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Supplementary 1. Significant biological process identified for observed collagen types of our study using ShinyGO ver. 0.60

Functional category	Enrichment FDR	Genes in list	Total genes	Genes
Extracellular matrix organization	1.72E-44	29	392	COL9A2 COL11A1 COL5A3 COL19A1 COL16A1 COL1A1 COL9A1 COL10A1 COL5A1 COL2A1 COL8A1 COL1A2 COL3A1 COL22A1 COL24A1 COL8A2 COL18A1 COL4A1 COL25A1 COL27A1 COL11A2 COL5A2 COL15A1 COL12A1 COL14A1 COL7A1 COL6A1 COL6A2 COL6A3
Extracellular structure organization	1.03E-42	29	460	COL9A2 COL11A1 COL5A3 COL19A1 COL16A1 COL1A1 COL9A1 COL10A1 COL5A1 COL2A1 COL8A1 COL1A2 COL3A1 COL22A1 COL24A1 COL8A2 COL18A1 COL4A1 COL25A1 COL27A1 COL11A2 COL5A2 COL15A1 COL12A1 COL14A1 COL7A1 COL6A1 COL6A2 COL6A3
Skeletal system development	1.21E-20	19	541	COL20A1 COL1A1 COL12A1 COL7A1 COL21A1 COL2A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A2 COL5A2 COL11A1 COL3A1 COL27A1 COL1A2 COL9A2 COL19A1 COL10A1
Cartilage development involved in endochondral bone morphogenesis	1.50E-20	11	47	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL1A1 COL2A1 COL27A1
Collagen fibril organization	4.18E-19	11	63	COL5A3 COL5A1 COL2A1 COL11A2 COL5A2 COL11A1 COL12A1 COL3A1 COL1A1 COL1A2 COL14A1
Growth plate cartilage chondrocyte differentiation	5.64E-19	9	24	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Chondrocyte development involved in endochondral bone morphogenesis	5.64E-19	9	24	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Endochondral bone morphogenesis	1.27E-18	11	72	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL1A1 COL2A1 COL27A1
Chondrocyte development	2.36E-18	10	48	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL27A1
Animal organ morphogenesis	2.59E-18	21	1,099	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL1A1 COL5A1 COL2A1 COL8A1 COL3A1 COL8A2 COL27A1 COL11A2 COL1A2 COL5A2 COL9A1 COL18A1
Chondrocyte differentiation involved in endochondral bone morphogenesis	3.91E-18	9	30	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Chondrocyte differentiation	3.91E-18	12	123	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL2A1 COL27A1 COL11A2
Chondrocyte morphogenesis	7.74E-18	8	18	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1
Chondrocyte morphogenesis involved in endochondral bone morphogenesis	7.74E-18	8	18	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1
Growth plate cartilage chondrocyte morphogenesis	7.74E-18	8	18	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1
Growth plate cartilage development	1.24E-17	9	35	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Growth plate cartilage morphogenesis	1.24E-17	8	19	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1
Connective tissue development	2.16E-17	14	280	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A2 COL11A1 COL1A1 COL5A1 COL2A1 COL27A1
Cartilage development	3.82E-17	13	216	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A2 COL11A1 COL1A1 COL2A1 COL27A1
Endochondral bone growth	8.36E-17	9	43	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Bone morphogenesis	1.10E-16	11	115	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL1A1 COL2A1 COL27A1
Bone growth	1.48E-16	9	46	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Skeletal system morphogenesis	1.65E-16	13	245	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL1A1 COL2A1 COL27A1 COL11A2
Cartilage morphogenesis	6.39E-16	8	30	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1
Anatomical structure morphogenesis	4.74E-14	24	2,785	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL5A1 COL5A2 COL11A1 COL1A1 COL2A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL25A1 COL27A1 COL11A2 COL15A1 COL1A2 COL9A1

