinal (vitanim A_2 aldehyde) in crayfish eye. Vision Research 24:783-787.

Suzuki, T., K. Uji, and Y. Kito. 1976. Studies on cephalopod rhodopsin: photoisomerization of the chromophore. Biochem Biophys Acta 428:321-338.

Swofford, D. L. 2002. PAUP*: Phylogenetic analysis using parsimony (*and other methods). Sinauer, Sunderland, Massachusetts.

Tamas, I., L. Klasson, B. Canback, A. K. Naslund, A. S. Eriksson, J. J. Wernegreen, J. P. Sandstrom, N. A. Moran, and S. G. E. Andersson. 2002. 50 Million years of genomic stasis in endosymbiotic bacteria. Science 296:2376-2379.

Taylor, R. S., S. Yan-bin, and F. R. Schram. 1998. New pygocephalomorph crustaceans from the Permian of China and their phylogenetic relationships. Paleontology 41:815-834.

Taylor, S. D., K. Dittmar de la Cruz, M. L. Porter, and M. F. Whiting. 2005. Characterization of the long-wavelength opsin from Mecoptera and Siphonaptera: Does a Flea see? Molecular Biology and Evolution 22:1165-1174.

Teller, D. C., R. E. Stenkamp, and K. Palczewski. 2003. Evolutionary analysis of rhodopsin and cone pigments: connecting the three-dimensional structure with spectral tuning and signal transfer. FEBS Letters 555:151-159.

Teotónío, H., and M. R. Rose. 2000. Variation in the reversibility of evolution. Nature 408:463-466.

Teotónío, H., and M. R. Rose. 2001. Perspective: Reverse Evolution. Evolution 55:653-660.

Teotónío, H., and M. R. Rose. 2002. Reverse evolution of fitness in *Drosophila melanogaster*. Journal of Evolutionary Biology 15:608-617.

Thompson, J. D., T. J. Gibson, F. Plewniak, F. Jeanmougin, and D. G. Higgins. 1997. The ClustalX windows interface: Flexible strategies for multiple sequence alignment aided by quality analysis tools. Nucleaic Acids Research 24:4876-4882.

Thorley, J. L., and R. D. M. Page. 2000. RadCon: phylogenetic tree comparison and consensus. Bioinformatics 16:486-487.

Thorne, J. L., and H. Kishino. 2002. Divegence time and evolutionary rate estimation with multilocus data. Systematic Biology 51:689-702.

Thorne, J. L., H. Kishino, and I. S. Painter. 1998. Estimating the rate of evolution of the rate of molecular evolution. Molecular Biology and Evolution 15:1647-1657.

Towner, P., and W. Gartner. 1994. The primary structure of mantid opsin. Genetics 143:227-231.

Towner, P., P. Harris, A. J. Wolstenholme, C. Hill, K. Worm, and W. Gartner. 1997. Primary structure of locust opsins: a speculative model which may account for ultraviolet wavelength light detection. Vision Research 37:495-503.

Townson, S. M., B. S. W. Chang, E. Salcedo, L. V. Chadwell, N. E. Pierce, and S. G. Britt. 1998. Honeybee blue- and ultraviolet-sensitive opsins: Cloning, heterologous expression in *Drosophila*, and physiological characterization. The Journal of Neuroscience 181:2412-2422.

Tshudy, D. 2003. Clawed lobster (Nephropidae) diversity through time. Journal of Crustacean Biology 23:178-186.

Tudge, C. C., and D. M. Scheltinga. 2002. Spermatozoal morphology of the freshwater anomuran *Aegla longirostris* Bond-Buckup and Buckup, 1994 (Crustacea: Decapoda: Aeglidae) from South America. Proceedings of the the Biological Society of Washington 115:118-128.

Väinölä, R. 1986. Sibling species and phylogenetic relationships of *Mysis relicta* (Crustacea: Mysidacea). Annls. Zool. Fenn. 23:207-221.

Väinölä, R. 1990. Molecular time scales for evolution in *Mysis* and *Pontoporeia*. Ann. Zool. Fennici 27:211-214.

Väinölä, R. 1992. Evolutionary genetics of marine *Mysis* spp. (Crustacea: Mysidacea). Marine Biology 114:539-550.

Väinölä, R., B. J. Riddoch, R. D. Ward, and R. I. Jones. 1994. Genetic zoogeography of the *Mysis relicta* species group in northwestern Europe and North America. Can. J. Fish. Aquat. Sci. 51:1490-1505.

