

GEPHE SUMMARY

Gephebase Gene		GepheID
heavy metal atpase4 (HMA4) (<a +heavy+metal+atpase4+(hma4)+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Gene+Gephebase=">https://www.gephebase.org/search-criteria?/and+Gene+Gephebase="+heavy+metal+atpase4+(HMA4)+"#gephebase-summary-title)		
Entry Status		Martin
Published		
		Main curator

PHENOTYPIC CHANGE

Trait Category			
Physiology (<a +physiology+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Trait+Category=">https://www.gephebase.org/search-criteria?/and+Trait+Category="+Physiology+"#gephebase-summary-title)			
Trait			
Metal tolerance (<a +metal+tolerance+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Trait=">https://www.gephebase.org/search-criteria?/and+Trait="+Metal+tolerance+"#gephebase-summary-title)			
Trait State in Taxon A			
Arabidopsis thaliana			
Trait State in Taxon B			
Arabidopsis halleri			
Ancestral State			
Data not curated			
Taxonomic Status			
Interspecific (<a +interspecific+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Taxonomic+Status=">https://www.gephebase.org/search-criteria?/and+Taxonomic+Status="+Interspecific+"#gephebase-summary-title)			
Taxon A		Taxon B	
Latin Name		Latin Name	
Arabidopsis thaliana (<a +arabidopsis+thaliana+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms=">https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms="+Arabidopsis+thaliana+"#gephebase-summary-title)		Arabidopsis halleri (<a +arabidopsis+halleri+"#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms=">https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms="+Arabidopsis+halleri+"#gephebase-summary-title)	
Common Name		Common Name	
thale cress		-	
Synonyms		Synonyms	
thale cress; mouse-ear cress; thale-cress; Arabidopsis thaliana (L.) Heynh.; Arabidopsis thaliana (thale cress); Arabidopsis_thaliana; Arbisopsis thaliana; thale kress		Arabis halleri; Cardaminopsis halleri; Arabidopsis halleri (L.) O’Kane & Al-Shehbaz; Arabis halleri L.; Cardaminopsis halleri (L.) Hayek	
Rank		Rank	
species		species	
Lineage		Lineage	
cellular organisms; Eukaryota; Viridiplantae; Streptophyta; Streptophytina; Embryophyta; Tracheophyta; Euphyllophyta; Spermatophyta; Magnoliophyta; Mesangiospermae; eudicotyledons; Gunneridae; Pentapetales; rosids; malvids; Brassicales; Brassicaceae; Camelineae; Arabidopsis		cellular organisms; Eukaryota; Viridiplantae; Streptophyta; Streptophytina; Embryophyta; Tracheophyta; Euphyllophyta; Spermatophyta; Magnoliophyta; Mesangiospermae; eudicotyledons; Gunneridae; Pentapetales; rosids; malvids; Brassicales; Brassicaceae; Camelineae; Arabidopsis	
Parent		Parent	
Arabidopsis () - (Rank: genus) (https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=3701)		Arabidopsis () - (Rank: genus) (https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=3701)	
NCBI Taxonomy ID		NCBI Taxonomy ID	
3702 (https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=3702)		81970 (https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=81970)	
is Taxon A an Intraspecies?		is Taxon B an Intraspecies?	
No		No	

GENOTYPIC CHANGE

Generic Gene Name		UniProtKB Arabidopsis thaliana	
HMA4		O64474 (http://www.uniprot.org/uniprot/O64474)	
Synonyms		GenebankID or UniProtKB	
ARABIDOPSIS HEAVY METAL ATPASE 4; ATHMA4; heavy metal atpase 4; T20K24.12; T20K24_12; At2g19110		CCM73193 (https://www.ncbi.nlm.nih.gov/nuccore/CCM73193)	
String			
3702.AT2G19110.1 (http://string-db.org/newstring.cgi/show_network_section.pl?identifier=3702.AT2G19110.1)			
Sequence Similarities			
Belongs to the cation transport ATPase (P-type) (TC 3.A.3) family. Type IB subfamily.			
GO - Molecular Function			
GO:0005524 : ATP binding (https://www.ebi.ac.uk/QuickGO/term/GO:0005524)			
GO:0046872 : metal ion binding (https://www.ebi.ac.uk/QuickGO/term/GO:0046872)			
GO:0005385 : zinc ion transmembrane transporter activity (https://www.ebi.ac.uk/QuickGO/term/GO:0005385)			
GO:0008551 : cadmium-exporting ATPase activity			

(<https://www.ebi.ac.uk/QuickGO/term/GO:0008551>)
GO:0016463 : zinc-exporting ATPase activity
(<https://www.ebi.ac.uk/QuickGO/term/GO:0016463>)
GO:0015086 : cadmium ion transmembrane transporter activity
(<https://www.ebi.ac.uk/QuickGO/term/GO:0015086>)