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Supplementary 1. Continued

Functional category	Enrichment FDR	Genes in list	Total genes	Genes
Bone development	1.90E-13	11	228	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL1A1 COL2A1 COL27A1
Cell adhesion	3.73E-13	19	1541	COL5A3 COL16A1 COL5A1 COL26A1 COL3A1 COL19A1 COL1A1 COL12A1 COL7A1 COL6A1 COL6A2 COL8A1 COL6A3 COL8A2 COL6A5 COL18A1 COL14A1 COL15A1 COL6A6
Biological adhesion	3.91E-13	19	1,548	COL5A3 COL16A1 COL5A1 COL26A1 COL3A1 COL19A1 COL1A1 COL12A1 COL7A1 COL6A1 COL6A2 COL8A1 COL6A3 COL8A2 COL6A5 COL18A1 COL14A1 COL15A1 COL6A6
Tissue development	8.27E-13	21	2,168	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A2 COL1A1 COL5A1 COL5A2 COL11A1 COL19A1 COL2A1 COL1A2 COL3A1 COL18A1 COL4A1 COL27A1 COL8A1
Endodermal cell differentiation	8.32E-12	7	51	COL12A1 COL5A1 COL5A2 COL11A1 COL7A1 COL6A1 COL8A1
Endoderm formation	2.08E-11	7	58	COL12A1 COL5A1 COL5A2 COL11A1 COL7A1 COL6A1 COL8A1
Animal organ development	3.55E-11	24	3,779	COL20A1 COL1A1 COL12A1 COL7A1 COL21A1 COL2A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A2 COL5A2 COL11A1 COL19A1 COL5A1 COL8A1 COL1A2 COL3A1 COL8A2 COL27A1 COL4A1 COL5A3 COL9A1 COL18A1
Organ growth	4.06E-11	9	183	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Cellular response to amino acid stimulus	8.26E-11	7	71	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Endoderm development	2.70E-10	7	84	COL12A1 COL5A1 COL5A2 COL11A1 COL7A1 COL6A1 COL8A1
Tissue morphogenesis	1.92E-09	12	719	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL3A1 COL5A1 COL4A1
Response to amino acid	3.04E-09	7	119	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Formation of primary germ layer	6.14E-09	7	132	COL12A1 COL5A1 COL5A2 COL11A1 COL7A1 COL6A1 COL8A1
Protein heterotrimerization	1.98E-08	4	13	COL1A1 COL1A2 COL6A1 COL6A2
Supramolecular fiber organization	2.55E-08	11	712	COL5A3 COL5A1 COL2A1 COL11A2 COL5A2 COL11A1 COL12A1 COL3A1 COL1A1 COL1A2 COL14A1
Anatomical structure formation involved in morphogenesis	3.36E-08	13	1,164	COL12A1 COL5A1 COL5A2 COL1A1 COL2A1 COL8A1 COL8A2 COL18A1 COL4A1 COL15A1 COL11A1 COL7A1 COL6A1
Cell differentiation	7.51E-08	22	4,459	COL6A1 COL20A1 COL12A1 COL7A1 COL21A1 COL6A2 COL6A3 COL14A1 COL1A1 COL5A1 COL5A2 COL11A1 COL19A1 COL2A1 COL3A1 COL18A1 COL4A1 COL25A1 COL27A1 COL11A2 COL15A1 COL8A1
Gastrulation	8.23E-08	7	195	COL12A1 COL5A1 COL5A2 COL11A1 COL7A1 COL6A1 COL8A1
Cellular developmental process	1.71E-07	22	4,671	COL6A1 COL20A1 COL12A1 COL7A1 COL21A1 COL6A2 COL6A3 COL14A1 COL1A1 COL5A1 COL5A2 COL11A1 COL19A1 COL2A1 COL3A1 COL18A1 COL4A1 COL25A1 COL27A1 COL11A2 COL15A1 COL8A1
Cellular response to acid chemical	1.71E-07	7	218	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Response to acid chemical	2.63E-07	8	360	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL18A1 COL4A1 COL5A2
Cell morphogenesis involved in differentiation	5.50E-07	10	756	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL18A1 COL25A1
Circulatory system development	1.46E-06	11	1,077	COL1A1 COL11A1 COL5A1 COL2A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1 COL1A2
Developmental growth	2.21E-06	9	667	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Blood vessel development	2.77E-06	9	687	COL1A1 COL5A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1 COL1A2
Collagen metabolic process	3.52E-06	5	113	COL1A2 COL1A1 COL5A1 COL19A1 COL15A1
Vasculature development	3.72E-06	9	715	COL1A1 COL5A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1 COL1A2
Protein-containing complex subunit organization	3.94E-06	15	2,465	COL5A3 COL5A1 COL2A1 COL11A2 COL5A2 COL16A1 COL11A1 COL1A1 COL12A1 COL1A2 COL3A1 COL6A1 COL6A2 COL14A1 COL7A1
Cardiovascular system development	3.98E-06	9	724	COL1A1 COL5A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1 COL1A2
Ossification	7.85E-06	7	396	COL6A1 COL1A1 COL11A1 COL2A1 COL1A2 COL11A2 COL5A2
Cell morphogenesis	1.08E-05	10	1,067	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL18A1 COL25A1