Van Dover, C. L., E. Z. Szuts, S. C. Chamberlain, and J. R. Cann. 1989. A novel eye in 'eyeless' shrimp from hydrothermal vents of the Mid-Atlantic Ridge. Nature 337:458-460.

van Ham, R. C. H. J., J. Kamerbeek, C. Palacios, C. Rausell, F. Abascal, U. Bastolla, J. M. Fernandez, L. Jimenez, M. Postigo, F. J. Silva, J. Tamames, E. Viguera, A. Latorre, A. Valencia, F. Moran, and A. Moya. 2003. Reductive genome evolution in *Buchnera aphidicola*. Proceedings of the National Academy of Science USA 100:581-586.

Van Straelen, V. 1928. On a fossil freshwater crayfish from eastern Mongolia. Bulletin of the Geological Society of China 7:173-178.

Vanhoutte, K. J. A., B. J. L. Eggen, J. J. M. Janssen, and D. G. Stavenga. 2002. Opsin cDNA sequences of a UV and green rhodopsin of the satyrine butterfly *Bicyclus anynana*. Insect Biochemistry and Molecular Biology 32:1383-1390.

Vassilatis, D. K., J. G. Hohmann, H. Zeng, F. Li, J. E. Ranchalis, M. T. Mortrud, A. Brown, S. S. Rodriguez, J. R. Weller, A. C. Wright, J. E. Bergmann, and G. A. Gaitanaris. 2003. The G protein-coupled receptor repertoires of human and mouse. Proceedings of the National Academy of Science USA 100:4903-4908.

Verslycke, T. A., N. Fockedey, C. L. McKenney, S. D. Roast, M. B. Jones, J. Mees, and C. R. Janssen. 2004. Mysid crustaceans as potential test organisms for the evaluation of environmental endodcrine disruption: A review. Environmental Toxicology and Chemistry 23:1219-1234.

Wake, M. H. 1992. "Regressive" evolution of special sensory organs in Caecilians (Amphibia: Gymnophiona): Opportunity for morphological innovations. Zool. Jb. Anat. 122:325-329.

Wald, G., and E. B. Seldin. 1968. Spectral sensitivity of the common prawn, *Palaemonetes vulgaris*. J. Gen. Physiol. 51:694-700.

Watling, L. 1981. An alternative phylogeny of peracarid crustaceans. Journal of Crustacean Biology 1:201-210.
Watling, L. 1983. Peracaridan disunity and its bearing on eumalacostracan phylogeny with a redefinition of eumalacostracan superorders. Crustacean Issues 1:213-228.
Watling, L. 1999. Toward understanding the relationships of the Peracarida orders: the necessity of determining exact homologies. Pp. 73-89 *in* F. R. Schram and J. C. von Vaupel Klein, eds. Crustaceans and the Biodiversity Crisis. Proceedings of the Fourth International Crustacean Congress. Leiden, The Netherlands: Brill NV, Amersterdam.
Weiyun, A., and C. Minjuan. 1990. Electrophysiological studies on the visual characteristics of *Portunus trituberculatus* (Miers). Oceanologia et Limnologia Sinica 21:490-494.
Wernegreen, J. J., H. Ochman, I. B. Jones, and N. A. Moran. 2000. Decoupling of genome size and sequence divergence in a symbiotic bacterium. Journal of Bacteriology 182:3867-3869.
Wheeler, W. C., G. Giribet, and G. D. Edgecombe. 2004. Arthropod systematics: The comparative study of genomic, anatomical, and paleontological information. Pp. 281-295 *in* J. Cracraft and M. J. Donoghue, eds. Assembling the Tree of Life. Oxford University Press, New York.
Whelan, S., and N. Goldman. 2001. A general empirical model of protein evolution derived from multiple protein families using a maximum-likelihood approach. Molecular Biology and Evolution 18:691-699.
White, R. H., P. K. Brown, A. K. Hurley, and P. R. Bennett. 1983. Rhodopsins, retinula cell ultrastructure and receptor potenials in the developing pupal eye of the moth *Manduca sexta*. Journal of Comarative Physiology 150:153-163.
Whitfield, R. P. 1880. Notice of new forms of fossil crustaceans from the Upper Devonian rocks of Ohio, with decriptions of new genera and species. Am. J. Sci. 19:33-42.
Whiting, M. F. 2002. Mecoptera is paraphyletic: Multiple genes and phylogeny of Mecoptera and Siphonaptera. Zoologica Scripta 31:93-104.
Whiting, M. F., S. Bradler, and T. Maxwell. 2003. Loss and recovery of wings in stick insects. Nature 421:264-267.
Whiting, M. F., J. C. Carpenter, Q. D. Wheeler, and W. C. Wheeler. 1997. The Strepsiptera problem: Phylogeny of the holometabolous insect orders inferred from 18S and 28S ribosomal DNA sequences and morphology. Systematic Biology 46:1-68.
Wiens, J. J. 1999. Phylogenetic evidence for multiple losses of a sexually selected character in phrynosomatid lizards. Proceedings of the Royal Society of London B 266:1529-1535.
Wiens, J. J. 2001. Widespread loss of sexually selected traits: how the peacock lost its spots. Trends in Ecology and Evolution 16:517-523.
Wilkens, L. A., and J. L. Larimer. 1976. Photosensitivity in the sixth abdominal ganglion of decapod crustaceans: A comparative study. Journal of Comarative Physiology A 106:69-75.