GO - Biological Process

GO:0030001 : metal ion transport (<https://www.ebi.ac.uk/QuickGO/term/GO:0030001>)
GO:0015691 : cadmium ion transport (<https://www.ebi.ac.uk/QuickGO/term/GO:0015691>)
GO:0046686 : response to cadmium ion
(<https://www.ebi.ac.uk/QuickGO/term/GO:0046686>)
GO:0032025 : response to cobalt ion (<https://www.ebi.ac.uk/QuickGO/term/GO:0032025>)
GO:0010038 : response to metal ion (<https://www.ebi.ac.uk/QuickGO/term/GO:0010038>)
GO:0010043 : response to zinc ion (<https://www.ebi.ac.uk/QuickGO/term/GO:0010043>)
GO:0055069 : zinc ion homeostasis (<https://www.ebi.ac.uk/QuickGO/term/GO:0055069>)
GO:0006829 : zinc ion transport (<https://www.ebi.ac.uk/QuickGO/term/GO:0006829>)

GO - Cellular Component

GO:0016021 : integral component of membrane
(<https://www.ebi.ac.uk/QuickGO/term/GO:0016021>)
GO:0005886 : plasma membrane (<https://www.ebi.ac.uk/QuickGO/term/GO:0005886>)
GO:0009506 : plasmodesma (<https://www.ebi.ac.uk/QuickGO/term/GO:0009506>)

	Presumptive Null
No (https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title)	
Gene Amplification (https://www.gephebase.org/search-criteria?/and+Molecular Type=~Gene Amplification~#gephebase-summary-title)	Molecular Type
	Aberration Type
Complex Change (https://www.gephebase.org/search-criteria?/and+Aberration Type=~Complex Change~#gephebase-summary-title)	
	Molecular Details of the Mutation
Gene duplication	
	Experimental Evidence
Linkage Mapping (https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Linkage Mapping~#gephebase-summary-title)	
	Main Reference
Evolution of metal hyperaccumulation required cis-regulatory changes and triplication of HMA4. (2008) (https://pubmed.ncbi.nlm.nih.gov/18425111)	
	Authors
Hanikenne M; Talke IN; Haydon MJ; Lanz C; Nolte A; Motte P; Kroymann J; Weigel D; Kr��mer U	

Abstract

Little is known about the types of mutations underlying the evolution of species-specific traits. The metal hyperaccumulator *Arabidopsis halleri* has the rare ability to colonize heavy-metal-polluted soils, and, as an extremophile sister species of *Arabidopsis thaliana*, it is a powerful model for research on adaptation. *A. halleri* naturally accumulates and tolerates leaf concentrations as high as 2.2% zinc and 0.28% cadmium in dry biomass. On the basis of transcriptomics studies, metal hyperaccumulation in *A. halleri* has been associated with more than 30 candidate genes that are expressed at higher levels in *A. halleri* than in *A. thaliana*. Some of these genes have been genetically mapped to broad chromosomal segments of between 4 and 24 cM co-segregating with Zn and Cd hypertolerance. However, the in planta loss-of-function approaches required to demonstrate the contribution of a given candidate gene to metal hyperaccumulation or hypertolerance have not been pursued to date. Using RNA interference to downregulate HMA4 (HEAVY METAL ATPASE 4) expression, we show here that Zn hyperaccumulation and full hypertolerance to Cd and Zn in *A. halleri* depend on the metal pump HMA4. Contrary to a postulated global trans regulatory factor governing high expression of numerous metal hyperaccumulation genes, we demonstrate that enhanced expression of HMA4 in *A. halleri* is attributable to a combination of modified cis-regulatory sequences and copy number expansion, in comparison to *A. thaliana*. Transfer of an *A. halleri* HMA4 gene to *A. thaliana* recapitulates Zn partitioning into xylem vessels and the constitutive transcriptional upregulation of Zn deficiency response genes characteristic of Zn hyperaccumulators. Our results demonstrate the importance of cis-regulatory mutations and gene copy number expansion in the evolution of a complex naturally selected extreme trait. The elucidation of a natural strategy for metal hyperaccumulation enables the rational design of technologies for the clean-up of metal-contaminated soils and for bio-fortification.

	Additional References
Hard selective sweep and ectopic gene conversion in a gene cluster affording environmental adaptation. (2013) (https://pubmed.ncbi.nlm.nih.gov/23990800)	

RELATED GEPHE

	Related Genes
5 (FPN2, FRD3 (FERRIC REDUCTASE DEFECTIVE3), heavy metal atpase3 (HMA3), heavy metal atpase5 (HMA5), Molybdenum transporter1 (MOT1)) (https://www.gephebase.org/search-criteria?/or+Taxon ID=~3702~/and+Trait=Metal tolerance/or+Taxon ID=~81970~/and+Trait=Metal tolerance/and+groupHaplotypes=true#gephebase-summary-title)	
	Related Haplotypes
1 (https://www.gephebase.org/search-criteria?/or+Gene Gephebase=~heavy metal atpase4 (HMA4)~/and+Taxon ID=~3702~/or+Gene Gephebase=~heavy metal atpase4 (HMA4)~/and+Taxon ID=~81970~#gephebase-summary-title)	

EXTERNAL LINKS

COMMENTS