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Supplementary 1. Continued

Functional category	Enrichment FDR	Genes in list	Total genes	Genes
Sensory organ morphogenesis	1.22E-05	6	270	COL11A1 COL2A1 COL8A1 COL8A2 COL5A1 COL5A2
Embryonic morphogenesis	1.22E-05	8	615	COL12A1 COL5A1 COL5A2 COL11A1 COL2A1 COL7A1 COL6A1 COL8A1
Protein trimerization	1.40E-05	4	68	COL1A1 COL1A2 COL6A1 COL6A2
Cellular component morphogenesis	2.34E-05	10	1,172	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL18A1 COL25A1
Negative regulation of endodermal cell differentiation	2.78E-05	2	3	COL5A1 COL5A2
Cell development	4.05E-05	13	2,230	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL11A1 COL3A1 COL18A1 COL25A1 COL27A1
Cell-substrate adhesion	5.61E-05	6	358	COL16A1 COL26A1 COL3A1 COL5A3 COL1A1 COL8A1
Growth	5.87E-05	9	1,028	COL20A1 COL12A1 COL7A1 COL21A1 COL6A1 COL6A2 COL6A3 COL14A1 COL27A1
Sensory organ development	6.80E-05	7	565	COL11A1 COL2A1 COL8A1 COL8A2 COL5A1 COL4A1 COL5A2
Embryo development	6.94E-05	9	1,054	COL12A1 COL2A1 COL5A2 COL5A1 COL11A1 COL7A1 COL6A1 COL8A1 COL1A1
Regulation of endodermal cell differentiation	8.43E-05	2	5	COL5A1 COL5A2
Cellular response to organonitrogen compound	9.26E-05	7	597	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Negative regulation of gastrulation	0.000169193	2	7	COL5A1 COL5A2
Tendon development	0.000169193	2	7	COL11A1 COL5A1
Cellular response to nitrogen compound	0.000193845	7	675	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Skin development	0.000210062	6	464	COL1A1 COL5A2 COL5A1 COL1A2 COL3A1 COL5A3
Protein heterooligomerization	0.000232986	4	146	COL1A1 COL1A2 COL6A1 COL6A2
Eye morphogenesis	0.000282727	4	154	COL8A1 COL8A2 COL5A1 COL5A2
Sensory perception of sound	0.000286045	4	155	COL11A2 COL11A1 COL1A1 COL2A1
Sensory perception of mechanical stimulus	0.000451121	4	175	COL11A2 COL11A1 COL1A1 COL2A1
Skin morphogenesis	0.000662156	2	14	COL1A1 COL1A2
Eye development	0.000684379	5	368	COL8A1 COL8A2 COL5A1 COL4A1 COL5A2
Visual system development	0.000710421	5	372	COL8A1 COL8A2 COL5A1 COL4A1 COL5A2
Blood vessel morphogenesis	0.000791349	6	603	COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1
Sensory system development	0.000792835	5	383	COL8A1 COL8A2 COL5A1 COL4A1 COL5A2
Collagen-activated tyrosine kinase receptor signaling pathway	0.000818394	2	16	COL1A1 COL4A1
Regulation of cell-substrate adhesion	0.000924216	4	216	COL16A1 COL26A1 COL1A1 COL8A1
Visual perception	0.000996123	4	221	COL11A1 COL1A1 COL2A1 COL18A1
Sensory perception of light stimulus	0.001036053	4	224	COL11A1 COL1A1 COL2A1 COL18A1
Cartilage condensation	0.001216748	2	20	COL11A1 COL2A1
Notochord development	0.001216748	2	20	COL2A1 COL5A2
Cell aggregation	0.001328299	2	21	COL11A1 COL2A1
Response to organonitrogen compound	0.00194041	7	1,019	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Negative regulation of embryonic development	0.002000621	2	26	COL5A1 COL5A2
Response to oxygen-containing compound	0.002106908	9	1,725	COL16A1 COL1A1 COL6A1 COL6A2 COL1A2 COL3A1 COL18A1 COL4A1 COL5A2
Endochondral ossification	0.002106908	2	27	COL1A1 COL2A1