Wilkie, S. E., P. R. Robinson, T. W. Cronin, S. Poopalasundaram, J. K. Bowmaker, and D. M. Hunt. 2000. Spectral tuning of avian violet- and ultraviolet-sensitive visual pigments. Biochemistry 39:7895-7901.

Williams, A. J., D. M. Hunt, J. K. Bowmaker, and J. D. Mollon. 1992. The polymorphic photopigments of the marmoset: spectral tuning and genetic basis. EMBO J 11:2039-2045.

Wills, M. A. 1998. A phylogeny of recent and fossil Crustacea derived from morphological characters. Pp. 189-209 *in* R. A. Fortey and R. H. Thomas, eds. Arthropod Relationships. Chapman & Hall, London.

Wittmann, K. J. 1999. Global biodiversity in Mysidacea, with notes on the effects of human impact. Pp. 511-525 *in* F. R. Schram and J. C. von Vaupel Klein, eds. Crustaceans and the Biodiversity Crisis. Proceedings of the Fourth International Crustacean Congress. Leiden, The Netherlands: Brill NV, Amersterdam.

Wooley, S., J. Johnson, M. J. Smith, K. A. Crandall, and D. A. McClellan. 2003. TreeSAAP: Selection on amino acid properties using phylogenetic trees. Bioinformatics 19:671-672.

Yamamoto, Y., and W. R. Jeffery. 2000. Central role for the lens in cave fish eye degeneration. Science 289:631-633.

Yan, E. C., M. A. Kazmi, S. De, B. S. W. Chang, C. Seibert, E.P. Marin, R.A. Mathies, and T. P. Sakmar. 2003. Function of extracellular loop 2 in rhodopsin: Glutamic acid 181 modulates stability and absorption wavelength of metarhodopsin II. Biochemistry 41:3620-3627.

Yang, Z. 1996. Among-site rate variation and its impact on phylogenetic analysis. Trends in Ecology and Evolution 11:367-372.

Yang, Z. 1997. PAML: a program package for phylogenetic analysis by maximum likelihood. Comput. Appl. Biosci. 13:555-556.

Yang, Z. 1998. Likelihood ratio tests for detecting positive selection and application to primate lysozyme evolution. Molecular Biology and Evolution 15:568-573.

Yang, Z. 2004. A heuristic rate smoothing procedure for maximum likelihood estimation of species divergence times. Acta Zoologica Sinica 50:645-656.

Yang, Z., and J. P. Bielawski. 2000. Statistical methods for detecting molecular adaptation. Trends in Ecology and Evolution 15:496-503.

Yang, Z., and R. Nielsen. 1998. Synonymous and nonsynonymous rate variation in nuclear genes of mammals. Journal of Molecular Evolution 46:409-418.

Yang, Z., R. Nielsen, N. Goldman, and A.-M. K. Pedersen. 2000. Codon-substitution models for heterogeneous selection pressure at amino acid sites. Genetics 155:431-449.

Yang, Z., W. S. W. Wong, and R. Nielsen. 2005. Bayes empirical Bayes inference of amino acid sites under positive selection. Molecular Biology and Evolution 22:1107-1118.

Yang, Z., and A. D. Yoder. 2003. Comparison of likelihood and Bayesian methods for estimating divergence times using multiple gene loci and calibration points, witih application to a radiation of cute-looking mouse Lemur species. Systematic Biology 52:705-716.

Yoder, A. D., and Z. Yang. 2000. Estimation of primate speciation dates using local molecular clocks. Molecular Biology and Evolution 17:1081-1090.

Yoder, A. D., and Z. Yang. 2004. Divergence dates for Malagasy lemurs estimated from multiple gene loci: geologic and evolutionary context. Molecular Ecology 13:757-773.

Yokoyama, R., and S. Yokoyama. 1990. Convergent evolution of the red- and green-like visual pigmen genes in fish, *Astyanax fasciatus*, and human. Proceedings of the National Academy of Science USA 87:9315-9318.

Yokoyama, S. 2000. Evolution of vertebrate visual pigments. Progress in Retinal and Eye Research 19:385-419.

Yokoyama, S. 2002. Molecular evolution of color vision in vertebrates. Gene 300:69-78.

Yokoyama, S., and F. B. Radlwimmer. 1999. The molecular genetics of red and green color vision in mammals. Genetics 153:919-932.

Yokoyama, S., and F. B. Radlwimmer. 2001. The molecular genetics and evolution of red and green color vision in vertebrates. Genetics 158:1697-1710.

Yokoyama, S., F. B. Radlwimmer, and N. S. Blow. 2000. Ultraviolet pigments in birds evolved from violet pigments by a single amino acid chage. Proceedings of the National Academy of Science USA 97:7366-7371.

Yokoyama, S., and Y. Shi. 2000. Genetics and evolution of ultraviolet vision in vertebrates. FEBS Letters 486:167-172.

Yokoyama, S., and T. Tada. 2000. Adaptation of the African and Indonesian coelacanths to deep-sea environments. Gene 261:35-42.

Yokoyama, S., and T. Tada. 2003. The spectral tuning in the short wavelength-sensitive type 2 pigments. Gene 306:91-98.

Yokoyama, S., and H. Zhang. 1997. Cloning and characterisation of the pineal gland-specific opsin gene of marine lamprey (*Petromyzon marinus*). Gene 202:89-93.

Yokoyama, S., H. Zhang, F. B. Radlwimmer, and N. S. Blow. 1999. Adaptive evolution of color vision of the Comoran coelacanth (*Latimeria chalumnae*). Proceedings of the National Academy of Science USA 96:6279-6284.

Zeiger, J., and T. H. Goldsmith. 1989. Spectral properties of porphyropsin from an invertebrate. Vision Research 29:519-527.

Zeiger, J., and T. H. Goldsmith. 1993. Packaging of rhodopsin and porphyropsin in the compound eye of the crayfish. Vis. Neurosci 10:193-202.

Zeiger, J., and T. H. Goldsmith. 1994. Behavior of crayfish rhodopsin and metarhodopsin in digitonin: the 510 and 562 nm 'visual pigments' are artifacts. Vision Research 34:2679-2688.

Zhang, X.-J., W. A. Baase, and B. W. Matthews. 1991. Towards a simplification of the protein folding problem: A stabilizing polyalanine alpha-helix engineered in T4 lysozyme. Biochemistry 30:2012-2017.

Zhukovsky, E. A., and D. D. Oprian. 1989. Effect of carboxylic acid side chains on the absorption maximum of visual pigments. Science 246:928-930.

Zhukovsky, E. A., P. R. Robinson, and D. D. Oprian. 1992. Changing the location of the Schiff base counterion in rhodopsin. Biochemistry 31:10400-10405.

Ziedins, I. P., and V. B. Meyer-Rochow. 1990. ERG-determined spectral and absolute sensitivities in relation to age and size in the half crab *Petrolisthes elongatus*. Experimental Biology 48:319-328.

Zuckerkandl, E., and L. Pauling. 1965. Evolutionary divergence and convergence in proteins. Pp. 97-166 *in* V. Bryson and H. J. Vogel, eds. Evolving genes and proteins. Academic Press, New York.

Zuker, C. S. 1996. The biology of vision in *Drosophila*. Proceedings of the National Academy of Science USA 93:571-576.

Zuker, C. S., C. Montell, K. Jones, T. Laverty, and G. M. Rubin. 1987. A rhodopsin gene expressed in photoreceptor cell R7 of the Drosophila eye: homologies with other signal-transducing molecules. J. Neurosci. 7:1550-1557.