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Supplementary 1. Continued

Functional category	Enrichment FDR	Genes in list	Total genes	Genes
Replacement ossification	0.002106908	2	27	COL1A1 COL2A1
Positive regulation of cell-substrate adhesion	0.002114695	3	120	COL16A1 COL26A1 COL8A1
Collagen-activated signaling pathway	0.002200282	2	28	COL1A1 COL4A1
Tube development	0.002297181	7	1,062	COL2A1 COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1
Angiogenesis	0.002458093	5	511	COL8A1 COL8A2 COL18A1 COL4A1 COL15A1
Embryonic skeletal system development	0.002557741	3	130	COL11A1 COL1A1 COL2A1
Cellular response to endogenous stimulus	0.002663128	8	1,432	COL1A2 COL3A1 COL16A1 COL1A1 COL2A1 COL6A1 COL4A1 COL5A2
Response to nitrogen compound	0.003106753	7	1,126	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Regulation of gastrulation	0.004000051	2	39	COL5A1 COL5A2
Tube morphogenesis	0.004000051	6	860	COL8A1 COL3A1 COL8A2 COL18A1 COL4A1 COL15A1
Cellular response to oxygen-containing compound	0.004336995	7	1,199	COL16A1 COL1A1 COL6A1 COL1A2 COL3A1 COL4A1 COL5A2
Platelet activation	0.005153577	3	170	COL3A1 COL1A1 COL1A2
Collagen biosynthetic process	0.005153577	2	45	COL1A1 COL5A1
Collagen catabolic process	0.00676383	2	52	COL19A1 COL15A1
Muscle organ development	0.007291989	4	404	COL11A1 COL19A1 COL3A1 COL6A3
Response to endogenous stimulus	0.007384374	8	1,704	COL1A2 COL3A1 COL16A1 COL1A1 COL2A1 COL6A1 COL4A1 COL5A2
Osteoblast differentiation	0.009918403	3	218	COL6A1 COL1A1 COL11A2
Response to mechanical stimulus	0.009918403	3	218	COL1A1 COL3A1 COL11A1
Cell-matrix adhesion	0.012694247	3	239	COL16A1 COL3A1 COL5A3
Cellular response to transforming growth factor beta stimulus	0.013022982	3	242	COL1A2 COL3A1 COL1A1
Response to transforming growth factor beta	0.013965951	3	249	COL1A2 COL3A1 COL1A1
Muscle tissue morphogenesis	0.01495667	2	81	COL11A1 COL3A1
Heart morphogenesis	0.01529508	3	259	COL11A1 COL5A1 COL2A1
Muscle organ morphogenesis	0.017253391	2	88	COL11A1 COL3A1
Roof of mouth development	0.019027953	2	93	COL2A1 COL11A2
Proteoglycan metabolic process	0.01965475	2	95	COL11A1 COL2A1
Embryonic skeletal system morphogenesis	0.020285472	2	97	COL11A1 COL2A1
Heart development	0.020836988	4	563	COL11A1 COL5A1 COL2A1 COL3A1
Wound healing	0.023548948	4	585	COL3A1 COL1A1 COL5A1 COL1A2
Inner ear morphogenesis	0.023876811	2	107	COL11A1 COL2A1
Camera-type eye development	0.025198949	3	319	COL8A1 COL8A2 COL4A1
Integrin-mediated signaling pathway	0.027180477	2	116	COL3A1 COL16A1
Camera-type eye morphogenesis	0.027180477	2	116	COL8A1 COL8A2
Protein complex oligomerization	0.030767183	4	641	COL1A1 COL1A2 COL6A1 COL6A2
Muscle structure development	0.031164942	4	645	COL11A1 COL19A1 COL3A1 COL6A3
Ear morphogenesis	0.031516389	2	127	COL11A1 COL2A1

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Supplementary 1. Continued

Functional category	Enrichment FDR	Genes in list	Total genes	Genes
Blood coagulation	0.032902607	3	359	COL3A1 COL1A1 COL1A2
Odontogenesis	0.032902607	2	131	COL1A1 COL1A2
Hemostasis	0.033373859	3	364	COL3A1 COL1A1 COL1A2
Coagulation	0.033373859	3	364	COL3A1 COL1A1 COL1A2
Regulation of embryonic development	0.034035599	2	135	COL5A1 COL5A2
Cellular response to growth factor stimulus	0.03763252	4	694	COL1A2 COL3A1 COL1A1 COL2A1
Response to wounding	0.041368017	4	716	COL3A1 COL1A1 COL5A1 COL1A2
Muscle tissue development	0.041483075	3	400	COL11A1 COL19A1 COL3A1
Response to growth factor	0.042075918	4	723	COL1A2 COL3A1 COL1A1 COL2A1
Sensory perception	0.045210101	5	1,114	COL11A2 COL11A1 COL1A1 COL2A1 COL18A1
Biomineral tissue development	0.048448123	2	167	COL1A2 COL1A1
Regulation of cell adhesion	0.04941311	4	765	COL16A1 COL26A1 COL1A1 COL8A1

FDR, fractional degradation rate.